Review of Road Cost Recovery

Occasional Paper

Efficient road pricing is required both to generate funds which may be used for roadworks and to ration the use of what is an expensive asset. The important elements of road pricing theory are outlined and these indicate that both the structure and level of charge are important in rationalising road use and optimising the role of road transport in our modern economy.

bureau of
transport and communications
economics

Occasional Paper 90

Review of Road Cost Recovery

D.P. Luck and I.J. Martin

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE, CANBERRA

ISSN 0157-7085
ISBN 0 644 07875 8

First published 1988
Reprinted 1990

Printed in Australia by Better Printing Service, 1 Foster Street, Queanbeyan N.S.W. 2620

ABSTRACT

Efficient road pricing is required both to generate funds which may be used for roadworks and to ration the use of what is an expensive asset. The important elements of road pricing theory are outlined and these indicate that both the structure and level of charge are important in rationalising road use and optimising the role of road transport in our modern economy. Some recent road cost recovery studies are examined in the light of the principles outlined.

Estimates are made of the costs of road use and level of cost recovery by class of road user. The calculations focus on those road costs which can be attributed to particular vehicle types, chiefly the damage caused to road pavements by heavy vehicles. Alternative approaches to the allocation of other road costs such as the costs of new road construction are discussed. The results show that while there is considerable over recovery of costs attributed to private motorists, operators of heavy vehicles pay only a small share, in terms of road user charges, of the costs incurred by their use of roads.

The current imbalance in road cost recovery between motorists and operators of heavy vehicles is shown to be largely the result of the increasing reliance on fuel taxes as a source of revenue for roadworks. The current road pricing structure is discussed, in particular its disincentives for efficient road supply as well as efficient road use. The Paper concludes with a discussion of the advantages, for both road investment and the economy in general, in moving away from fuel taxes towards a road pricing system more closely geared to the road costs incurred by individual road users.

FOREWORD

In recent years there has been a growing interest in the issues of cost recovery and pricing in the road sector. The abolition of road maintenance charges in 1979, the subsequent introduction of State fuel franchise schemes, the 1984 report of the National Road Freight Industry Inquiry (NRFII) and in 1986, the report of the Inter-State Commission (ISC) on cost recovery arrangements for interstate land transport, have heightened public interest in these issues.

Associated with these events and reports, a number of cost recovery studies have been commissioned in Australia over the last decade. While they have all pointed to inefficiency and inequity in current cost recovery and pricing arrangements, they have also, unfortunately, contributed to public confusion concerning both the real level of road cost recovery in Australia and the principles behind the efficient pricing of roads.

In 1985 the then Bureau of Transport Economics (BTE) provided to the Inter-State Commission background material aimed at assisting the Commission in its study of appropriate charges on interstate road vehicles. Included was an earlier version of this Paper entitled 'Review of Australian Road Cost Recovery Studies and Alternative Estimates for 1981-82' (BTE 1985a). This aimed at comparing a number of recent studies and discussed the theoretical aspects of road pricing and cost recovery. It also provided road cost recovery estimates for 1981-82 based on economic theory.

The original Paper attracted a large amount of public attention and accordingly it was decided to prepare a formal publication containing similar material, but with the cost recovery estimates updated to current values. The original Paper has also been expanded to include the results of the Bureau's recent examination of the United States

1982 road cost allocation study. In addition some of the more general macroeconomic issues relating to efficient pricing in the roads sector are addressed and practical problems in road cost recovery are outlined.

The research for this Paper was undertaken by Mr D. P. Luck and Mr I. J. Martin, with the assistance of Mr S. Daskalakis.

M. HADDAD
Director

Bureau of Transport and Communications Economics
Canberra
September 1988

CONTENTS

TABLES

FIGURES

SUMMARY

The three main aims of this Paper are: first, to outline the theory of pricing as it applies to roads and road cost recovery; second, to review some recent studies on road cost recovery, particularly their application of pricing principles; and third, to provide estimates of the level of road cost recovery on Australian roads for the financial year 1986-87. Recovery levels are estimated for several different vehicle types both in terms of the cost of damage caused to roads and their share of annual road expenditure.

The basic road pricing principle is that users should be required to pay at least as much as the costs they cause, that is, marginal or avoidable cost. This generally means that users should be charged for the cost of repairing the damage they cause, but they could also be charged for congestion and other costs. Pricing has implications for the efficient use of the existing road system as well as investment in upgrading the road system.

The number of different studies investigating road cost recovery levels and issues, and the range of estimates that these studies have arrived at, indicate the degree of interest in the issue and also how poorly the economic theory and concepts have been understood.

While the basic principle of pricing seems to be generally accepted in the various studies, most have limited their estimates of costs to encompass only expenditure on road works. The recovery of other resource costs such as the costs of congestion, noise and air pollution and traffic administration, is ignored for several reasons, but mainly because they are either too difficult to estimate, or because they require no direct outlay by governments. While pavement damage costs have been the main focus of the studies, frequently, the estimates of pavement damage cost have been based on misunderstandings. As a consequence of this, a wide range of results has been obtained. This has led to a deal of confusion in the debate in this country over road cost recovery.

The road damage costs caused directly by vehicles, termed avoidable pavement damage cost in this Paper, includes only the resource cost of maintaining the road pavement. It is estimated to have been about $2000 million in 1986-87. This compares with a total annual road expenditure in that year of $4200 million.

The pavement damage cost estimates, and the resulting estimates of recovery levels, are higher than those of other Australian studies. This is chiefly due to the inclusion of local roads in this study while most of the other studies were confined to a consideration of arterial roads. On local roads, damage costs are generally a greater proportion of total costs than for arterial roads. There is, however, little available data on travel by road type in Australia, particularly by type of vehicle, or on actual pavement damage levels by road type. Consequently, it is difficult to reconcile the results of this study with those of other studies.

The principle factors influencing pavement damage are the axle loads of vehicles, the distance travelled by those vehicles and the structural quality of the road pavement. The fact that pavement damage increases dramatically as vehicle loads increase implies that the heaviest vehicles (trucks of six or more axles) cause much more damage than ordinary motor cars. In fact, on some roads these trucks cause more than 10 000 times more damage per kilometre. In addition, the average annual distance travelled by heavy trucks is much more than that of cars.

Of the $2000 million of pavement damage cost, nearly $1100 million is shown to be attributable to the 28 400 heaviest trucks (those of six or more axles) and about $900 million is attributable to the other 475 000 trucks and buses (those with less than six axles, but mostly small two-axle trucks). The 8.7 million cars cause negligible pavement damage.

The balance of annual road expenditure has been allocated using two different methodologies. The economic efficiency method allocates the remaining $2200 million in such a way that its recovery would not overly distort the pattern of demand for road usage. An equity method used follows the cost-based approach employed in the United States' road cost allocation study. The allocations which result from the two methods are shown to be similar, although this is largely coincidental.

The other side of the cost recovery equation is the level of charges currently being paid by road users for use of the road network. There are no clear guidelines as to which revenue paid by road users can be legitimately matched against road costs. Several definitions of road user charges were considered. The definition chosen implies that actual payments for use of the road infrastructure are estimated to total $7100 million in 1986-87. Most of this revenue to governments is represented by fuel excise payments and vehicle registration fees.

The expenditure recovery estimates are only reliable within a broad range. However, the main results are quite clear. While motorists are responsible for little pavement damage cost they more than cover their share of fully allocated expenditure, including expenditure on upgrading the road system. Operators of smaller trucks just meet their pavement damage cost, while operators of larger rigid trucks, depending on loading and usage, under-recover pavement damage cost by up to $4500 per vehicle.

The major area of concern, however, is the level of under-recovery of avoidable pavement damage cost by the heaviest freight vehicles; about $18 000 for the average six-axle articulated truck and nearly $50 000 for the heaviest articulated vehicles. Buses travelling on long distance routes also under-recover their avoidable pavement damage cost by over $20 000 each. Under-recovery of these vehicles' share of fully allocated expenditure is even more substantial.

The problems are not limited simply to the question of whether or not road expenditure is recovered. Road pricing has important implications for efficient resource use. Indeed the problem of under-recovery of damage cost by freight vehicles is a significant one for the Australian economy. Heavy trucks have a large share of the freight task in terms of tonne-kilometres carried by these vehicles. Since they are, in some areas, significant competitors with rail, it is necessary to consider to what extent the distribution of the freight task between the two modes is distorted by inefficient pricing arrangements. This necessarily involves consideration of the pricing and cost recovery levels of both modes.

Higher road prices for road freight operators will assist rail to improve its cost recovery levels on freight. For instance, it may encourage a similar adjustment to rail prices or it may attract profitable freight from road transport. There may not be a large transfer of the freight task from road to rail since full cost recovery for heavy trucks implies an increase in charges of only about 1 to 2 cents per tonne-kilometre of freight, or about 20 to 40 per cent of current freight rates. If this increase is implemented gradually, the effect of higher prices on demand for road transport will be overwhelmed by the effect of growth in that part of the industry (over 10 per cent per year between 1981-82 and 1986-87). In the long-run, both modes should be concerned to achieve efficient prices and full cost recovery. Only then is the allocation of the freight task between modes likely to be an efficient one.

The most likely result of full road cost recovery will be that the transfer of long-distance freight from rail to road would slow down. Theoretically, rail should be the more efficient carrier of bulk goods over long distances. However, to make the most of this technical advantage, railways must become more efficient in their operations.

One of the most beneficial reasons for implementing a system of charging for pavement damage is to encourage behaviour which reduces the cost of road damage. The structure of the damage charge is therefore as important as the level of the charge in encouraging efficient use of roads. While the road damage estimates for heavy trucks may be higher in this Paper than those in previous studies, rather than focus on the precise level of charges required, emphasis should be placed on constructing an efficient charging mechanism and moving charges gradually in the right direction. The correct level of charges to apply to each vehicle can be determined with greater accuracy later, following better engineering research.

A charge structured to vary with the factors which cause damage cost to vary, essentially the vehicle's mass, axle configuration and distance travelled, would encourage behaviour which reduced damage costs. It would then be in both the user's and the community's interest to, for instance, carry loads on vehicles with more axles and not to overload vehicles. In order to achieve the benefits of correct pricing, it is also necessary that the charging system be applied without exemptions.

In the long-run, an appropriate charging system which reflects the costs caused, not only encourages the most appropriate use of the existing road system but also, given certain other conditions, the most appropriate investment in upgrading the system.

The key element of an efficient road pricing system would be the introduction of a correctly structured mass-distance charge aimed at recovering road damage costs. To this could be added fuel taxes and fixed registration charges to recover the balance of the annual road expenditure target.

The main benefit of the charging system would be a more efficient road industry, particularly, in the long-run, in respect of both supply and use of the road infrastructure. There are thus implications for the role of the Commonwealth and the States regarding road funding and road supply which should be carefully examined.

CHAPTER 1 INTRODUCTION

Road damage has been a problem in Australia since the time of the first roads. At various times throughout this century and the previous one, attempts have been made to restrict road damage both by restricting vehicle weights, axles and tyres and by charging for road damage, usually on the basis of the load carried or some other indicator of the potential for damage (Department of Main Roads 1976). These approaches have met with mixed success.

Currently, the Australian road system is conservatively estimated to be worth at least $40 billion. In use it depreciates by over $2.5 billion per annum. Most of this cost is due to damage caused by vehicle loads, especially heavy vehicles.

With the increasing costs of roadworks and the large increase in the number of heavy trucks using the roads in recent years, public attention has been directed towards the question of who should pay for the costs. The large increase in fuel excise payments by motorists since 1982 has also focused attention on the manner in which users are charged for their road use as well as the level of charges which users should pay and what share of costs they should meet.

These issues gave rise to a number of studies considering road pricing and road cost recovery levels. The National Road Freight Industry Inquiry (NRFII) (1984), was one of the most recent studies to consider road cost recovery. Following this Report, an initial 'fast-track' package of reforms based on NRFII recommendations was endorsed by the Australian Transport Advisory Council (ATAC). The package includes legislation providing for the registration of vehicles and the licensing of operators engaged in interstate trade and commerce.

In the Second Reading Speech of the *Interstate Road Transport Bill 1985*, the Minister for Transport said that the legislation should be seen in the context of a principle requiring users to meet the full costs of government-provided infrastructure and services. For this reason the Inter-State Commission (ISC) was subsequently directed to investigate the current level of recovery of Government costs associated with road use by freight and passenger vehicles engaged in interstate trade and the recovery of costs by interstate rail freight and passenger services. The Commission was directed to recommend appropriate charges for 1986-87 for different classes of road freight and passenger vehicles engaged in interstate trade in accordance with the Interstate Road Transport Legislation.

Previous studies have taken different approaches to estimating road cost recovery, and there has been little agreement on the basic principles of analysis. This Paper canvasses the basic economic principles in road pricing and cost recovery analysis and reviews several studies which generally followed these principles. A consultant's report prepared for the NRFII (Nicholas Clark & Associates 1984), which analyses cost recovery levels for both road and rail, is also examined as it formed a major input into the NRFII's consideration of road cost recovery levels. The Paper also considers how applicable the United States' approach to pavement cost allocation is to Australia.

APPROACH TO THE STUDY

The main purpose of this Paper is to outline the principles of road pricing and demonstrate how these principles may be applied in cost recovery calculations. It has been noted in earlier Bureau papers (for example, BTE 1985a) that there are a number of objectives which can be pursued in pricing roads. Different objectives will lead to different road pricing structures and different cost recovery results.

In examining the principles of road pricing and their application to cost recovery calculations, a number of recent Australian studies and an overseas study are examined with the aim of demonstrating the methodology and problems involved in cost recovery calculations. Detailed efficiency-based cost recovery calculations, as well as a similar but equity-based set of calculations, are undertaken for 1986-87.

These calculations are used to indicate problems with the current road pricing system in Australia. Suggestions are made for improving the efficiency and equity of the system. Finally, some problems inherent in establishing efficient road pricing mechanisms are discussed, along with the benefits to society of a properly structured efficiency-based road pricing system.

STRUCTURE OF THE PAPER

Chapter 2 outlines the theoretical aspects of road pricing and road cost recovery analysis.

Chapters 3 and 4 examine four cost recovery studies. Two based on economic efficiency principles are examined in Chapter 3. They are those of Webber, Both and Ker (1978) and the University of Tasmania's Transport Economics Centre (1981). Some comments are also provided on the Review of Road Vehicle Limits (RoRVL) study (NAASRA 1985). A study by Nicholas Clark and Associates (1984) for the NRFII is examined in Chapter 4 along with certain aspects of the 1982 cost allocation study undertaken by the United States Federal Highway Administration (US FHA 1982 and 1984).

In Chapters 5, 6 and 7 estimates are prepared on cost recovery on Australian roads for various vehicle types in 1986-87. The data sources are discussed in Chapter 5. In Chapter 6 estimates are made of avoidable cost (largely road damage costs) by vehicle type. In Chapter 7 a simplified Ramsey pricing analysis is undertaken to demonstrate an efficiency-based allocation of costs or expenditures over and above avoidable cost. For comparison, an equity-based analysis is also presented, broadly following the methodology of the United States 1982 study.

In Chapter 8 there is a discussion of a broad range of issues relating to the implementation of an efficiency-based road pricing scheme. A summary of the main issues identified in this Paper is provided in Chapter 9.

Four Appendixes are included. They cover respectively: the various social costs associated with road use; government revenues from road use; details of pavement construction cost savings and deterioration relationships used in the United States' cost allocation study; and an alternative efficiency-based road pricing system.

CHAPTER 2 ROAD PRICING AND COST/EXPENDITURE RECOVERY: PRINCIPLES, CONCEPTS AND ISSUES

In Australia, as in other countries, the provision of roads is undertaken by governments rather than by private enterprise. Some of the reasons for this are outlined in BTE (1985b, 3-4). The provision of roads by the public sector means that it may not be necessary for the costs of roads to be recovered from road users. Governments can fund the provision of roads from other revenue sources such as income taxation. In fact at the Federal Government level, at times road expenditure has been funded from Consolidated Revenue, although road users have been subject to a range of taxes and charges. These charges have not always been related to road use.

There are a number of reasons why it is desirable to charge road users for their use of roads. Given the current public interest in the performance of public enterprises and public provision of goods and services it is also worth examining the principles that might govern the financing of roads if road authorities were forced to act more in line with private business undertakings.

In general there are three main objectives for pricing road use: economic efficiency, equity, and revenue raising.

The main economic rationale for directly pricing road use is the desirability of achieving an economically efficient allocation of the scarce resources of society. Economic theory can provide guidelines as to how to properly charge each road user. In general, the theory is based on a model of a firm operating in a perfectly competitive market. Thus, in the case of public provision of roads, economic efficiency can be maximised when the conditions of perfect competition exist. Ideally, two major aspects of road provision should be considered in this context - efficient investment (supply of roads) and efficient pricing (which provides the demand signals).

Generally, the debate about cost recovery of road expenditure from road users focuses only on the demand side. It is assumed that investment decisions have been made wisely. Of course, this is not always the case. Where it is excessive, there is a case for not recovering the full cost from road users. This issue is not, however, fully explored in this Paper on the grounds that the second and third objectives noted above, the equity and financial objectives, require that full cost recovery from road users, rather than, say, taxpayers, is achieved on an annual basis.

As well as an objective of recovering annual road expenditure from road users, governments may also wish to achieve other, chiefly equity, objectives. This may result in losses in overall efficiency, usually via higher road costs. It is important that these losses be identified to ensure the social benefits of meeting these alternative objectives are greater than the costs, and that the objectives cannot be met in other, more efficient, ways.

If roads were to be provided by a public enterprise, charged with maximising economic efficiency, it would be paramount for the enterprise to identify both the most efficient provision of roads and the most efficient means of recovering its costs through road pricing. The latter issue is the subject of this Paper and is explored in detail. As well, the equity objectives sought by governments should be clearly identified and costed wherever possible. Specific provision should be made for meeting these objectives, for example, through identifiable subsidies. Finally, the enterprise would need to have control over both its revenue and its expenditure. Unfortunately, road authorities (both State and local) do not operate as enterprises and they are divorced from the revenue raising from road users (or road pricing) and only operate as suppliers of roads, largely as contractors to governments. They have very little incentive to operate efficiently since they are largely not confronted by market forces. Additionally, as this Paper attempts to demonstrate, the current demand signals are in any case not optimal because of inefficient road pricing.

EFFICIENCY PRINCIPLES FOR ALLOCATING ROAD COSTS/EXPENDITURE

It was noted in BTE (1985b) that the appropriate pricing policy to maximise economic efficiency is to price at short-run marginal cost (in practice the concept of avoidable cost is used in road studies instead).

The components of road cost are outlined in Table 2.1. The analysis in this Paper focuses primarily on the first and last of these costs. Estimates are made of the size of the other costs. However, they are largely ignored in cost recovery studies since the cost recovery target is taken as the level of expenditure on road works. Each of

TABLE 2.1 COMPONENT COSTS OF ROAD USE

Cost component	*Short-term relationship to output*	*Affected party*
Pavement damage Repair cost	Mainly variable/some fixed	Government (outlay on road pavement maintenance, resealing etc)
Increased vehicle operating cost from driving on damaged roads	Variable	Road users
Road congestion delay increased vehicle operating cost	Variable	Vehicle operator and other road users
Vehicle operating cost	Mainly variable/some fixed	Vehicle operator
Traffic administration and policing	Variable and fixed	Government
Road accidents	Variable	Vehicle operator, other road users, Government (hospitals, courts, police, ambulance)
Other externalities	Mainly variable/some fixed	Other road users, non-road users, Government (pollution control etc)
Requirement for pavement upgrading and construction	Fixed	Government (outlay on new roads)

Source BTCE analysis.

these other costs can be priced using separate pricing instruments, particularly as the levels of these costs vary differently with road use from road maintenance and construction costs. Pricing of each of these other costs requires a separate study and is beyond the scope of this Paper.

There is a problem with this measure of short-run marginal cost, however, in that it is less than the total of annual road expenditure. This is because aggregate short-run marginal (pavement damage) cost will not cover all costs and especially fixed costs (for example, construction of new pavements and bridges). In addition, it is not possible to attribute all variable costs to individual users on the basis of road use. Some costs are common or joint costs; costs which are not solely caused by particular vehicle operators. Some examples of these include the costs of mowing median strips or operating traffic lights. Thus, if roads were to be provided by a public enterprise and/or a requirement set for full recovery of annual road expenditure, an appropriate pricing structure needs to be developed to recover from road users the additional expenditure over and above the level of short-run marginal cost.

If all short-run marginal costs were considered, however, including congestion cost, it is likely that in some years they may in total exceed annual road expenditure. This was one argument used in the United States against adopting efficient road pricing in favour of an equity-based road pricing system (see United States Department of Transportation 1982). The level of annual road expenditure is largely a budgetary decision based on a range of factors besides the demand for road use. In the absence of such a broad interpretation of short-run marginal cost, economic theory suggests that any cost to be allocated to road users in excess of short-run marginal cost, should be allocated according to the demand for road use of each road user (referred to as an allocation based on Ramsey pricing, following the work of F. Ramsey in 1927). This two part allocation scheme (that is, allocating marginal cost and then adopting Ramsey pricing for the balance) is a 'second best strategy', but it results in the least loss of efficiency from allocation above marginal cost in order to meet a specific revenue target. The Ramsey pricing rules for pricing above marginal cost are also discussed by Baumol and Bradford (1970) and Taplin (1980).

The two key elements in allocating cost among road users on an economic efficiency basis are thus the level of marginal cost and the demand for road use by each road user. These two elements are discussed below along with the theoretical basis of marginal cost pricing. This will be followed by a discussion of the term, 'avoidable cost' which is usually used instead of 'marginal cost' in discussions on road cost recovery. Some problems associated with using an avoidable cost estimate are also outlined.

Long-run and short-run costs

The association between short-run and long-run costs and optimal short-run and long-run pricing (and investment) policies requires clarification. It is a fundamental source of confusion in Australian cost recovery studies (and not just in the road sector).

Fundamentally, economics is about decision-making; deciding between alternative uses of given resources. There are both short-run decisions regarding use of a particular asset and long-run decisions regarding supply of assets. Short-run decisions include: 'Should a particular trip take place?'; ' Which route should be used?'; 'Which vehicle is most appropriate?'; and 'To what level (or weight) should the vehicle be loaded?' Generally, the particular decision-maker will make the most appropriate decision (in terms of maximising his own net benefits). This will be consistent with maximising overall net benefits to society only when the user is faced with *all* of the costs and benefits of his decision to use an asset already provided. It is important, therefore, that any costs imposed on other sectors of the community be redirected (or internalised) to the user in order that the correct decision be made. Regarding use of a particular road, only those costs which will increase as a result of a decision to use the road, or how or when to use it (that is, short-run marginal cost), should be considered. Fixed cost will not be influenced by any individual's use of the road. User decisions are therefore optimally based on short-run marginal cost alone. Efficient road pricing, which attempts to encourage optimal road use, should therefore also be based on the short-run marginal cost of road use.

Long-run decisions must also be made. These include: 'Should a particular road be constructed?'; 'Where and when should it be constructed?'; 'For which vehicles and to what level (or capacity) should it be constructed?' Usually, road funds should be invested in those projects which produce maximum net benefits over the whole lifetime of the investment.

Essentially, long-run decisions are about providing capacity and short-run decisions are about using it. These different decisions will require different cost information because the nature of the costs of each decision is different although the decisions will generally interact.

The benefits, of course, are another matter. As far as short-run decisions are concerned, it is usually assumed that the individual user is in the best position to assess benefits from his own use. Occasionally, governments will take a different view of the benefits which may be derived and may, accordingly, seek to influence user decisions on this basis. For long-run decisions, it is common to assume that the benefits to be derived from an investment are revealed by the user's willingness to pay for use of it. Again, if governments make a different assessment, they may seek to influence an investment decision accordingly.

In the case of road investment and usage, a fairly long-term decision must be made as to the capacity of the asset having regard to pricing policy (and consequent demand). Shorter-run pricing decisions are then made regarding the use of the road by given vehicles at given times. For example, a leading economist has stated: (Vickrey 1985, 1331-1333)

> Pricing decisions are relatively short-run decisions, or at least they should be flexible enough to adapt to changing condititions, even when physical plant cannot be. The marginal cost that is relevant to a pricing decision is a marginal cost of the output that will be affected by the pricing decision over the period for which that decision is to be considered not subject to possible revision. To attempt to import into a pricing decision considerations of fixed costs that will not be affected even indirectly by that decision is to chase a very wild goose indeed.

For short-run user decisions, capacity is fixed, therefore the cost of providing capacity should not influence decisions to use the asset. If the demand is close to capacity however, then one additional user may increase the cost to other users by increasing congestion as well as road damage. If the congestion and damage costs are included in the price of road use, this will encourage use of the road only when there is a net benefit. The revenues available to the suppliers of roads from the congestion and road damage charges should encourage further investment in expansion of the system. In this way, efficient road pricing can be said to encourage the correct demand signals.

Long-run and short-run cost relationships

The discussion in the preceding section has outlined the difference between long-run and short-run costs. The basic distinction is that in the long-run capacity can be varied whereas in the short-run it cannot. Thus, in the short-run if there is an increase in output this must be accommodated within the constraints of the existing system. If it is cheaper to accommodate the new output level by expanding the system (or contracting it for a fall in output) this can only be done by a long-run decision. For instance, this could be done by building new roads (for increased output) or closing down old roads (for a decrease in output). The only output level where long-run and short-run costs coincide is where the design level of output equals the actual level of output. In all other cases short-run costs are higher than long-run costs since there is more scope for reducing costs in the long-term than the short-term. This particular relationship is summarised in Figure 2.1 and is discussed in greater detail in most elementary microeconomic texts.

The above analysis can be demonstrated in the case of roads if a composite measure of output such as tonne-kilometres (tkm) is used. Referring to Figure 2.1, if the road is properly designed for, say, 'a' tkm, and this is the level that is actually utilised, then the short-run cost per tkm is equivalent, at 'c', to the long-run cost per tkm. Of course, if the actual level utilised is at 'b' then the short-run average cost at 'd' is higher than the cost if the road had been designed for 'b', that is an average cost of 'e'. This is true of all output levels that differ from the design level. Other design levels, say, at 'f' or 'g', could be contemplated. For each design level there corresponds a different short-run average cost function.

As noted, the long-run (investment) decisions will have an impact on the short-run (user) decisions and vice versa. An example of the former is that building stronger pavements will allow heavier vehicles to use a road without causing excessive damage. An example of the latter is that if numerous vehicles use a particular road, perhaps causing congestion, then this excess demand provides a signal and an incentive to expand the investment.

An optimal target is for the lowest combination of costs for the estimated future output requirements. There are various dimensions to this problem. Increasing pavement capacity in terms of road width or number of lanes will decrease congestion cost faced by all road users. A balance is sought between the additional construction cost and the savings in congestion cost. Another balance is required between the cost of increasing pavement capacity in terms of pavement thickness or strength and lower pavement damage cost (manifested both as lower road maintenance cost and lower vehicle operating cost). Similar balances are sought between the cost of accidents and the cost of safety design features such as overpasses and controlled intersections, or between

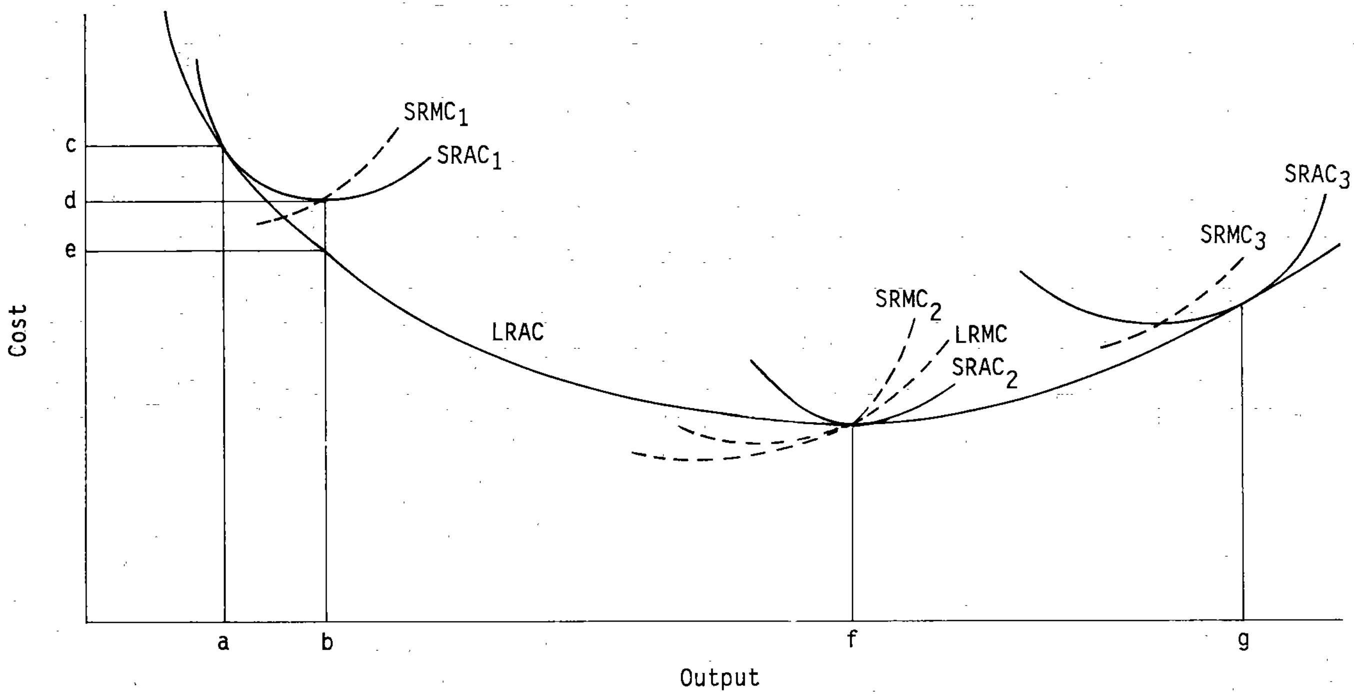


Figure 2.1 Long-run and short-run cost relationships

lowering visual impacts of roads and the increase in design costs to do this.

To complicate matters further, these trade-offs are not independent of each other but are interrelated. For instance, an increase in pavement width may decrease pavement damage cost as truck weights are spread over a wider surface area. Increasing pavement strength may result in heavier trucks being able to use the road, but may mean that fewer of them are required to perform a given task. This may affect both congestion cost and accident cost as well as vehicle operating cost.

From this multi-dimensional viewpoint it is quite a complicated task to find the lowest cost combination of life-cycle costs. What is especially obvious, however, is that where an optimal decision is constrained by annual budget limits and an inadequate appreciation of the trade-offs, then investment decisions may be far from optimal and may actually increase the variable costs in the short-term. Road investment is constrained by annual budget limitations. There are numerous potential road investment projects that have positive net benefits that are not taken up because of funding constraints. In addition, because users are not paying appropriate prices and therefore are not adequately revealing their preferences, there can be no guarantee that the trade-offs perceived by road planners are the appropriate ones.

Figure 2.2 is a stylised diagram of just two dimensions of the costs of road use. The cost plane represents the sum of all costs of road use as outlined in Table 2.1. Further, it represents the lowest cost combination of inputs to achieve particular configurations of output when road capacity can be varied. For convenience it may be assumed that costs such as traffic administration, policing, safety, externalities and vehicle operating costs are relatively constant per unit of output. In fact these may decline slightly on average as vehicle loads increase. The trade-offs to be considered here are between pavement construction cost on the one hand and pavement damage or pavement congestion costs on the other hand.

On the traffic volume axis, as volume increases beyond some initial level, the average cost may be reduced by increasing pavement width (or even pavement strength or thickness). The increase in construction costs is more than offset by lower congestion cost. Up to a certain level of traffic volume, wider roads can be provided at lower and lower average cost. For this range there are increasing returns to scale in terms of traffic volume. At some level ('a', in Figure 2.2) there are constant returns to scale and beyond this there

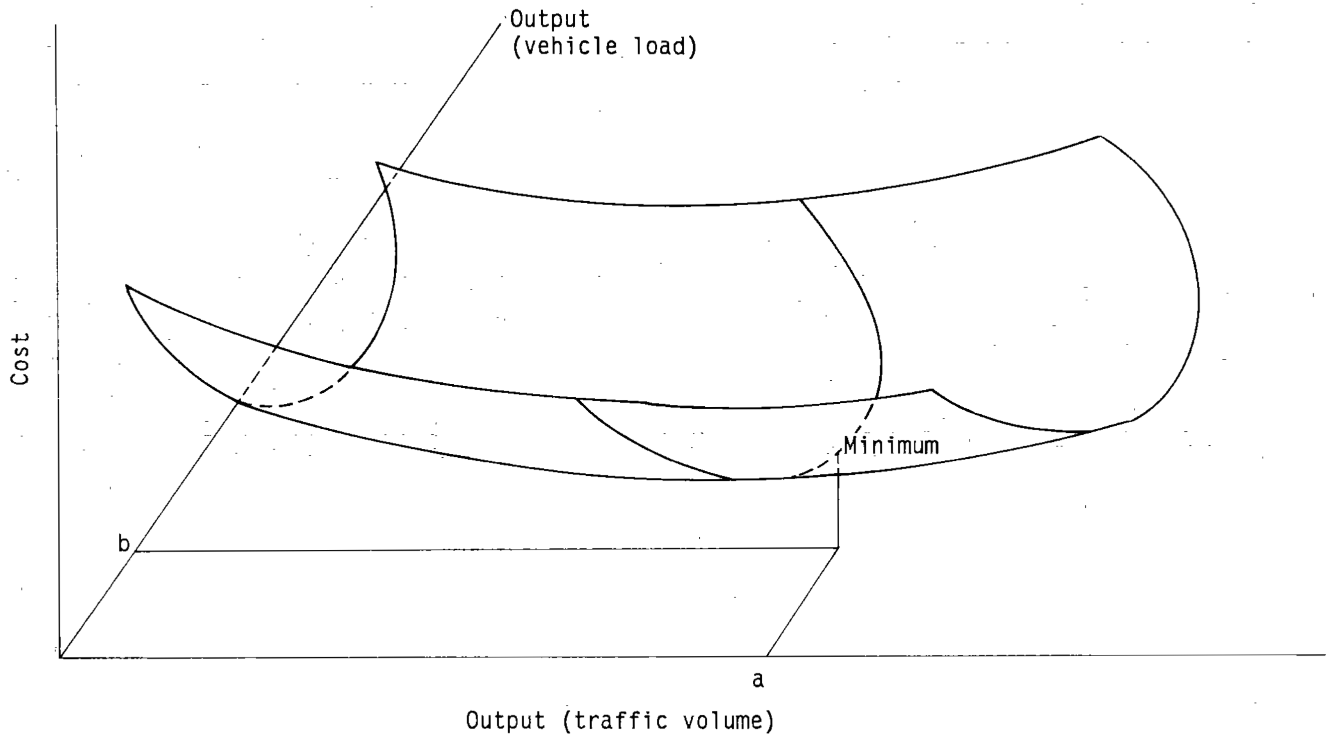


Figure 2.2 Economies of scale in road provision: long-run average cost plane

are decreasing returns to scale. It is unlikely that on most roads in Australia, especially rural roads, traffic volumes would get to such a level that average cost would begin to increase. In this aspect of pavement provision, what is defined in the literature as a 'natural monopoly', is evident. That is, because average cost is, over the relevant range, always decreasing as output increases, it is always cheaper for one supplier to supply total output than for this to be shared by two or more suppliers.

Such is not the case with respect to axle loadings, however. In the short-run, on a given pavement, road damage caused by trucks increases dramatically with axle loads (or with total mass on a given number of axles). Thus on this axis, cost increases rapidly with loads. However, road damage cost can be reduced on average if pavements are made thicker. The greater construction cost is offset by reduced damage cost and also by lower vehicle operating cost. Up to a certain level of vehicle or axle loading, more road use (in terms of tonne-kilometres of travel) can be provided at lower average cost. For this range, and in this aspect, there are increasing returns to scale in road use. At some level ('b', in Figure 2.2) there are constant returns to scale and beyond this there are decreasing returns to scale. The recent RoRVL study conducted by the National Association of Australian State Road Authorities (NAASRA 1985) found that for the range of vehicle loads (for a six-axle truck), from 38 to 42.5 tonnes, there were increasing returns to scale. The RoRVL results indicated that the benefit/cost ratio of moving progressively upwards from 38 tonnes fell rapidly. If benefits per unit of output are approximately constant, then the results of the RoRVL study, showing a rapid approach to the point where costs would exceed benefits, is due to a decline in the returns to scale experienced at current and anticipated traffic levels. However, due to assumptions in the study, which are discussed in the next chapter, it is unlikely that the returns to scale on Australian roads continue to increase much beyond the 38-tonne level (much less the 42.5-tonne level) for most road types. The optimum is likely to occur at lower mass levels on thinner pavements.

This analysis of economies of scale is somewhat different from that normally undertaken for business undertakings. Normally, scale refers to the size of the firm in terms of its output or of a machine. Here it would probably be more correct to refer to economies of road capacity and economies of pavement strength than refer to economies of scale. However, in essence the same principle is demonstrated - it requires a decreasing increment in either pavement width or depth to enable a given increment in traffic volume or total freight carried.

The particular cost structure of road provision and use has some important implications for road pricing and road cost recovery in the context examined here. Although only two of the various costs of road use outlined in Table 2.1 require a public outlay on pavement infrastructure, these two are significant and represent a large proportion of all costs of road use. Moreover, they have impacts on the other component costs. This latter point is of special significance when the overall requirement is to perform the required transport task at the lowest overall cost. This is usually achieved by allowing competitive market activity to take its course. In this case, that of government (or non-market) authority provision of infrastructure, there is an obligation for such provision to be the most beneficial and to be provided in the most efficient way.

Implications for road pricing and cost recovery

For most industries, and with most assets, the lowest cost combination of inputs will achieve a level of output which satisfies only a fraction of demand. Thus, a number of such assets, each perhaps owned or operated by different firms, may be appropriate in order to achieve the best (constant) returns to scale for the entire output demanded. Where there are constant returns to scale, the marginal cost just equals the average cost of output. Thus, prices set equal to long-run marginal cost, at this level, will on average just recover all costs.

If the equilibrium between demand and capacity is maintained, and any increase in demand is just met by an increase in capacity, then a 'steady state' exists between demand and supply. The steady state is both an abstract concept and an elusive target. Demand increases more or less continuously, perhaps at different rates in different systems, but capacity is generally increased in large, discrete units, and even then may not always match the requirements. If the long-run equilibrium could be maintained, by a continuous adjustment to capacity, then the short-run cost curves would be equivalent to the long-run cost curve. Referring again to Figure 2.1, the short-run cost curves would collapse into the long-run cost curve. In other words, pricing at short-run marginal cost would be equivalent to pricing at long-run marginal cost. As the steady state or long-run equilibrium cannot be continuously maintained, pricing at long-run marginal cost achieves a different result from pricing at short-run marginal cost.

Another important reason why roads may not achieve the optimal cost target in a steady state system, has to do with the nature of the road provision industry. As noted above there are generally increasing returns to scale in road provision; that is, if more output is required, this can generally be provided by supplying a larger road (in terms of width, number of lanes, or pavement strength) at lower average cost. There are economies of scale in the supply of roads. In terms of Figure 2.1, for most roads in Australia, output is well to the left of the minimum of the long-run average cost at point 'f'. In this case, prices set at short-run marginal cost will be higher than prices at long-run marginal cost.

There are important implications for Australian road users of such a situation.

First, there can be no guarantee, as there generally is in a competitive situation, that road provision is technically efficient. Although road construction may be fairly efficient due to a degree of competition in the tendering process, this is no guarantee that the design parameters are the most efficient for the demand requirements. The roads provided may not be the most suitable for the use to be made of them. In the absence of competition in road supply, this needs to be the subject of thorough and continuous review by road authorities and the road-using public and industry.

Second, pricing at long-run marginal cost, in addition to not achieving allocative efficiency, also will not recover all costs since, over the relevant range of outputs, average cost, both short-run and long-run, exceeds long-run marginal cost.

As noted by Vickrey (1985, 1332),

> One cannot get around the problems posed by indivisibilities or economies of scale by attempting to bring fixed costs into the picture through notions of long-run marginal cost. To attempt to do so leads only to confusion and inefficiency.

Thus, if recovery of fixed (or joint and common) costs is a requirement, then a modification to the short-run marginal cost pricing rule in accordance with Ramsey pricing (or the inverse elasticity rule) is the constrained optimum or second-best rule.

Measurement of avoidable cost

In practice it is difficult to measure the marginal cost of road use since there is no unique measure of output and because it is difficult to identify a marginal unit and its cost. In the 'theory of the firm', on which microeconomic analysis is largely based, it is assumed that there is a single discrete output (for example, tins of soup). However, the output of roads is more esoteric. It is movement of vehicles, people and goods, all of which cannot strictly be equated. To get around this problem the concept of 'avoidable cost' is used. This is roughly 'the cost that would be avoided if a given vehicle did not use the road'. It can be defined for a given trip or even broken down into smaller units such as the cost of moving one tonne of freight over one kilometre.

Avoidable cost is an imprecise concept that requires specification of the subject or item that will be 'avoided'. This is necessary since the avoidable cost will vary depending on the scale of the subject under consideration in, say, time or distance. The avoidable cost per kilometre, for instance, will be much lower than the avoidable cost of a particular trip. The former might include only a small increment to fuel cost, some pavement damage cost and perhaps some additional handling cost. The latter includes not only larger increments of these cost components, but also additional components such as the cost of the driver's wages, terminal charges and perhaps additional vehicle maintenance.

The same qualification also applies to the time scale under consideration. Short-term decisions regarding usage have fewer avoidable cost components than longer-term decisions regarding variations in capacity. All the same, long-run avoidable cost, which includes the cost of additions to (or subtractions from) capacity, also requires specification. The long-run avoidable cost of a particular transport system is quite a different concept to the long-run avoidable cost of all travel by particular groups of vehicles. The former may include all construction and operating costs whereas the latter would include only the operating cost of the vehicles under consideration and only some increments of construction and would specifically exclude some common and joint cost items such as the purchase of right-of-way.

That the short-run has fewer avoidable cost components than the long-run sometimes erroneously leads people to believe that costs in the short-run are on average less than they are in the long-run. Of course the opposite is true. Because a particular road is *fixed* in the short-run, the costs of using it are also given and may be higher than those for an 'optimum' road. Over the longer-term, however, they may be avoided perhaps in favour of some cheaper alternative.

The avoidable cost to be used in road pricing is the cost which can be avoided if a particular decision to use the road is not made. Usually this encompasses decisions on particular trips: whether or not to undertake them and even how to undertake them. It is the avoidable cost of trips therefore which is estimated in this Paper, although this may be presented as an average avoidable cost per unit for smaller units such as the cost per tonne-kilometre.

Whereas marginal cost is the cost of an additional unit of output, the avoidable cost (of units of output) is an average cost, usually over a given range, of output. Avoidable cost includes all costs that could be avoided if a given vehicle were not to undertake a particular trip. The major element of avoidable cost considered in this Paper is damage caused to road pavements and bridges. As noted earlier, other costs, including traffic control, congestion, pollution and accident costs, as well as increases in the vehicle operating cost resulting from pavement damage, are excluded from consideration in this Paper.

Ideally, it is appropriate to measure the avoidable cost of each individual vehicle when measuring avoidable pavement cost, as each vehicle will cause a different amount of damage. However, it is not practicable to measure the damage caused by each and every vehicle as it passes over each point of the road surface. Engineering research has identified relationships between particular vehicle characteristics and damage caused to road pavements and bridges. In general terms, the most important determinants of damage to the road system are the level of traffic and the axle loads of vehicles. It has been widely accepted that pavement damage to a given road is related to the fourth power of the axle load, and to vary directly with distance. A unit has been devised, equivalent standard (or single) axle load (ESAL) to compare the damage caused by different vehicle axle loads. It should be noted, however, that the fourth power rule is only an approximate average. For stronger pavements, for example, those constructed of concrete, a higher power applies, whereas for weak pavements a lower power may apply. However, as will be shown in Chapter 5, if a power of 5 or more, or 3, or even 2 is used, it makes very little difference to the allocations of avoidable cost to trucks. The average allocation to cars will increase with lower powers but will still be small.

Pavement damage also varies with road type, different vehicle suspensions, vehicle speed and tyre pressures and hence the damage functions should be regarded as approximations. Ideally, the prices charged should vary with each of these variations in costs. However, the effects of these secondary aspects are not well understood at present and require additional research. Generally, motor cars cause negligible damage to the road system, while the heaviest road vehicles impose the most damage to pavements and also to bridges.

Pavement damage results in the need to repair roads to maintain their capacity and condition. These repair costs comprise:

- routine maintenance costs to repair minor cracking in pavement seals, repair potholes and so on;

- resealing costs (repair and sealing of major cracks and minor pavement deformation); and
- reconstruction costs (complete repair of major pavement deformation, usually by replacement of the entire pavement).

Each of these cost components is related to the life of a road. Essentially, a road is designed to accommodate a given number of standard axle passes. With each vehicle passage, the effective life of the road is reduced and its required maintenance, resealing and reconstruction is brought forward. The avoidable cost can be calculated as the life-cycle costs in terms of the costs of maintenance, resealing and restoration required to repair this damage.

Pavement life-cycle cost approach

Figure 2.3 shows a stylised profile of the roughness or condition of a road. Roughness is used since it is a convenient measure, but any composite indicator of pavement serviceability may be appropriate.

At initial construction the road is fairly smooth (R_O). As heavy axle loads pass over the road its roughness increases and cracks appear in the pavement. Water may enter these cracks with the results that potholes may form. Routine annual maintenance will reduce some surface roughness, seal cracks and fix potholes but will not reduce deformation of the pavement. Gradually more and more maintenance is required and seal deterioration and pavement deformation becomes unacceptable. Normal levels of routine maintenance may not be sufficient to reseal all cracks or restore the level of roughness to below the maximum acceptable level (R_A). Resealing the road becomes a more economic proposition. This will fill surface cracks and, if thick enough, considerably reduce pavement deformation.

Overall roughness may be returned to a level close to R_O. However, pavement and sub-grade deformation are continuing to increase and eventually the whole road reaches a point where even resealing is not an efficient proposition. The rate of deterioration through rutting, spalling, cracking and general failure increases rapidly, requiring major rehabilitation or reconstruction of the pavement and perhaps the base and sub-base. The road has come to the end of its service life.

At this point it may also be upgraded or improved to cater for an increased level of expected traffic and axle load passes. This upgrading is not an element of the avoidable cost of an additional unit of output, but the rehabilitation component is.

In essence, all these road works (apart from upgrading) are substitutes for each other but with differing cost effectiveness in

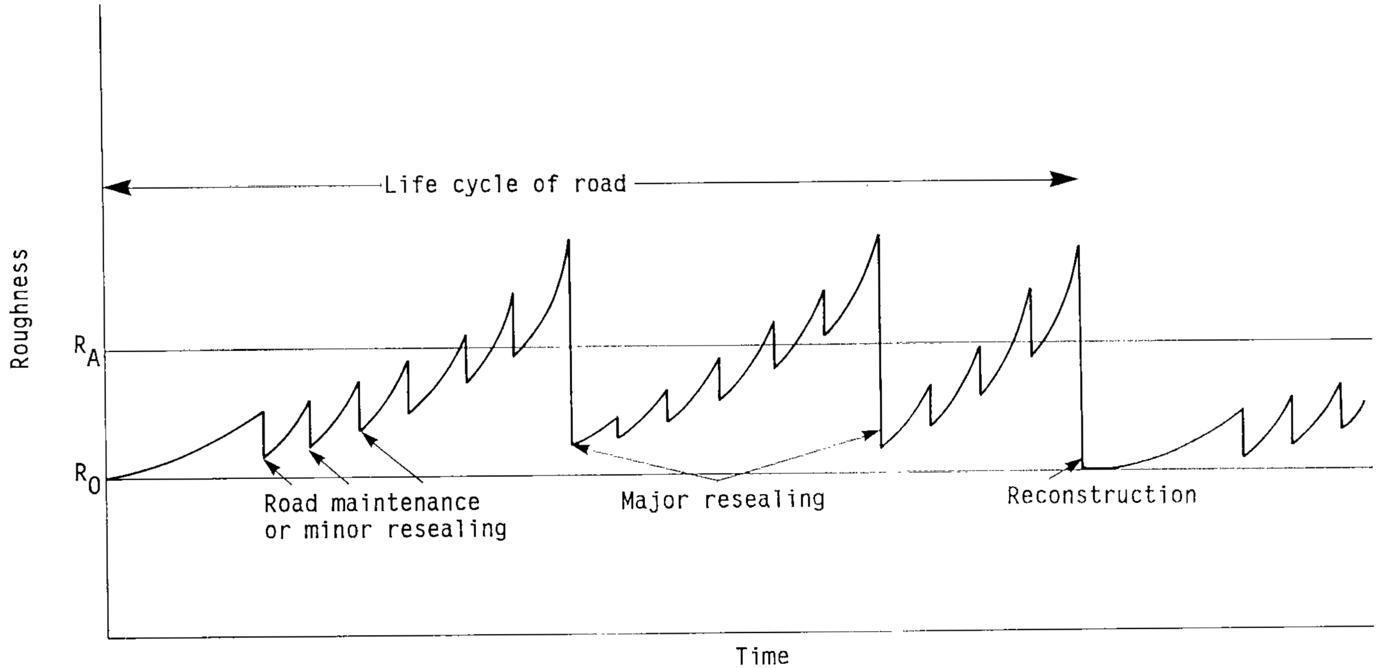


Figure 2.3 Stylised roughness profile of a road

addressing the various manifestations of road damage (for example, surface cracking, potholes or rutting). When considering the upkeep of a road, there is always a trade-off between routine maintenance and the frequency of resealing and reconstruction. Ideally, road authorities would employ an optimal combination of routine maintenance, resealing and resconstruction to prevent overall deterioration of the road system. In practice, the life-cycle costs may not always be optimised, due to constraints on road resources, budget constraints and/or poor management or work practices. Poor planning of road requirements can be another problem. These problems will act to increase the avoidable cost of vehicle travel and increase the economically efficient charge above its long-run optimal level.

There is an important distinction to be made between avoidable cost and actual road maintenance expenditure. While motor vehicles cause damage to the roads as they are driven over the surface, actual road maintenance is not carried out continuously. Costs, in terms of damage, are occurring all the time but maintenance, resealing and reconstruction of roads are undertaken at discrete time intervals in accordance with engineering practice. Thus, in any given time period, avoidable pavement damage cost may not equal expenditure incurred to repair the damage. Thus, under what is termed the PAYGO (pay-as-you-go) approach, road construction and maintenance expenditure in a given year is assigned to vehicles using the roads during that year, whereas in fact most of the damage being repaired in a given year was caused by vehicles using the roads in previous years. The resource cost was incurred in one year whereas the expenditure was outlayed in a later year. As a further complication, resealing and rehabilitation are normally categorised as road construction expenditure. Accordingly, the level of expenditure classed as road maintenance in most published statistics should not be taken as a proxy for avoidable pavement damage cost.

Use of Ramsey prices

It was noted earlier that the economically efficient method of collecting revenue above avoidable cost is to use Ramsey pricing. This requires that the difference between the revenue target and the sum of the avoidable costs be allocated among users in inverse proportion to their individual price elasticities of demand for road use.

In BTE (1985b) it is noted that this rule applies where there is no competition between road and rail. For those areas, such as some long-distance freight, where there may be competition, it is appropriate to modify the Ramsey pricing rule to take account of the degree of competition between the two modes (refer Turvey 1971). Taplin (1980) has argued that a satisfactory procedure is to equate the price/short-run marginal cost ratios for both modes as suggested by Kolsen (1968). Here the road price refers to the freight rate charged to customers and marginal cost includes not only the marginal vehicle operating cost for both modes (for example, fuel consumed, wages and vehicle maintenance costs) but also the other components of full social cost: pavement damage, congestion, traffic administration and so on. Because there is evidence that railways are not recovering their short-run marginal cost on some services, there may be an argument for reducing the Ramsey pricing charge for roads or even pricing road transport below its short-run marginal cost. Before making this adjustment to the Ramsey pricing rule, one should be satisfied that:

- the Ramsey pricing rule will lead to significant shifts in traffic from one mode to the other compared with the situation when both modes are priced at short-run marginal cost; and
- pricing for these rail services cannot be adjusted to the appropriate level.

With regard to the first point, there is some evidence to the contrary; that a rise in road freight rates of one or two cents per tonne-kilometre will not lead to a significant loss of traffic to rail. This is because most freight travelling by road is not price competitive with rail. Much freight travelling by road does so because of other factors beside price, including speed of delivery and overall quality of service considerations. This being the case, interference with the economically efficient pricing rules to allow for the fact that rail may not be recovering its short-run marginal cost, is probably not warranted.

Altering the optimal pricing arrangement for road transport for this reason is, in any case, a 'second best' arrangement. The optimal policy, in economic terms, would be to ensure that freight in both modes is priced at least at short-run marginal cost.

An additional aspect to consider is that the short-run marginal cost of rail services may be artificially high because of externally imposed restraints (for example, over-manning in some areas resulting from government-imposed policies or railway management). Some railway costs are not truly operating costs but more in the nature of industrial relations costs. There is little evidence that road transport has suffered any competitive disadvantage with rail because of such policies. Indeed, if anything, the opposite may be true.

Accordingly, road cost recovery rates should not be artificially reduced simply because of subsidies to railways.

Ramsey pricing has been criticised because it ignores equity considerations in allocating costs. This is of course true of any non-equity approach to cost allocation - not just the efficiency approach. The usual response to this criticism is that equity adjustments are better carried out directly rather than indirectly through the pricing system. It is possible, however, to make provision for explicit incorporation of equity aspects using the Ramsey pricing allocation method (see Diamond and Mirlees, 1971). In the absence of such provisions, Ramsey pricing could result in the allocation of more costs to lower income groups than to higher income groups. In the Ramsey pricing allocation undertaken in Chapter 7, the market segmentation is based on broad market characteristics such as freight:passenger and business:domestic, rather than community income groupings. Any inequities will be the result of chance rather than by design. Ramsey pricing is no better or worse in this respect than any other approach. In fact, by leaving distributional questions to be resolved in some more appropriate manner, this cost allocation system does not impose a narrow and non-representative view of equity onto road users.

Demand elasticities

The main problem with the Ramsey pricing approach is the need to determine robust, usable estimates of demand elasticities. There is very little empirical data on demand elasticities in Australia and most researchers have assumed elasticities from overseas studies or have based their estimates on the limited Australian work. However, this may not be appropriate as elasticities are likely to differ between different countries and change over time. For example, it is possible that road users are becoming more immune to fuel price changes as a consequence of the large nominal price increases of the 1970s. The inflation expectations of road users may also change over time and so affect road users' responses to price increases.

Where information on elasticities is scarce, there is still merit in adopting Ramsey pricing since the pricing process will generate information on demand elasticities. Private firms generally price according to demand even where information is limited. Sometimes they conduct market research, or they may achieve approximate Ramsey prices by an iterative process.

If a Ramsey pricing approach is to be adopted, simplifying assumptions have to be made. Whatever values are assumed, it is prudent to conduct sensitivity tests on the results because slight differences in assumed elasticities can make large differences in the expenditure recovery calculations for users with fairly inelastic demand. (This is mainly due to the effect of taking the inverse of small numbers.) It does not necessarily mean that a great loss of efficiency would have occurred if the prices had actually applied, since low demand elasticities imply that users are relatively indifferent to the resulting change in price.

EQUITY APPROACHES TO ALLOCATING ROAD COSTS/EXPENDITURE

Given the problems of practical implementation of Ramsey pricing for roads alternative approaches have been adopted in some cost recovery studies. Others have adopted alternative approaches for other reasons. The United States Congress for example, directed the United States Federal Highway Administration (US FHA) to adopt an equity approach.

Since road cost allocation is, in effect, at least a notional distribution of resources between competing sectors, allocations which do not maximise welfare (that is, a non-efficiency approach) are based on some other concept such as equity. There is, in a sense, an implicit trade-off between an efficient allocation of resources and an equitable allocation.

Equity generally takes the form of a requirement for both horizontal and vertical equity. Horizontal equity implies nothing more than that users of similar amounts pay the same. Vertical equity implies that users of greater amounts pay more. Generally, the equity criterion is taken to mean a requirement that users pay for road use in some proportion to their use. Within this loose definitional framework, however, it is impossible to define equity in practice since it is a subjective notion. Hence there are many possible equity approaches, and their application is largely arbitrary. Nevertheless, certain guidelines can be established.

The United States FHA has identified three broad approaches to obtaining an equitable distribution of costs among road users. These are:

- the cost-occasioned approach
- the benefits approach
- the ability to pay approach.

These three approaches have been outlined in BTE (1985b). The only one used extensively in practice has been the cost-occasioned approach. Each of the studies examined in Chapter 4 involves variations of this approach. In the examination of the United States cost allocation study in Chapter 4, it will be seen that a detailed and refined methodology has been established over many years.

Generally, the cost-occasioned equity approach allocates short-run avoidable cost in a manner similar to the efficiency approach. However, it also allocates common and joint costs on the basis of a long-run notion of responsibility for causing specific costs to be incurred. The allocation is generally based on various engineering relationships but is essentially arbitrary.

It is useful to note that the main difference between the Ramsey pricing approach and the cost-occasioned approach in the allocation of costs/expenditure above avoidable cost is that the former is demand-based while the latter is cost-based.

An efficiency approach to road pricing seeks to maximise welfare in society as a whole. Given this maximisation, various equity objectives can then be achieved by means of direct subsidy. An alternative viewpoint suggests that, with the range of interests affected by road pricing and given the current level of debate, full cost recovery might be more readily achieved where particular costs are clearly tied to particular users - a cost-occasioned approach. The implications of such a trade-off, in terms of loss in economic welfare, needs to be properly assessed. In many studies, they are simply ignored.

COST RECOVERY CALCULATIONS

Road cost/expenditure recovery calculations are in essence an arithmetical, ex-post comparison of revenues obtained from road user charges, with cost/expenditure incurred in the provision and use of the road system. The results indicate the impact of current road pricing policies in achieving particular goals. For example, they can indicate which road users are making an acceptable contribution towards the costs of roadworks. Cost recovery calculations are thus a means rather than an end in themselves.

Cost/expenditure recovery calculations must be structured in accordance with the pricing objective sought if they are to be useful as a guide to road pricing decisions. If economic efficiency has been taken as the primary objective there are three basic steps required in the calculations:

- the determination of the costs to be recovered;

- the allocation of costs among road users; and
- the determination of road use payments made by users.

Cost recovery target

In theory, cost recovery analyses should be based on the economic cost over the full life of the asset. The economic cost includes the opportunity cost of the resources tied up in the road system, plus the amount by which the value of resources changes over the period (for example, depreciation).

The opportunity cost is the cost of not using road resources elsewhere in the economy and is the best return that could have been obtained by investing elsewhere all the resources tied up in the road system. The change in value of the road resource (depreciation) is predominantly due to wear and tear and damage to the existing infrastructure.

In this exercise, however, the cost to be recovered is set at the level of annual expenditure on road construction and maintenance. This is largely because the studies examined in this Paper used this approach and because it is the publicly perceived annual cost of providing roads. This approach of recovering from road users in each year the total of expenditure on roads in that year, is referred to as the 'pay-as-you-go' or 'PAYGO' approach to road cost recovery.

The accent here is on road infrastructure expenditure. Items such as traffic control, policing of traffic regulations and road safety education are excluded from cost recovery calculations, as are vehicle operating costs and externalities such as accident costs, pollution and congestion costs. These items are discussed in more detail in Chapter 5.

The cost/expenditure recovery target adopted under this PAYGO approach is likely to be far less than the economic cost of the road system (which would include the opportunity cost of the $40 billion or more in road assets) and also much less than the total financial cost of the road system to the whole community (which would include all the social costs of roads).

Allocation of costs among road users

The allocation of costs among road users has been discussed in detail above. In short, the achievement of efficiency requires that road users just be charged their short-run marginal cost of road use and then a fixed, or a combination of a fixed and variable charge based on Ramsey principles. Thus, the cost recovery calculations require the identification of the level of short-run marginal costs of each road user (in practice, each road user class) and then allocating the balance of the cost recovery target among users using Ramsey pricing rules.

The methodology is described in detail in Chapters 6 and 7. The allocation of short-run marginal cost largely involves determining the level of road damage repair cost each year and establishing relationships between the level of road use by each vehicle and the level of road damage caused by the vehicle (for example, using the concept of ESALs). The total level of road damage cost can then be apportioned among vehicle types using the relationships. The Ramsey pricing calculations are simple arithmetical calculations but require information on the elasticities of demand for road use for each vehicle type, output prices and total output (in tonne-kilometres or passenger-kilometres).

An equity-based cost recovery allocation is also described in Chapter 7. It requires a similar breakdown of short-run marginal cost but instead of a Ramsey pricing calculation, it requires an allocation of other costs (road construction cost, new bridge cost, administration cost and so on) either on the basis of engineering relationships or arbitrary rules such as annual vehicle-kilometres travelled by each vehicle.

Road revenue

The last step in the cost recovery calculations is to compare the cost allocated to each vehicle type with the road user payments made to the various levels of government. Unfortunately, there is little agreement among researchers on the definition of a road user payment.

Road users pay a large number of taxes and charges to various governments in Australia but not all are paid as specific road user charges. Therefore, not all government revenue from road users can be automatically considered as arising from charges for road use. A charge on road use may not necessarily be a charge for road use.

Most government revenue is earned from three sources. These are:

- economic 'rents' from the ownership or control of resources;
- general taxation revenue raised from the broad community; and
- revenue from specific charges for specific services provided.

Revenue earned by way of economic rent should not be considered as road cost recovery revenue as it arises from the ownership or control of resources sold. An example of this is the production levy on crude oil and LPG. Some studies have incorrectly included this revenue in the estimate of cost recovery revenue. It is not a charge on road use. Given the import parity pricing policy, the price to consumers would be the same whether the crude oil levy was paid or not. In fact the levy currently applies only to 'old' oil and not 'new' oil (discovered after 1977).

Similarly, revenue earned from road users which is intended as a contribution to general revenue rather than a road user charge may not be considered as road cost recovery revenue. Such charges would still be made on road users even if governments were not responsible for road provision. A very broadly defined study, such as one which wished to show that the road sector was contributing more to government revenue than the government was spending on road-related activities, would include general taxation on the revenue side. Such a study should include all government expenditures related to roads such as those on policing, administration, accidents (including hospitals), legal costs and the expenditures of road transport departments and authorities.

The question of isolating the government revenue which should be matched against government road expenditure requires a definition of government road user charges. A broad definition of road user charges would include all taxes and charges paid by road users as a consequence of their use of a road vehicle. These include:

- all fuel excises and fuel taxes;
- vehicle sales taxes;
- customs duties;
- registration fees;
- sales taxes on vehicle parts and tyres;
- stamp duties on all documents relating to vehicle ownership; and
- several other charges such as drivers' licence fees, road and bridge tolls, number plate fees, parking fees and so on.

A more restrictive definition would include only those charges which were unique to vehicle ownership and use. Thus, sales taxes, customs duties and stamp duties would be excluded since they are general taxes paid on a wide range of goods.

This raises a question regarding the categorisation of the Commonwealth fuel excise since this is in part hypothecated (tied) to road expenditure, and so this part is clearly specified as a road user charge and falls almost entirely on road users. However, the excise is also partly intended to raise general revenue, and so this part is clearly not intended as a road user charge. For instance, while much of the fuel excise is hypothecated to roads, the Federal Treasurer indicated in the 1986-87 Budget Speech that the increase in the excise by 3 cents per litre (about 14 per cent) in that Budget was intended to raise general revenue, not to recover road expenditure (Budget Statement No 4, 299). This is evidently true of a large proportion of the fuel excise revenue. However, in the absence of explicit guidelines, the estimates made in this Paper treat all Commonwealth fuel excise as contributing to road expenditure recovery revenue. Similar considerations apply to State fuel franchise fees. In this Paper, all State fuel franchise fees which are collected in all States except Queensland, are treated as road user charges. The reason for this approach was that each cent per litre of fuel excise has an effect on road use whether hypothecated to road use or not.

A still much more restrictive definition would include only those charges that are legally, formally, or in practice, designated by governments as road user charges to be hypothecated to road use. These would include:

- the hypothecated share of Commonwealth fuel excise, that is, the share accruing from the Australian Bicentennial Road Development (ABRD) levy and that hypothecated under the Australian Land Transport Program (ALTP);
- State fuel franchise revenue actually tied to road works (excluded would be revenue from excises on motor spirit in New South Wales and amounts withheld for general revenue purposes in other States);
- the bulk of State registration fees;
- a share of drivers' licence fees in some States only; and
- other specific charges such as road and bridge tolls, some road transport taxes, etc.

The Terms of Reference for the Inter-State Commission (ISC) study (1986) directed that the Commission adopt a restrictive definition, particularly regarding Commonwealth fuel excise. Only that element of fuel excise hypothecated to road works was to be considered as a road user charge.

Without firm guidelines as to what is or is not a road user charge, there are numerous possible definitions. For the purpose of this

Paper, certain revenue sources were excluded from all three definitions. The most important of these is the levy imposed by the Commonwealth Government on crude oil production. The production levy is a rent return to the Government due to its ownership and control of the resource. Alternatively, it may be considered as a general taxation measure but not a road user charge. This is because it is levied on producers. A similar argument applies to State petroleum royalties. The reasons for this are discussed more fully in Appendix II.

Some other charges excluded are a share of drivers' licence fees in some States, along with some number plate fees and parking fees which are all specifically tied to items other than road infrastructure expenditure (for example, traffic administration, policing, parking and traffic accident research).

The definition of a road user charge is fairly arbitrary and depends largely on the purpose of the analysis.

The first definition is considered to cover adequately revenue from road users but is too broad for the purposes of an expenditure recovery exercise. Many of the items included are taxes which are also paid by other consumers on a wide range of goods and so can be considered as representing a contribution by road users, along with other consumers, to the general revenue of Commonwealth and State governments.

Payments which are clearly taxes should be excluded from calculations of the level of recovery of avoidable cost and similarly should not be regarded as part of the price for road use. Electricity or gas authorities do not reduce charges to particular firms for their usage of electricity or gas on the basis that some firms pay more taxes, either directly or indirectly, than others - neither should governments supplying roads. The issue of whether governments should 'tax' road transport, over and above 'pricing' to recover avoidable cost, is a separate issue. There are, for example, arguments that intermediate goods or services, of which road transport is an example, should not be taxed and only final goods and services taxed. On the other hand, some equity considerations, as discussed above, may lead governments to want to recover a fair share of joint and common costs from operators of trucks rather than recover all these costs from motorists or taxpayers. Any taxes so imposed may of course have some impact on the demand for road use as do charges for road use. Which particular taxing or charging mechanisms are used to recover road costs does not really matter, the key issue being that the charges should be related to marginal cost, as argued in this chapter, and any taxes be levied so as to minimise distortions to demand patterns.

The third definition is considered too narrow, as some charges which are not formally designated or (in practice) used by governments as user charges are nevertheless regarded as charges for road use by most researchers on technical grounds (for example, they vary directly with road use and are identical to hypothecated taxes). The intermediate definition is the one used in Chapter 5 of this Paper to determine aggregate revenue from charges for road use. Some adjustments to this definition are made for some of the cost recovery comparisons in Chapters 6 and 7.

OPTIMALITY IN ROAD PRICING AND INVESTMENT

As noted above, the set of conditions for optimal road investment and usage are quite specific and unlikely to be approximately achieved with respect to Australian roads. Many Australian roads, usually for quite complex reasons, are provided with a vast degree of over-provision of capacity. On many other roads, particularly in city areas, there is a good degree of under-provision of capacity. Apart from these questions of whether the road infrastructure provided is the most suitable for road user requirements, the lack of competition in provision also begs the question of whether the roads that are provided, are provided at the lowest cost. In many overseas countries, roads of a given capacity would be built quite differently from Australian construction methods. Concrete roads, for example, are much more common in the United States and Europe than they are in Australia.

The effect of non-optimal pricing may also be quite significant. For example, failure to fully price for pavement damage and congestion may lead to an over-use of road resources. It may be that these resources could be employed more usefully elsewhere in the economy, or that the roads we have could be used more effectively or made to last longer.

The result of inefficient road investment and road user decisions is a significant and dramatic cost to the community in terms of loss of opportunity. A few recent overseas studies have attempted to measure the cost of inefficient pricing and investment. These have shown the cost in the United States, for example, to be in the order of hundreds or even thousands of millions of dollars per annum (see, for example, Small and Winston 1986, United States Department of Transportation 1982). These costs include among others, higher road damage costs than are necessary and higher rail deficits.

While the measurement of opportunity cost may be difficult, there are some more obvious impacts on the broader economy which underline the estimates.

Inefficient road prices may affect the locational pattern of industry, perhaps causing over-centralisation and in some cases, over-decentralisation. An incorrect cost structure also does not allow the most appropriate industries to develop. Effectively providing subsidies to those industries which use large amounts of transport may be to the disadvantage of an alternative industry which competes for resources and may provide significant economic returns including export earnings to the country.

Add to these aspects an annual road damage bill of about $2000 million, the wasteful congestion and queuing on many of our cities' main roads and the large deficits suffered by most rail systems and the case for a more efficient approach to transport pricing and investment, particularly through efficient pricing, becomes stronger.

In summary, we may be sacrificing economic growth 'for what are basically very petty short-run distributional considerations' (Gruen 1986, 193).

While the impacts may be fairly obvious, there is also an obvious need for research on the actual effects of such inefficiency in transport pricing and for analysis of the cost-effectiveness of implementing change. Some initial steps in this direction are outlined in Chapter 8.

CHAPTER 3 EFFICIENCY-BASED ROAD COST/EXPENDITURE RECOVERY

The identification of avoidable road costs is a key aspect of an efficiency-based road cost/expenditure recovery analysis. However, few of the numerous Australian road cost recovery and road pricing studies (including those reviewed in BTE (1985a)) have successfully identified and measured the components of avoidable road cost. The bulk of avoidable road costs are those related to wear and tear on the pavement. The initial research in this area was carried out in the United States in the 1960s by the American Association of State Highway Officials (AASHO). In Australia, the National Association of Australian State Road Authorities (NAASRA) sponsored the Economics of Road Vehicle Limits (ERVL) study in the mid-1970s which drew largely on this United States work.

The ERVL Study gave rise to several reports and papers including a study of separable (avoidable) pavement costs by Webber, Both and Ker (1978). This latter study is reviewed in this chapter as it gives one of the clearest assessments of the components of avoidable pavement costs for the Australian road system.

Continued upgrading of the road system and the increase in the number of heavy vehicles in the late 1970s and early 1980s gave rise to significant pressure from road transport operators and shippers for further increases in vehicle loading limits. The Review of Road Vehicle Limits (RoRVL) was undertaken by NAASRA in the mid 1980s to assess the economic impact of further increasing vehicle limits. The usefulness of this study for updating estimates of avoidable pavement cost is discussed as a postscript to the review of the Webber, Both and Ker study.

An alternative method of establishing the level of avoidable pavement cost was followed in a 1981 study, 'Pricing Tasmania's Roads' (Transport Economics Centre 1981). This study was prepared at the University of Tasmania's Transport Economics Centre (TEC). The study estimated avoidable pavement costs on Tasmanian roads in 1979-80 using regression analysis. It went further than the Webber, Both and Ker study by allocating all annual road expenditure. Indeed, it was the first Australian study to allocate road expenditure based on economic efficiency principles. As such, it is useful to consider its methodology, its degree of adherence to economic efficiency principles and its applicability to the allocation of national, as against only Tasmanian, road costs.

This chapter examines both the ERVL and the TEC studies. The discussion covers the methodology used to estimate avoidable cost and, in the case of TEC study, the Ramsey pricing analysis adopted for recovering costs/expenditure above avoidable cost.

The reviews include a discussion of the avoidable pavement cost components, an assessment of the levels of those costs and the reasonableness of the Ramsey pricing allocations in the TEC study. There are also comments on problems with the studies and adjustments to the results which might be required to update and improve the accuracy of the estimate of the level of avoidable pavement costs. Comment is made on issues which are important to the determination of the level of avoidable pavement costs, the allocation of these costs and the allocations following Ramsey pricing rules.

WEBBER, BOTH AND KER STUDY

Background

The purpose of the Webber, Both and Ker study was to provide an estimate of the separable pavement costs which could be attributed to various types of trucks. This was to form part of the consideration of alternative road pricing schemes by the Meech Committee which was convened to advise the Australian Transport Advisory Council (ATAC) on the implementation of alternative road charges. The Paper is largely an updated version of the original report to the Meech Committee prepared by Pittard, Webber and Both (1977). The authors were directed to use the NAASRA ERVL study methods and data to derive their estimates.

Methodology

An examination of the methodology employed by Webber, Both and Ker requires a brief discussion of the ERVL methodology. The ERVL study was concerned with the evaluation of changes in costs and benefits which would result from an increase in commercial vehicle mass and dimension limits. These were assessed both nationally and in particular regions.

As part of the study, a comprehensive vehicle classification survey and a vehicle mass and dimension survey were conducted in 1974-75.

The classification survey attempted to identify the relative importance of various vehicle configurations and body types in terms of vehicle numbers, distances travelled and freight load carried. The mass and dimension data were used to establish detailed characteristics of vehicles. Information on the quality and extent of the road system was also gathered.

The cost changes measured in the benefit-cost analysis were mainly the avoidable pavement costs of heavier freight vehicles. The four cost components which were expected to change as vehicle limits increased were:

- remaining life of pavements;
- pavement reseal frequency;
- routine pavement maintenance; and
- pavement strength requirements.

The Webber, Both and Ker study considered the avoidable pavement costs of trucks only. Motor cars were excluded on the assumption that they caused negligible damage to road pavements.

It was assumed on the basis of the AASHO work that damage to road pavements was approximately proportional to the fourth power of the axle load of each vehicle. The road damage is thus a function of vehicle mass and the number of axles but it also depends on other factors such as the spacing of axles, number of tyres per axle and the dynamic characteristics of each vehicle. Vehicle axle loads are converted into a number of equivalent standard axle loads (ESALs) for each vehicle, by dividing the sum of the fourth powers of the weights on each axle by the fourth power of a defined standard axle load. Damage is then assumed to be a linear function of ESALs multiplied by distance travelled, or ESAL kilometres.

The total of the four components of avoidable pavement cost was estimated for each of three rigid truck and four articulated vehicle types using ERVL truck survey data. A computer program developed by State road authorities was used to simulate the effects, in terms of road maintenance, resealing, reconstruction and upgrading costs, of removing each of the vehicle categories from the total fleet. The avoidable pavement cost for each vehicle type was calculated as the difference in costs between a base run with all seven vehicle types and runs in which one vehicle type was excluded.

Reductions in avoidable pavement costs were realised in several ways:

- an increase in the remaining life of pavements (owing to a reduction in their rate of deterioration) was realised by the deferral of the need for reconstruction;
- a similar reduction in the deterioration of seals enabled a decrease in pavement reseal frequency;
- reduced pavement loadings meant that the pavement required less routine maintenance; and
- a reduced pavement strength requirement gave rise to a reduction in construction costs.

Calculations

The savings in pavement costs for each vehicle type removed were calculated for each of the 25 years, from 1976 to 2000. A computer program produced a table of cost savings over the 25 years for each vehicle type excluded, for each of the cost components. This represented the cost savings of any works postponed as a result of removing each vehicle type from the 1976-80 period to later periods. The study then determined the amount of savings in each subsequent year that was attributable to road users in the base year (1976-77).

For reconstruction and resealing it was assumed that the pavement life was directly proportional to the rate of application of standard axle repetitions. Given average truck ESALs, the discounted cost for each of the 25 years was then allocated on the basis of cumulative truck-kilometres. The sum of savings over 25 years represented the avoidable pavement cost per truck-kilometre for that component (reconstruction or resealing).

Avoidable routine maintenance costs were considered to have a much shorter term causal relationship than 25 years. It was found that there was little change in routine maintenance savings from one year to the next. To avoid the risk of an unrepresentative value in a single year, a five-year average (1976 to 1980) was estimated, although this tended to slightly understate the amount attributable in the base year due to traffic growth over the five-year period.

The routine maintenance component was calculated as the change in costs over the five years divided by the truck-kilometres over that period.

Avoidable pavement costs, including strengthening, for two-axle rigid trucks (for example) were calculated as:

. service life	1.108 c/km
. resealing	0.266 c/km
. routine maintenance	0.048 c/km
. strengthening	0.067 c/km
Total avoidable pavement cost	1.489 c/km (1974-75 prices)

A summary of the estimates made for all trucks is shown in Tables 3.1 and 3.2.

Problems with methodology

There are five main areas of concern or comment in applying the methodology of Webber, Both and Ker to road pricing or cost/expenditure recovery estimates. These are:

- the cost components, namely inclusion of 'strengthening' component and omission of bridge costs;
- the estimation of average axle loads;
- the use of the fourth power rule;
- road use data; and
- the apparent diseconomies of scale.

Cost components

Within the definition formulated in Chapter 2, each of the four cost components identified is a short-run avoidable pavement cost with the exception of the pavement strength requirement. Change in the pavement strength requirement is a long-run cost. It is fixed in the short-run since pavement strength cannot be automatically or continuously adjusted. It cannot be directly attributed to current users and therefore should not be used for efficiency-based avoidable cost pricing of an existing facility (that is, to clear the market in the short-run). This does not mean, however, that it should not have been included in any long-run benefit-cost analysis of increasing vehicle weight limits. Its inclusion as a long-run cost component suggests that, by increasing pavement capacity in terms of strength, optimal short-run costs could be lowered from the existing levels (refer Figure 3.1).

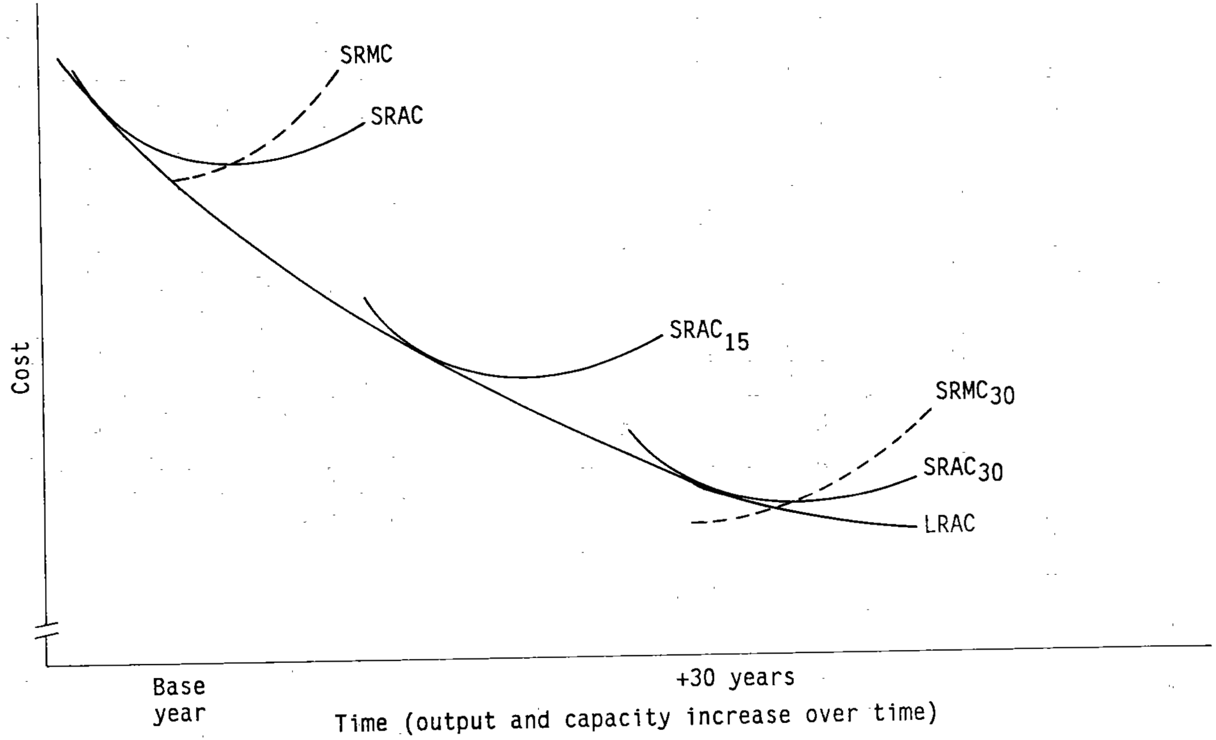


Figure 3.1 Long-run and short-run cost aspects of the Review of Road Vehicle Limits study

The authors found that the strengthening component was a relatively minor contributor to the overall level of separable cost (for example, 4.5 per cent for two-axle rigid trucks). It can therefore be netted out without unduly affecting the results. Some upward adjustment will be required to the estimated levels of the remaining three components to obtain estimates of road damage costs on current (unstrengthened) roads. The short-run cost on strengthened roads will be lower than current cost because of economies of scale of the new strengthened road. Thus the ERVL study and the Webber, Both and Ker study will tend to underestimate current short-run costs. This issue is discussed further in relation to the RoRVL study.

No assessment was made in the Webber, Both and Ker paper of short-run avoidable bridge costs, although the ERVL study assumes that bridge costs 'form 30 per cent of the total cost of the alternative set of limits' (NAASRA 1976, 68). The NAASRA Roads Study (NAASRA, 1984a) indicated that bridges are a significant component of road costs and the BTE has estimated (BTE 1984b) that expenditure on bridges is in the order of 6 to 10 per cent of all road expenditure. It would be expected that a significant proportion of the maintenance and restorative costs of bridges are avoidable. The NRFII consultant's paper reviewed in the next chapter (Nicholas Clark and Associates 1984) arbitrarily assigned 18 per cent of bridge expenditure as an avoidable cost of truck use. This represents slightly more than 1 per cent of annual arterial road expenditure.

Estimation of average axle loads

In estimating average axle loads of each vehicle class, the Webber, Both and Ker study adopted definitions used by road maintenance charge legislation applicable at that time. Accordingly, the average assessed mass of various truck types was assumed to be equal to the average tare mass plus 40 per cent of average payload capacity for each truck type (Webber, Both and Ker, 1978, 304, Table 1). While this procedure may have had legislative backing, it is not a reliable estimate of average loadings. A more precise estimate would be obtained by relating the avoidable cost to the actual load as indicated by a frequency distribution of loads on vehicles in each class although this would involve a more complex procedure. A typical frequency distribution of axle loads is included as an example in Webber, Both and Ker (1978, 302, Figure 1).

Using average loading to assess damage levels of particular vehicle groups is likely to lead to an underestimate due to the effect of the fourth power rule.[1] This rule implies that the road damage caused by vehicles with above average loading increases at a much faster rate than does the load. A 10 per cent increase in load for a fully laden six-axle articulated truck (from 26 to 28.6 tonnes) leads to a 30 per cent increase in damage. This problem of estimating average truck damage was resolved in the RoRVL study by calculating actual ESALs for each truck identified in a number of surveys throughout Australia. A frequency distribution of ESALs was thus obtained.

Use of the fourth power rule

The fourth power rule has been challenged several times. Its relevance to Australian road damage functions has been questioned on the basis that Australian road conditions differ from those in the United States where the rule originated. It has also been suggested that a damage function based on dynamic loadings would be more realistic. The fourth power rule is generally taken as a usable guide for stronger roads but is less realistic for poor quality roads. In the latter case, a lower power may be more appropriate since United States and World Bank studies have shown that the damage caused by cars relative to trucks is greater on weaker roads (perhaps a ratio of 10:10 000 compared with 10:100 000 on stronger roads). Of course a greater level of damage results from any given vehicle passing over weaker roads. Damage was found in the AASHO studies to be inversely related to the seventh power of pavement strength. This point is also noted by McDonell (1980, 3/7).

The fourth power rule also appears to be valid only over a certain range, however. For instance, its applicability to very low loading levels, such as those applied by cars, is not known with certainty. Application of the fourth power rule to cars implies very low damage, while some studies have reported no pavement damage due to cars and others have reported net benefits to pavements due to cars. Research in Australia by the Australian Road Research Board has supported the fourth power rule as a useful guide (see Lay 1986, Chapter 14).

Road use data

The ERVLs study estimates of road use were significantly different from those made by the Australian Bureau of Statistics' Survey of Motor Vehicle Usage (SMVU) (ABS 1978). However, it was noted by

---

1. An average of two or more positive numbers raised to the fourth power will always be less than the average of the fourth power of each number (eg 3^4 is less than $\frac{2^4 + 4^4}{2}$).

McDonell (1980, 3/13-3/14) that, while the ABS SMVU was more comprehensive, it may have underestimated road use by heavy vehicles due to the survey methods used. This is an ongoing problem with ABS survey data on heavy vehicle travel and one which may lead to some overestimation of avoidable cost per vehicle-kilometre.

Diseconomies of scale
Table 3.1 shows avoidable pavement cost per tonne-kilometre increasing as vehicle size (capacity) increases. The apparent implication that there are no economies of scale was a cause for comment by Standingford (1985, 6). The increase in avoidable pavement cost as vehicle capacity increases suggests diseconomies of scale with respect to pavement costs. However, this may simply reflect the greater loadings on each axle in the larger vehicle categories and the effect of the fourth power rule. The question of overall economies of scale of large vehicles involves a consideration of all cost components, public and private, as discussed in Chapter 2. Larger vehicles may be more economic per tonne-kilometre when all costs are taken into account, at least up to a certain point. As well, a different picture appears if one compares all vehicles loaded to the same gross vehicle mass as the gross mass limit for the largest vehicle (38 tonnes). Those with more axles will produce less damage costs and less cost per tonne of load.

Results and adjustments

The major results of the Webber, Both and Ker paper are shown in Tables 3.1 and 3.2. They indicate that the level of avoidable cost in 1976-77 was about $224 million. This represented some 15 per cent of that year's total road expenditure, and about 27 per cent of that year's arterial road expenditure. An adjustment to the Webber, Both and Ker estimates which takes account of the problems noted above, would result in significantly higher figures in real terms. The most likely adjusted figure is around $335 million in 1976-77 prices.

With these adjustments, and allowing for changes in vehicle loading and travel up to the 1985 ABS SMVU, the Webber, Both and Ker methodology would imply that avoidable pavement costs on arterial roads are currently about 47 per cent of arterial road expenditure.

REVIEW OF ROAD VEHICLE LIMITS STUDY

In 1984, following pressure from truck and bus operators and industry and operator groups and associations, NAASRA established the Review of Road Vehicle Limits (RoRVL) study team. The task of the study team was to: 'review the mass and dimension limits and associated regulations applying to vehicles using Australian roads with the objective of enabling the road transport industry to improve its economic viability' (NAASRA 1985, iv).

The road transport industry claimed that it could achieve an improvement in its economic viability through an increase in vehicle mass and dimension limits. The study was essentially a comparison of the estimated costs and benefits of increased vehicle limits.

The study team conducted surveys of heavy vehicles, collected data on Australian arterial roads and discussed possible changes to vehicle limits with various interested groups. The economic analysis was limited to assessing the 'benefits to heavy vehicle operations and to motorists' and comparing these to assessed 'road and bridge damage costs' (NAASRA 1985, iv). On the basis of this analysis, the study team presented several options for increased vehicle limits to NAASRA and ATAC in 1985. Option A, allowing vehicles up to 41 tonnes gross mass and in particular, 20 tonnes on the two-axle group, was adopted in the eastern States by September 1987. Higher limits already applied in South Australia, Western Australia and the Northern Territory.

TABLE 3.1 AUSTRALIA-WIDE SEPARABLE PAVEMENT COSTS ESTIMATED BY WEBBER, BOTH AND KER, 1976-77

Truck type	*Separable costs (c/truck-km)*	*Average tare mass* (*tonnes*)	*Average payload capacity* (*tonnes*)	*Average assessed mass*[a] (*tonnes*)	*Separable costs (c/tonne-km)*
2-axle rigid	1.9	4.7	8.5	8.1	0.23
3-axle rigid	2.6	7.1	11.7	11.8	0.22
4-axle rigid	3.6	8.8	14.8	14.7	0.25
3-axle articulated	4.0	7.7	13.9	13.3	0.30
4-axle articulated	5.2	9.6	19.1	17.2	0.30
5-axle articulated	6.0	11.7	20.4	19.9	0.30
6-axle articulated	7.5	13.1	22.2	22.0	0.34

a. Assessed mass is defined as being equivalent to tare mass plus 40 per cent of payload capacity.

Notes 1. Analysis excludes Northern Territory.
2. Costs are in 1976-77 prices.

Source Webber, Both and Ker (1978, 304).

TABLE 3.2 ESTIMATE OF AVOIDABLE PAVEMENT COSTS ON AUSTRALIAN ARTERIAL ROADS[a] BY WEBBER, BOTH AND KER, 1976-77

Truck type	*Travel in 1976-77*[b] *(million truck-km)*	*Separable costs (c/truck-km)*	*Avoidable cost in 1976-77 ($m)*
2-axle rigid	4 331	1.9	81
3-axle rigid	882	2.6	23
4-axle rigid	236	3.6	8
3-axle articulated	410	4.0	16
4-axle articulated	777	5.2	40
5-axle articulated	690	6.0	42
6-axle articulated	183	7.5	14
Total	7 509	..	224

a. The annual pavement cost is for 1976-77 and is in 1976-77 prices.
b. Derived from ERVL study.
.. Not applicable.

Source Webber, Both and Ker (1978, 304).

It was noted above that the ERVL methodology understates short-run costs as it is assumed that there will be a new strengthened road. In essence, both the RoRVL and ERVL studies include this long-run component. This measure includes the share of cost increments due to an increase in vehicle limits (and correspondingly ESAL kilometres) following pavement strengthening, whereas pavement strengthening is a long-run and not a short-run cost. The former is a useful input into an investment decision about upgrading or strengthening roads but not for considering appropriate use of existing roads.

To assess the impact of the new limits, a computer simulation model, NAASRA Improved Model for Project Assessment and Costing (NIMPAC), was used. The model simulates road projects (maintenance, resealing, reconstruction, upgrading, duplications, widening and so on) given a range of input conditions. For the RoRVL analysis a base case was established, representing the expected expenditure on all types of road works assuming the current base traffic levels (with some future growth, of course) over 30 or 31 years. This was compared with expected road works assuming a higher level of ESAL kilometres with each of the new limit options. The difference in costs between each option and the base case represented the costs in terms of road works of each option. A similar procedure was used to estimate additional vehicle operating costs to other road users resulting from higher levels of road roughness with the new limits.

The RoRVL study team undertook two studies: one based on the assumption that no additional expenditure would be made available for road works; the other based on the assumption that the additional road cost generated by the model would in fact be funded. In the former case the costs of the new limit would largely be manifest as higher vehicle operating costs to other users and in the latter case they would be reflected in higher road expenditure.

In practice there is always a trade-off between higher levels of road expenditure and higher vehicle operating costs. Reductions in the latter are the chief benefit of road works. However, it is a matter of judgment as to what combination of these should form the basic assumption behind the RoRVL analysis.

By and large, only the results of the unrestrained budget analysis were emphasised in the RoRVL report. This is, in part, because the restrained budget analysis implies no additional road expenditure by State road authorities. It is more accurate to say that the costs are there, even if the expenditure on road works to repair them is not available. The cost burden falls instead on all other users.

The unrestrained budget assumption is in some ways an optimising assumption. It minimises total costs through trading increased vehicle operating costs against additional road expenditure. As well, all costs are minimised by assuming that road maintenance and rehabilitation costs will be optimum and that roads will be upgraded to an optimum design standard. These assumptions will minimise road roughness and therefore vehicle operating costs. Thus, assumptions are built into the analysis about future road design, as well as judgments about funding levels.

The model responds to an increased level of ESAL kilometres by bringing forward road works as the life of each road is reduced. When the road is reconstructed it is upgraded to allow for higher future levels of ESAL kilometres. In the base case, the road is upgraded to ensure that the life of the new road will be 15 years. Similarly, for each option the road is upgraded to an even higher standard to cater for the additional ESAL kilometres and to ensure a pavement life also of 15 years. From the time of reconstruction it is then assumed that future road costs under all the options will be about the same as under the base case. Thus, for each option there are no additional costs after reconstruction of the road compared with the base case. The road costs due to higher limits are all costs brought forward to the time of reconstruction plus the additional upgrading costs. An optimisation occurs in trading off upgrading costs for future maintenance, resealing and reconstruction costs. The relative shares of upgrading costs and repair costs until reconstruction will depend on the remaining life of each road in the model. Thus, for different roads, either short-run or long-run costs will predominate.

Given the large economies of scale in pavement strength (discussed in Chapter 2) the additional upgrading costs are very small. For a 10 per cent increase in ESAL kilometres only a small increment to pavement thickness (about 1.4 per cent) is required.

As with the ERVL study, the RoRVL analysis implies a move over time to new short-run cost curves as shown in Figure 3.1. With the increase in capacity, a move is made from the generalised cost curves represented by $SRMC_0$ and $SRAC_0$ (short-run marginal and average cost curves) to $SRMC_{30}$ and $SRAC_{30}$. The new cost curves are lower because of economies of scale in road provision. These economies are reflected in the seventh power rule noted earlier.

Two consequences arise from these economies of scale. First, on an average per ESAL kilometre basis the increment to total costs of an additional ESAL kilometre, resulting from higher limits, may be lower than the current cost per ESAL kilometre.

Second, this reinforces the claim made in Chapter 2, that countries like Australia are unlikely to be able to take advantage of the enormous economies of scale in road provision to the extent that, say, the United States or European countries can. The lower traffic levels on Australian roads do not warrant the same level of road investment. As a consequence, road costs attributable to an average truck may be higher in Australia than in these countries.

Arising from the first point, the use of RoRVL results to measure short-run marginal cost will be invalid. Short-run marginal cost can only be measured by considering the existing road system, not one upgraded as in the RoRVL unrestrained budget analysis. In measuring short-run marginal cost one must not consider any costs beyond reconstruction of the road. This does not include any improvements associated with reconstruction. Short-run marginal cost is most easily measured as the average marginal cost of units of output, such as ESAL kilometres over the current life-cycle of a road. Ideally, one would wish to measure the cost of every ESAL kilometre but this is impractical. For the road system as a whole it would be more convenient, but less accurate, to measure the annualised expenditure on that element of restoring the asset that can be allocated among particular vehicles in a given year for all existing roads, and divide this by the number of ESAL kilometres over the year. The possible error results from the fact that expenditure on road restoration in a given year does not equate with costs; today's expenditure repairs the damage caused by yesterday's traffic.

The level of avoidable cost calculated from the RoRVL study data was about 4 to 7 cents on average per ESAL kilometre in 1984-85 prices for rural arterial roads (including National Highways) and outer urban arterial roads, (when bridge costs are included). This is much lower than the estimates obtained in the Webber, Both and Ker study after allowance is made for increased road costs from 1976-77 to 1984-85. The Webber, Both and Ker estimate is about 12 cents per ESAL kilometre for all arterial roads in 1984-85 prices. The reason for this difference is not clear although there are a great number of problems with the conduct of, and data and models used in, the RoRVL study. (For example, inadequate or inaccurate road inventory data in some States, assumptions concerning the numbers of operators who may take advantage of new limits being based on the assumption of no increases in road use charges, and underestimates of vehicle overloading at higher limits). These are discussed more fully in BTE (1987c).

Part of the reason seems to be associated with the question of economies of scale and the move to a lower cost function. These were noted above. The RoRVL results imply that for an average 15 per cent per annum increase in ESAL kilometres in New South Wales, for example, costs would increase by only 4.73 per cent. Such dramatic economies of scale, although possible given the arguments presented earlier, are nevertheless unlikely in practice for only a relatively small (10-20 per cent) increase in ESAL kilometres even for option C (increase to 42.5 tonnes). The results suggest either that costs are dramatically understated in the RoRVL study or that current road design practices are far from optimal, compared with those in the NIMPAC model.

One suggestion is that the increase in traffic is overstated or the increase in costs understated. This could occur if, say, the current level of overloading of heavy vehicles was not fully taken into account or that a similar level of overloading was not also assumed for each option. That this may be so is suggested in paragraph 292, of the RoRVL report (NAASRA 1985, 96). In fact, it is suggested there that traffic may be overestimated by 100 per cent. In addition, paragraph 301 on p100 suggests that costs may be understated by 50 per cent. Thus, overall road damage costs shown may be but one-quarter of the correct figure for the level of long-run marginal cost, with short-run marginal cost, of course, even higher. The results obtained in Chapters 6 and 7 for short-run avoidable cost suggest this may indeed be the case. A thorough analysis of the RoRVL study would need to be undertaken to examine this and other possible problems with the RoRVL methodology.

The findings of the RoRVL study give rise to further questions. If road damage costs can be dramatically reduced by a marginal increase in pavement strength, why is this not being done? Is availability of funds the sole constraint or is a major reassessment of current road design called for? Additionally, could we not gain some of the advantages by upgrading roads without increasing limits? Some of the benefits claimed by the RoRVL study for the unrestrained budget case may be due to upgrading currently under-designed roads simply to cater for the expected traffic increases that would result without higher limits. Does not the restrained budget case better represent the benefits and costs of higher limits? It is noteworthy that in paragraph 266, and elsewhere in the report, the RoRVL study team back away from recommending option C (gross mass of 42.5 tonnes for a six-axle articulated truck) despite their results showing a positive net present value for that option.

Given these questions, many doubts can be raised about the conclusions of the RoRVL study, since the restrained budget case results in far fewer net benefits. Given problems with the study, the models, data used, roughness relationships and other areas of concern, there is some doubt that there are in fact any net benefits to society from higher mass limits. More precisely, the move to higher limits may be warranted on the better standard roads but is less likely to be warranted on poorer quality roads.

One point demonstrated by the RoRVL study, and which applies to other benefit-cost studies, is that by varying assumptions almost any results can be achieved. A good study will discuss all the assumptions made and their implications. Further, one must be careful with how the results of such studies are used. In the case of the RoRVL study, once one understands the methodology used, it becomes clear that the results cannot be used to provide estimates of short-run marginal cost; it was never intended that they should.

TRANSPORT ECONOMICS CENTRE STUDY

It was noted at the beginning of this chapter that the Webber, Both and Ker study examined only avoidable cost while the TEC study went further and examined full cost recovery. The TEC study was the first study in Australia to use economic principles, that is, Ramsey pricing, to allocate costs (or expenditure) above avoidable cost. The analysis below will focus on the Ramsey pricing methodology adopted in the study although some comments will be made on the assessment and allocation of avoidable cost in the study.

The purpose of the TEC paper was to outline an approach to recover total annual expenditure on the road system. This would bridge what then appeared to be a gap in the literature covering road pricing and cost recovery. The study was jointly funded by the Government of Tasmania and the Commonwealth Government under the Transport Planning and Research Program.

Methodology

The study team used regression analysis to make an assessment of the total avoidable pavement expenditures on Tasmanian roads that were attributable to heavy vehicles. These avoidable expenditures were then apportioned among heavy vehicles, partly on the basis of relative destructiveness and partly on the basis of vehicle width (using weight as a proxy). Finally, the balance of road expenditure (above avoidable cost) was allocated between trucks and cars on the basis of the inverse of the respective price elasticities of demand.

Data on vehicle classifications and annual traffic volumes on Tasmanian roads, required for the avoidable cost estimates, were provided by the Tasmanian Department of Main Roads (DMR). Particular problems in the collection of data are discussed in Chapter 3 of the Report. Details of road expenditure and costs were also provided by the DMR.

Avoidable cost was allocated on the basis of data on relative destructiveness from the ERVL study. Information on elasticities for the Ramsey pricing allocation was obtained from various overseas and Australian studies.

Avoidable cost estimation and allocation

A number of regression models (equations) were investigated for each expenditure category in order to show '... the effects on the coefficients for heavy vehicles of the inclusion or exclusion of other explanatory variables in the three equations ...' (TEC 1981, 29). Avoidable cost per unit of output was then calculated as the product of input costs and the respective coefficients.

The study did not involve any new research into the appropriate allocation of avoidable cost among road users. Instead, it relied upon relationships developed by AASHO which were used in the summarised form of the ERVLs Report (NAASRA 1976).

Total avoidable pavement cost was found to be quite small with respect to the State's annual road budget. The bulk of annual road expenditure was therefore allocated using Ramsey pricing techniques.

General applicability of the TEC avoidable cost measurement and allocation

The TEC study report contends that the routine seal maintenance equation alone identifies the short-run avoidable cost. However, in reality, the pavement thickness and width equations determine the cost required to restore pavement thickness or width after an additional heavy vehicle passing - clearly an avoidable cost. Thus, each of the three equations outlined in the TEC study in fact identifies a short-run avoidable cost component. Additionally, the study does not include wear-and-tear on pavement seal as an avoidable cost. Heavy vehicle passings cause both an increase in the need for routine maintenance, such as repairs to seal breaks, and decrease the life of the seal, which results in the need for more frequent resealing.

The reliability of the regression equations used for determining the influence of heavy vehicles on road expenditure is questionable for several reasons. Several variables with complicated or unpredictable influences are left in the equations and the determined 'influence' of the volume of heavy vehicle traffic is therefore somewhat uncertain.

It is unlikely that regression analysis will give robust estimates of avoidable cost on the broad scale of the TEC study. Certainly it is useful in examining individual aspects of avoidable cost (for example, cracking in seals, rutting in pavements and so on). However, in a broad analysis there are simply too many interrelated factors to consider. A priori, it is likely that broad regression analysis will find very little road damage due to axle loads alone. To assess short-run avoidable cost of axle loads requires assessing any impact due to axle loads.

Two of the avoidable cost components are allocated among vehicle classes on the basis of (traffic weighted) relative destructiveness. The third component, pavement width, is allocated among vehicles on the basis of traffic weighted relative vehicle weight as a proxy for vehicle width. However, the cost of additional pavement width is a long-run cost of change in capacity and therefore should not be included in short-run marginal (or avoidable) cost estimates. Also, it should be related to the size and volume of vehicles, not vehicle weights.

Ramsey pricing allocations

The Ramsey pricing relationship used by the TEC takes the general form:

Total cost recovery charge

$$= \frac{\text{k x existing price of road use}}{\text{Price elasticity of demand}} + \text{Marginal pavement cost}$$

where k is a constant set to achieve the recovery target (TEC 1981, 51).

This implies that, for those users with the most elastic demand, the cost recovery charge set will be closest to their marginal pavement cost.

Given marginal (or avoidable) pavement cost, the relationship requires information on three variables:

- the recovery target, which sets the constant;
- the price elasticity of demand; and
- the price of road use at which the demand elasticity applies.

Only two demand elasticities were estimated in the TEC study. The first of these was the elasticity of demand for freight transport (essentially heavy vehicles) which was derived from the elasticity of demand for goods carried. The resulting derived elasticities of demand for transport of the main products carried in Tasmania ranged from -0.02 to -0.16. The study suggests that the weighted mean in Tasmania would be less elastic than -0.10, but -0.13 was taken to ensure that elasticities were not underestimated.[2]

The second demand elasticity measured was for the use of cars, vans and utilities. The TEC used the results of various studies to estimate the elasticity values. These ranged from -0.1 for business and work use of cars to -1.3 for vacation car travel. The wide range in values was supported by estimates of the price elasticity of demand for petrol. These estimates ranged between -0.24 and -0.82. The TEC study concluded that -0.33 was an appropriate value. This was an estimated price elasticity of demand for petrol in the United States in 1979. The TEC suggested that '... demand could be no less elastic

2. Over-estimation would favour freight vehicles as it results in a lower allocation of common and joint costs to them.

...' than the United States value, as Australian petrol prices were higher than United States petrol prices, and demand becomes more elastic as petrol prices rise (TEC 1981, 51).

The estimated values for the two elasticities were taken as long-run price elasticities of demand. As the price elasticity of demand for fuel was used for cars, the appropriate travel price used was the fuel cost per kilometre, while for trucks, the appropriate freight transport price used was a general market rate per tonne-kilometre.

The constant value (k) was set depending on the cost recovery (or revenue) target. For the TEC study, a range of targets are shown but nominally the target was the State's total annual road budget. The resulting level of road charges suggests that the heavy vehicle share would be about seven times the share of light and medium vehicles. This would involve a substantial shift in the road cost burden to heavy vehicles.

Ramsey pricing allocations

In allocating costs among vehicle types the most significant problems occur in allocating costs above avoidable cost. As most of the costs are allocated using Ramsey pricing, the cost recovery levels of different users are relatively sensitive to elasticity measures.

The TEC study applies one demand elasticity value to operators of trucks and another to operators of cars. It should be preferable from an efficient viewpoint to discriminate prices as far as possible between different users rather than simply between two groups. However, the administrative difficulties alone would prevent perfect price discrimination. Nevertheless, anything less may mean that road users who have a highly elastic demand bear more efficiency loss than necessary, while those with a more inelastic demand bear much less efficiency loss. There is a trade-off between the degree of market segmentation and the application of different demand elasticities in order to minimise efficiency loss, on the one hand, and the equity arguments and administrative difficulties inherent in price discrimination on the other. It is, however, unlikely that a simple two-segment recovery analysis is sufficient for efficient cost recovery, even given the equity, administrative and political qualifications.

Given that there is insufficient information about price elasticities of demand of individual road users, it is necessary to use an average elasticity of demand for various road user groups when implenting a Ramsey pricing scheme. It should be acknowledged, however, that

Ramsey pricing presupposes a large degree of disaggregation and that any form of aggregation of users may introduce distortions to efficiency.

Estimating a weighted average elasticity of demand is difficult. There is too little information about the shape of demand curves to be able to determine robust measures of demand elasticity. The problem is compounded by the dynamic nature of demand. Elasticities vary seasonally, and also change over the long-run. Any given set of weighted average values would not be applicable for an extended period. The TEC study indicates that the elasticity values used are 'long-run' estimates. Demand tends to be more price elastic in the long-run than the short-run. Ramsey pricing based on short-run elasticities would require periodic and frequent adjustments, but Ramsey pricing based on long-run elasticities causes greater efficiency losses than necessary in the short-run.

There is a further problem in applying estimates of the price elasticity of demand for road use in Tasmania to road use nationally. For freight transport, the demand is derived from the demand for goods at the destination points. In Tasmania these are mainly primary goods from the agricultural, forestry and mining industries, much of which is exported. The bulk of mainland interstate road freight is manufactured goods. It is likely, therefore, that road freight on the mainland has a different elasticity of demand than that in Tasmania. A weighted average demand elasticity of -0.13 is unlikely to be appropriate for the mainland.

There are similar problems with the price elasticity of demand for travel by car. This comprises both derived demand for various travel needs, especially business travel, and a direct demand for travel. The wide range in elasticities indicated in the TEC study makes the choice of -0.33 seem quite arbitrary. It is possible that business-related travel by car is as price inelastic as the demand for freight transport. There is insufficient information currently available to determine a weighted average of elasticities of demand, although it may be possible to indicate robust measures for particular transport requirements. It is unlikely that -0.13 and -0.33 are representative of Australia-wide values.

Appropriate market disaggregation and appropriate estimates of demand elasticities are usually determined after much market analysis and from a sustained recent history of pricing and output levels. Accurate demand analysis is likely to be achieved by pricing authorities and private companies when there is an incentive (such as revenue or profit maximisation) to analyse demand accurately.

Overall assessment of the TEC study

The TEC study follows the 'second-best' economic efficiency approach to cost recovery. The overall level of avoidable pavement cost appears to be too low due to the omission of some avoidable cost components and the imprecise nature of the regression analysis. A better approach would be to base the allocation of avoidable cost between users entirely on the basis of relative destructiveness. This would be the case even for a 'first-best' cost recovery analysis. In addition, the uncertain nature of the demand elasticities and the allocation of costs (or expenditure) above avoidable cost between only two user groups, causes some uncertainty about the efficiency effects of the Ramsey pricing-based allocation. If adjustments were made to the TEC pricing scheme to allow for these problems, the overall cost allocation scheme would be different.

CHAPTER 4 EQUITY-BASED ROAD COST/EXPENDITURE RECOVERY

As part of its overall examination of the road freight industry, the National Road Freight Industry Inquiry (NRFII) considered the level of cost recovery on Australian arterial roads and commented on this aspect in its report (NRFII 1984). The Inquiry drew on a consultant's report (Nicholas Clark and Associates 1984) in which annual arterial road expenditure was allocated among six user categories, including four truck and two car categories. In some respects the approach used by Nicholas Clark and Associates (NCA) was based on economic efficiency although the overall approach was an equity one as specifically required by the NRFII. The basic methodology was that avoidable cost was allocated on the basis of relative road damage and common costs were allocated on the basis of relative road space. The balance, being joint costs, was allocated by four different methods for comparison, one of which was an application of the inverse price elasticity principle. The Report did indicate, however, that the approach required by the NRFII was not that preferred by the authors.

Some overseas studies have followed similar approaches and have used similar methodologies to those adopted by NCA. Indeed, the NCA study refers to some of these studies and relies on some of their findings. Some shortcomings in the allocation methodologies followed in New Zealand, the European Economic Community and the United Kingdom, which are also inherent in the NCA study, are noted in the second part of this chapter.

All of these allocations are concerned primarily with the level of recovery of annual construction and maintenance expenditure. In the study by NCA, the recovery target was the level of expenditure on Australian arterial roads in 1981-82. In New Zealand, the European Economic Community and the United Kingdom, the approaches were based on allocating their respective total road budgets, with the United Kingdom study also being concerned to allocate policing costs. The United States Federal Highway Administration study (US FHA 1982) also allocates total annual Federal road expenditure, both construction and maintenance, among vehicle types.

The main difference between the United States allocation methodology and that of the other equity approaches, lies in its attempt to rigorously establish causal relationships between vehicle use of roads and costs incurred. The approaches in the other countries largely drew on United States results but also contained large elements of judgment in the allocation of costs. Also, these other approaches appear to have missed or ignored some key issues addressed in the United States study.

The NCA and United States studies are briefly outlined and the specific points of concern are noted. Comments are also made on the adjustments which might be required to ensure that the results conform with the general principles set out in Chapter 2.

NICHOLAS CLARK AND ASSOCIATES STUDY

The main objectives of the NCA study were:

- to determine the overall level of cost recovery of road and rail transport in Australia; and
- to estimate the degree of cost recovery for various road user classes.

Methodology

The NCA Report is concerned with the level of cost recovery throughout Australia in 1981-82. In considering the first objective, an estimate was made of the economic costs of the road system (opportunity cost). However, the assessment of the levels of cost recovery of various road user groups considers only the level of recovery of annual expenditure on arterial roads.

The NRFII directed that annual arterial road expenditure, rather than economic cost, be used as the recovery target. Arterial road expenditure was considered to be a more appropriate base than total road expenditure as road freight is considered to be predominantly carried on arterial roads.

Expenditure information was obtained from the NAASRA Roads Study Report R4 (NAASRA 1984) and ABS data (ABS 1984). The NCA paper works through each of 15 expenditure components identified by NAASRA for national highways and the urban and rural arterial road networks. It determines the split between maintenance (or restorative) and augmentation (or upgrading) expenditures, and from that the split between avoidable, common and joint costs. In each case the allocation of expenditure to cost categories is partly based on overseas research and partly on the experience of the consultants or advice from road planning engineers. It is a fairly arbitrary approach due mainly to the paucity of information on road costs.

Fifteen per cent of all expenditure categories is allocated to administration and regarded as a joint cost. Allocation of the balance varies depending on the nature of the expenditure category. Avoidable truck costs are allocated between four truck types on the basis of relative damage. Relative damage of trucks is determined by the product of distance travelled and the equivalent standard axle loads (ESALs) calculated using the fourth power for rear axles (or axle groups), and using the power 5.5 for steering axles (as in the ERVL Study). Common costs are treated differently from joint costs and are allocated on the basis of road space used. The allocation criterion used is distance-weighted, passenger car equivalent units (PCU).

The NRFII directed that joint costs be allocated on four alternative bases including three equity approaches (vehicle-kilometres travelled (VKT) weighted by passenger car equivalent units (PCU); VKT weighted by gross vehicle mass (GVM); and vehicle value). The fourth approach, allocation on the basis of the demand for road space, is the alternative which most closely approximates Ramsey pricing. Under Ramsey pricing, both common and joint costs (in fact, any costs above short-run avoidable cost) should be allocated in inverse proportion to the price elasticities of demand for road use. The Inquiry advised that the following demand elasticity values be used:

- freight services, -0.1
- passenger services, -0.3.

The values chosen are apparently based on those determined in the TEC study. Using these values, NCA allocated three times the level of joint costs to each truck tonne-kilometre that was allocated to each car passenger-kilometre.

Problems with the methodology

There are five main problems in applying the NCA methodology to an efficiency-based cost recovery exercise. These are:

- the assessment of avoidable cost;
- the methodology for allocating costs among vehicle groups;
- the elasticity values used;
- the inappropriateness of both the cost data used and the methodology for estimating attributable costs; and
- the road user payments included.

Assessment of avoidable cost
NCA estimated the avoidable cost of each expenditure component after netting out the administrative costs and then splitting the expenditure between maintenance and augmentation. There are three concerns with this approach:

- the assessment of administrative costs;
- the avoidable augmentation costs; and
- the components of avoidable maintenance cost.

Fifteen per cent of each cost category is allocated as a joint cost on the basis that this amount represents the costs of administration of road construction and maintenance activity. The source of this estimate is given as McDonell (1980, 3/41), but this appears to be a misinterpretation of the McDonell estimates.[1]

The NAASRA expenditure components used in the NCA study each include a share of administrative costs which may vary depending on the type of activity (NAASRA 1983, 10 and 13). The NAASRA roads studies (1983 and 1984) do not indicate the overall level of general and engineering administrative expenditures, but it is unlikely to be as high as 15 per cent for all expenditure components.

Augmentation or improvement costs are the costs of increasing road capacity or service level. They are not avoidable in the short-run, that is, once the capacity has been provided. The resources have been committed whether or not expected traffic levels are achieved. They are only avoidable in the long-run for instance, if a particular group of users is excluded from the system. They are therefore long-run costs which, in an economic efficiency approach, would be distinguished from short-run avoidable cost. They would be allocated as a common or joint cost of vehicle travel, either by Ramsey pricing rules in an efficiency approach or by some other methodology in an equity-based approach.

---

1. At page 3/41 of McDonell's second report there is a component, 'administration', which amounts to about 15 per cent of road costs. This amount represents administration costs of road use including costs of the Department of Motor Transport, the Health Commission, the Police, the State Pollution Control Commission and the NSW Traffic Authority, to the extent that these are road 'system' costs. This has nothing to do with the administration of pavement construction and maintenance. While it may be desirable to recover these expenditures from road users, these costs would then be added to pavement construction and maintenance expenditures. A proportion of these costs will be avoidable with respect to vehicles and the remainder common and joint.

The NCA study team estimated that only 24 per cent of maintenance (or restorative) expenditure represented the avoidable pavement cost of trucks. This is about 14 per cent of the total maintenance and construction expenditure. The maintenance expenditure components and the estimated proportions of avoidable cost due to trucks are shown in Table 4.1

Although there are few analyses of the total level of avoidable cost in Australia, it is likely that the level of truck avoidable cost will be much higher than the NCA estimates. On the basis of ERVL, Webber, Both and Ker, the United States study and BTCE estimates, it is probable that virtually all of the restorative portions of road and bridge reconstruction (or rehabilitation), resealing (or resurfacing) and most of the maintenance expenditures can be assigned as truck avoidable costs. Of course, some augmentation (or upgrading) is often carried out when roads are reconstructed; thus, some proportion of costs classified as reconstruction costs would be more correctly classified as augmentation costs. In Chapter 7 it is suggested that from 12 to 30 per cent on average of the cost of reconstruction projects on various road categories represents augmentation and the balance is restoration of the asset.

Allocation of costs to vehicle groups
NCA allocated each of avoidable, common and joint costs by different methodologies. Avoidable cost was allocated between trucks of different size on the basis of their relative pavement damage.

In the NCA study both long-run and short-run avoidable costs were allocated among vehicle types on the basis of the product of maximum legal ESALs per vehicle and laden vehicle-kilometres (using the 1981-82 ABS SMVU). Use of maximum legal ESALs instead of actual ESALs will result in some inaccuracies although the extent of inaccuracy is difficult to determine. In addition, large unladen trucks cause some road damage. The more important point is whether this attribution rule is sufficiently robust for both types of costs. In the United States study, reviewed in the next section, different procedures were used for each type of cost.

Common costs are allocated on the basis of road space. The efficiency approach to allocating costs in excess of short-run avoidable cost requires that all other costs be allocated on a demand related basis.

Joint costs were allocated using the inverse elasticity rule although the procedure used was technically deficient. Three times as much of joint cost were allocated to a truck tonne-kilometre as was allocated

TABLE 4.1 MAINTENANCE AND AUGMENTATION PROPORTIONS OF TOTAL ROAD EXPENDITURE[a], AND TRUCK SHARES OF THESE EXPENDITURES
(per cent)

NAASRA expenditure category	*Estimated maintenance proportion*	*Estimated truck avoidable proportion of maintenance*	*Estimated augmentation proportion*	*Estimated truck share of augmentation*
Rural network[b]				
New works	0	..	100	20
Duplication	0	..	100	20
Reconstruction	60	30	40	20
Reseal	80	60	20	20
New gravel formation	100	20	0	..
New bridges	80	25	20	18
Resurface	100	80	0	..
Road maintenance	100	15	0	..
Bridge maintenance	100	25	0	..
Urban network				
Servicing and operating	100	0	0	..
Rehabilitation	80	20	20	20
Minor improvements	50	20	50	20
Major improvements	20	20	80	20
Additions	0	..	100	20
Long-term acquisitions[c]	0	..	0	..
Total arterial network	57	24	43	20

a. Net of 15 per cent for administration component.
b. Includes National Highways.
c. Allocated entirely as a common cost.
.. Not applicable

Source Nicholas Clark and Associates (1984 Chapter 3).

to a car passenger-kilometre on the basis that the demand for road use by cars (measured in passenger-kilometres) is three times as elastic as the demand for use by trucks (measured in tonne-kilometres of freight movement). This assumes, as the NRFII did (refer NCA 1984, 63), that a (marginal) tonne-kilometre has the same price (or resource cost) as a (marginal) passenger-kilometre. The elasticity calculations should be based on price per unit of output (assuming this reflects short-run marginal cost) and not simply units of output.

The TEC study correctly used output prices (TEC 1981, 51). An efficient pricing regime adequately reflects the relative worth of tonne-kilometres and passenger-kilometres.

Elasticity measures

The Inquiry advised NCA that -0.1 and -0.3 should be used as the values for the elasticities of demand for freight services and passenger services respectively. These values are slightly lower than those used in the TEC Report but are evidently based on the interpretative work of that Report. There are two main problems with using these estimates as noted in the review of the TEC study. These are:

- determining robust elasticity estimates; and
- determining estimates at a sufficient level of disaggregation of road users.

These were discussed in the preceding Chapter in the analysis of the TEC report.

Inappropriateness of cost data and allocation methodology

In assessing the overall level of road cost recovery, NCA considered both the economic costs of providing infrastructure, including depreciation and opportunity cost of capital, and annual road expenditure. In assessing cost recovery from each vehicle class, however, NCA considered only annual arterial road expenditure. A very broad estimate was made of the percentage of total annual distance travelled by each vehicle class on arterial roads.

The allocation of expenditure components as either maintenance or augmentation, and then as either avoidable, common or joint is not well supported and in places seems quite arbitrary. The analysis relies heavily on New Zealand interpretations and to a lesser extent on Finnish and United Kingdom studies, with little discussion on the appropriateness to Australia of those allocations.

The attribution of costs between avoidable, augmentation, common and joint and also between different vehicle types lacks rigour. It compares unfavourably with the procedures adopted for the United States cost allocation study. In that study damage relationships were established on the basis of fundamental research conducted over more than 20 years. These took into account the important factors relating to damage and other depreciation of roads and bridges and also the combined effect of weather and other environmental factors and traffic. The United States study is discussed in the next section.

Road revenue payments

Road users make payments to the three levels of government through a variety of charges and taxes. It was suggested in Chapter 2 that it is not easy to decide which particular payments should be designated as road user charges. Several of the payment types included in the NCA (1984) estimate of payments (Table 3.35, 81), would not be included within the second definition of recovery payments outlined in Chapter 2. Items such as the crude oil production levy and oil production royalties should not be regarded as road user payments under any definition. These are economic rents or royalties earned by governments through the ownership of particular resources rather than road cost recovery charges.

Under the second definition in Chapter 2, customs duties and sales taxes and property and income taxes would be considered as general taxation payments and so not regarded as recovery payments. If the second definition was accepted as being appropriate, the NCA estimate of road user payments would, by comparison, significantly overestimate road users' cost recovery payments. The nature of various payments by road users and the validity of matching these against road costs is discussed in the next chapter.

Results of the study

A summary of the allocation of arterial road costs to the six vehicle classes using the NCA approach is presented in Table 4.2. The allocation to cars and panel vans is slightly higher than the allocation to trucks. On a road use related basis, articulated trucks are allocated the highest share of road costs. However, cars are allocated the greatest share of costs overall.

Table 4.3 shows the estimated level of cost recovery by vehicle class. Heavy rigid trucks and articulated trucks are shown as fully recovering and almost recovering their allocated costs respectively. If an alternative analysis was made, which took account of the problems outlined above, the estimate of truck avoidable cost in 1981-82 would be about twice as large and the level of recovery payments would be about 70 per cent lower.

If the second definition of recovery payments outlined in Chapter 2 is adopted, the overall level of net cost recovery is about $434 million, not the $2254 million indicated in Table 4.3. If the truck avoidable costs are also adjusted, the articulated vehicles are shown to be not recovering either fully allocated cost or avoidable cost.

TABLE 4.2 ALLOCATION OF ARTERIAL ROAD EXPENDITURE AMONG VEHICLE CLASSES IN THE NICHOLAS CLARK AND ASSOCIATES STUDY, 1981-82
($ million)

Vehicle class	*Avoidable cost*	*Common cost*	*Joint cost*[a]	*All costs*
Cars and station wagons	38	326	212	576
Utilities and panel vans	7	57	30	94
Rigid trucks				
Light trucks	7	16	14	37
Medium trucks	3	6	8	17
Heavy trucks	85	21	57	163
Articulated trucks	170	30	189	389
Total	310	456	510	1 276

a. Joint cost allocated according to inverse elasticities of demand.

Source Nicholas Clark and Associates (1984, Table 3.40, 85).

TABLE 4.3 COST RECOVERY ESTIMATES IN THE NICHOLAS CLARK AND ASSOCIATES STUDY, FOR THE ARTERIAL ROAD NETWORK, BY VEHICLE CLASS, 1981-82
($ million)

Vehicle class	*Recovery payments*	*Total costs*[a]	*Net cost recovery*[a]
Cars and station wagons	2 206	576	1 630
Utilities and panel vans	422	94	328
Rigid trucks			
Light trucks	174	37	137
Medium trucks	72	17	55
Heavy trucks	272	163	109
Articulated trucks	383	389	-6
Total	3 530	1 276	2 254

a. Joint cost allocated according to inverse elasticities of demand.

Note Owing to rounding, figures may not add to totals.

Source Nicholas Clark and Associates (1984, Table 3.43, 89).

Tables 4.2 and 4.3 are the bases of tables used by the NRFII to indicate the degree of arterial road cost recovery (refer NRFII 1984, Tables F5 and F6, 419 and 420).

The key problem with the NCA study and the New Zealand, European Economic Community and United Kingdom cost allocation methodologies, is that they do not have a rigorous basis for the attribution of individual cost items among vehicle types. As will be seen in the next section, it is feasible to develop (at some cost) causal relationships between vehicle traffic and costs. All these studies ignore the problem of allocating economies of scale which, it will be seen, has been addressed in the United States. They also allocate a low percentage of routine maintenance costs to trucks. Consequently all of these studies considerably underestimate the level of road costs attributable to trucks.

UNITED STATES FEDERAL HIGHWAY ADMINISTRATION STUDY

The United States Federal Highway Administration (US FHA) cost allocation study of 1982, and the subsequent Federal highway road pricing scheme, are examined in some detail in BTE (1985b) and so will not be examined in depth in this Paper. The purpose of the discussion below is to compare certain aspects of the United States study with those of the NCA and other studies and to demonstrate how many of the assumptions and broad judgments in these studies were removed or refined in the United States study. This was achieved through either basic engineering research or a more correct analysis of the causal relationships between vehicle traffic and road costs.

Like those other studies, the United States study was based on equity objectives (as directed by the United States Congress) and in particular the cost-occasioned approach to equity. Economic efficiency was specifically rejected and, as a result, no specific attempt was made to identify short-run marginal or avoidable costs. Instead all costs were either attributed or allocated among vehicle types according to cost relationships formulated through basic research or else apportioned as residual costs. The latter apportionment was undertaken where no relationships could be found or where costs were truly common or joint.

While, as noted, the formal study incorporated an equity-based approach, the study team also undertook an efficiency-based study for which results were presented. The results of this study, which are discussed in a separate section later in the chapter, are interesting in that they indicate that short-run marginal cost may be much higher than any Australian study has indicated.

The discussion below concentrates on the methods used to attribute or allocate the main categories of costs and on the relationships formulated. A broad indication of the results of the study is also provided.

Methodology adopted to allocate cost

The main categories of cost examined were:

- new pavement cost
- pavement rehabilitation cost
- structure (mainly bridge) cost
- costs due to steepness of grade
- miscellaneous costs
- residual cost.

Table 4.4 indicates the cost allocations which resulted from this study.

New pavements

In previous cost allocation studies undertaken in the United States the incremental cost methodology (discussed in BTE 1985a) was used to allocate costs among road users. The incremental method was also adopted in the 1982 study, but it incorporated some important revisions, chiefly to overcome the recognised problem of allocating economies of scale in pavement design.

The general approach was to systematically remove vehicles and theoretically revise the road pavement design. The hypothetically saved costs are assigned to the hypothetically removed vehicle classes. However, there are economies of scale in pavement construction and the order in which vehicles are removed has a major influence on the costs assigned to vehicles. Whichever group was removed first would be allocated only the top depth of pavement construction cost and remaining vehicles would be allocated the bulk of the costs (for instance, remaining pavement, right of way, site preparation, etc). There is no particular reason why a specific class of vehicles should benefit from the economies of scale inherent in pavement strength. Thus, it must be ensured that the order in which vehicles are hypothetically removed does not favour any one class above any other class of vehicles.

The method adopted by the FHA to overcome this problem was to divide each vehicle class into an equally large number of parts and remove only a small share of each class before removing a similar share from

TABLE 4.4 UNITED STATES FEDERAL ROAD EXPENDITURE BY COST CATEGORY AND ATTRIBUTED AND RESIDUAL COSTS BY COST CATEGORY AND VEHICLE TYPE

(per cent)

Cost category	*Federal obligations*[a]	*Attributed*			*Residual*			*Total*		
		Cars[b]	*Trucks*[c]	*Total*	*Cars*[b]	*Trucks*[c]	*Total*	*Cars*[b]	*Trucks*[b]	*Total*
New pavement	22[d]	15	50	65	31	4	35	46	54	100
Rehabilitated pavement	31[f]	23	72	95	5	1	5	28	72	100
Structures	17	22	31	53	42	5	47	64	36	100
Grading	17	14	15	29	64	7	71	78	22	100
Miscellaneous	14	0	0	0	90	10	100	90	10	100
Total	100	16	38	53	42	5	47	58	42	100

a. Base period (1976-78) Federal-aid Highways obligations.
b. Includes motor cycles, vans and pickups.
c. Includes buses.
d. Includes new right-of-way costs.
f. Includes incidental right-of-way costs.

Notes 1. This table is not presented in the source. It has been constructed from Tables V-4, V-5 and V-6 in US Department of Transportation (1982) on the assumption that residual costs for each cost category were allocated among vehicle types by vehicle miles travelled (VMT) as shown in Table V-5 and as indicated on page V-10.
2. Owing to rounding, figures may not add to totals.

Source US Department of Transportation (1982, V4-V9).

the next class and so on. The amount of thickness saved varies tremendously at different points. However, the amount saved relative to other classes varies little. The equations used to determine savings in pavement thickness are detailed in Appendix III.

When pavement design or strength is reduced to a certain level it is no longer able to withstand the effects of weather or it becomes impracticable to construct. The cost of the minimum pavement design is a joint cost of all road users.[2] The United States study assigns the minimum design costs to all vehicles as a residual cost.

Costs associated with new pavement width are treated slightly differently from costs associated with pavement strength. The cost of the basic roadway width is assigned to all vehicles as a joint cost, but costs of width above the minimum required for the narrowest vehicles are assigned to wider vehicles using an incremental method. Pavement width as a function of vehicle width was determined by the study and converted to cost savings relationships. The vehicle population was divided into width increments. Within each increment, the incremental width costs were assigned to vehicle classes using their proportional share of pavement thickness costs.

Using these methods, 65 per cent of new pavement costs were found to vary with traffic and vehicle characteristics. The remainder are joint costs and were treated as residual costs in the United States study. Of attributed costs, 50 per cent are attributed to trucks and buses and 15 per cent to cars as is shown in Table 4.4. Cars are assigned a high proportion of residual costs and overall they are allocated 34 per cent (46 per cent if vans and pickups are included) of new pavement costs and trucks and buses 54 per cent. A more detailed disaggregation of costs can be found on pages V8-9 of US Department of Transportation (1982).

Pavement rehabilitation costs
Costs of existing pavements were allocated to vehicles using a different process from that applied for new pavement costs. The study team, with the assistance of engineering consultants, developed, both empirically and using existing theory, models of pavement deterioration as a function of ESALs. These models were developed for

---

2. The cost of minimum pavement design is in fact a joint cost of road users and property owners who are given access to property by the road. The United States study considers this in its Appendix F, but the recommended approach does not account for non-users.

a variety of pavement distresses for both flexible and rigid pavements. Details of these models are set out in Appendix III.

Table 4.4 indicates that 95 per cent of pavement rehabilitation costs were found to be related to traffic, and in particular ESALs, with over 70 per cent attributed to trucks. The remaining 5 per cent of rehabilitation costs are joint costs, caused by deterioration due entirely to weathering, or matters unrelated to road usage.

Structures

Costs associated with structures were considered under four cost categories: costs of new structures; replacement costs; repair costs; and width costs.

New structure costs were allocated using an incremental method. Unlike new pavement costs where a simple incremental approach was inappropriate due to economies of scale in pavement design, this approach was argued to be appropriate for structures such as bridges.

A new bridge is designed for the heaviest gross vehicle masses which will use the bridge. The design does not change substantially if lighter vehicles use the bridge, nor does it depend on the level of usage of the bridge. Axle load spacing is also a factor in bridge design, particularly for shorter bridges, but still it is gross vehicle mass which is the most important factor. Under the method used in the United States study, the heaviest vehicles were hypothetically removed and the differences in design costs were determined. These costs were then attributed to the hypothetically removed vehicles. The process was repeated until no significant difference between design costs was found. Costs below this point were considered joint costs and were assigned to all vehicles. Between 65 and 91 per cent of new bridge costs were found to be unrelated to vehicle mass.

In allocating structure replacement costs among road users a structural sufficiency rating was used. This rating determined the relative importance of load deficiency (ability to carry heavy loads) in the decision to replace the bridge and was used to find the proportion of replacement costs due to capacity deficiency (remaining life, given expected traffic levels, before structurally unsound). The resulting assignment function was applied separately to each design increment (or decrement), determined by hypothetically removing vehicles. The costs attributed to vehicles above the capacity mass were assigned using vehicle miles travelled (VMT) as a measure of the responsibility of each vehicle class for generating the need for the bridge replacement.

Bridge repair costs principally consist of deck repair or replacement costs, but as yet robust relationships between bridge wear and traffic characteristics are not available. The 1982 study adopted the approach of assigning bridge repair costs as residual costs, using VMT. This method assigns less repair costs to heavy vehicles than the approaches used in the US studies from 1956 to 1965. These studies used an incremental approach.

New bridge width costs were allocated using the same process used for new pavement width costs. This process was also used for replacement structure width costs, but width increments were divided by the assignment function for deficiency costs. Since a breakdown into more detailed cost items was not available for repair costs, repair width costs were not considered. Width costs of structures were assumed to fall by 80 per cent with reductions in vehicle width, based on width cost savings found for sample bridges examined. For example, a 20 per cent reduction in bridge width results in a 16 per cent reduction in bridge costs.

Around 53 per cent of total structure costs were found to be related to traffic - 23 per cent to passenger vehicles and 30 per cent to trucks. Residual costs were allocated to vehicles using VMT as a measure of road usage. The major share (about 90 per cent) of residual costs was allocated to cars under this method.

Grading

Grading costs, or costs that could be saved if vehicles were better able to negotiate grades, were examined by a consultant. Assignment functions for grading costs were derived for each functional class of road by considering the distribution of road length in mountainous, rolling and flat terrain. Cost savings expected in each terrain type were estimated by determining maximum negotiable grades as a function of weight-to-power ratios. Proportional savings in earthworks as a function of maximum grades were also determined. These were then applied to the proportion of grading costs which involved earthworks to give estimates of cost savings. Using the assignment function, costs were assigned to vehicle classes in weight-to-power increments. Grading width cost assignments followed an identical process to bridge width costs.

Table 4.4 indicates over 70 per cent of grading costs were not related to traffic or vehicle characteristics. The remaining 29 per cent of grading costs were attributed to traffic, 14 per cent due to passenger vehicles and 15 per cent due to trucks.

Miscellaneous costs
Along with pavement, structure and grading costs, a number of other road costs were considered. These costs were classified as miscellaneous and are regarded as joint costs which do not vary with vehicle characteristics or numbers. Miscellaneous costs included, for example, the costs of:

- guard rails and attenuators
- traffic signs
- pavement markings
- erosion control.

These costs are all associated with provision of the basic road and were allocated on the basis of VMT. Thus, 90 per cent of miscellaneous costs were allocated to cars, as shown in Table 4.4.

Residual costs
Under the United States equity-based approach, the difference between total cost and costs which were directly attributed to vehicles, was allocated to vehicles according to their contribution to road usage. These costs were termed 'residual costs'. The study's preferred method for this allocation procedure was to use PCE-VMT (passenger car equivalent vehicle miles travelled). However, lack of data, notably distributions of vehicle classes across travel times, prevented this. Thus, VMT was used as the best alternative measure. This means a large proportion of residual costs were allocated to passenger vehicles, and a small proportion to trucks.

Applicability of results to Australia

The main feature of the results presented in Table 4.4 is the high share of costs attributed to trucks. The vehicle mix is different from that in Australia, but not substantially, so that, *a priori,* one should expect a similar result if the United States study approach were applied to Australian roads. Other factors may come into play, however. Certainly, the two countries have different climatic conditions but the United States study allocated only a small share of total cost as a joint cost due to weather. The overall higher standard of roads in the United States, which, one can assume, achieve better economies of scale than in Australia, should produce a lower allocation of costs to trucks in the United States both in new road construction and in lower relative damage cost.

The actual assessed road damage costs estimated in the United States' study are, however, very high, as will also be shown in the examination of the alternative United States' efficiency study.

Alternative efficiency study

Appendix E of the 'Final Report on the Federal Highway Cost Allocation Study' (US FHA 1982) outlined the methodology and results of an economic efficiency cost allocation study. The study team correctly argued that pricing should be based on short-run marginal cost and this study was therefore aimed at assessing the short-run marginal cost of road use. The main costs identified were:

- pavement repair cost
- vehicle user cost
- administration cost
- delay or congestion costs
- cost of air pollution
- accident costs
- cost of noise pollution.

In this Paper, only pavement repair cost is discussed in detail as the emphasis is on costs to road authorities and not on road user costs and externalities. It is recognised, however, that the latter should be considered when determining optimal or second best prices. However, the results for other costs will be noted.

Pavement repair cost

In assessing pavement repair cost a number of assumptions were made at the outset:

- Costs of pavement repair represent the costs of restoring the asset to its original condition. Thus, they represent the costs of damage to the road pavement.
- The investment in restoring the pavement asset corrects damage caused by road use, although the interaction with environmental factors is taken into account. This reflects a problem with the PAYGO approach which recovers expenditure rather than cost. One has to assume that the expenditure level is 'correct'.
- Marginal vehicle operating cost is assessed as an average over the life of a pavement since they may be less when they occur towards the end of the pavement's life (fewer vehicles will pass over the road from that time until reconstruction, so vehicle operating cost increases due to the road damage may be less).
- Differences caused by weather in the vulnerability of pavements to axle loads are not great enough to overwhelm the relationship between axle weight and pavement damage for a given road design.

It was also assumed that normal routine maintenance activities would be undertaken as an attempt to ensure that the intended life of the pavement would eventuate. Again, this assumes the 'correct' level of road maintenance expenditure. This and the assumptions above are all required in allocating costs under the PAYGO approach although rarely are they acknowledged.

The analysis involved using more simplified design equations than those used in the main equity-based study. The basic method involved assessing the remaining average life of the existing range of road types in the country in terms of ESALs. Repair costs were then assessed using the simpler damage relationships. The results of the analysis are presented in Table 4.5.

The range of costs indicated for the various road types is very large and, *a priori,* it could be expected that such a range might be found in Australia. The highest figure, for urban local roads, of US$0.80 per mile or US$0.50 per kilometre, is much higher than any figure found in any study in Australia. Updating to 1986-87 prices would further increase the estimate. The lowest figures, when converted to Australian dollars, are comparable to those shown in some Australian studies. The ESAL lifetimes shown for the various road types are only a little above the averages for Australian roads and so these costs could be used as a benchmark for a similar study applied to Australian roads.

The inclusion of vehicle operating costs makes a significant difference to the above costs as shown in Table 4.6. In this table all costs have been discounted by 7 per cent over seven years (the assumed average remaining life of pavements in the United States study). A similar table to Table 4.6 was not prepared for other marginal costs. However, a table showing typical costs for a range of vehicles over a range of roads was presented. This is reproduced as Table 4.7.

There are a number of interesting results in this table.

- Motor cars are assigned no pavement repair costs or user costs (vehicle operating costs). This appears sensible since they cause negligible road damage.
- The effect of the fourth power rule is shown in the case of a four-axle combination of 50 tonnes. The pavement damage caused by such a vehicle is enormous. A similar mass on nine axles, the last case in the table, results in only about 1 per cent of the damage.

TABLE 4.5 ESTIMATED PAVEMENT REPAIR COSTS PER ESAL, BY FUNCTIONAL SYSTEM

($US 1981 prices)

	Rural			*Urban*		
Functional system	*Per-mile cost of resurfacing and shoulders*[a] *($'000)*	*ESAL life-time (millions)*	*Resurfacing cost ($/ESAL mile)*	*Per-mile cost of resurfacing and shoulders ($'000)*	*ESAL life-time (millions)*	*Resurfacing cost ($/ESAL mile)*
Interstate	518	6.0	$0.09	2 242[a]	9.0	$0.25
Arterial	310	1.5	$0.21	986	1.5	$0.66
Collector	112	0.4	$0.28	321	0.5	$0.64
Local	40	0.08	$0.50	80	0.1	$0.80

a. Unit resurfacing costs were estimated using tables in FHA, 'Performance-Investment Analysis Process', *Technical Report*, US DoT, September 1978.

Source US Department of Transportation (1982, E-25).

TABLE 4.6 AVOIDABLE PAVEMENT DAMAGE AND VEHICLE OPERATING COSTS, BY FUNCTIONAL SYSTEM
(US cents per ESAL mile, 1981 prices)

		Vehicle operating costs			
Functional system	*Pavement damage*	*Vehicle wear*	*Travel time*	*Running cost*	*Total*
Interstate					
Rural	5.0	3.8	0.9	-0.9	8.7
Urban	15.0	10.6	2.4	-2.9	25.2
Arterial					
Rural	13.0	4.1	1.0	-1.1	17.0
Urban	41.0	7.6	7.0	0.3	55.9
Collector					
Rural	17.0	3.2	0.8	-0.9	20.1
Urban	40.0	6.6	6.1	0.2	52.9
Local					
Rural	31.0	2.4	0.6	-0.7	33.4
Urban	50.0	9.7	9.0	-0.4	69.1

Note Owing to rounding, figures may not add to totals.

Source US Department of Transportation (1982, E-28).

- As one would expect, user costs rise steeply with pavement repair costs.
- For cars in urban areas, congestion costs are by far the most significant costs.
- Overall costs for urban roads are higher than for rural roads.
- If congestion costs are ignored, cars in 1982 were over-recovering their short-run marginal cost while trucks were considerably under-recovering their costs.

It was stated in the study that if road user charges were set at these levels the revenue raised would be considerably more than current actual expenditure. In fact, they would raise about twice current expenditure. The main reason for this lies in the congestion cost estimates. High congestion costs indicate under-capacity in the road system (or at least on some urban roads) and are a signal to expand

TABLE 4.7 EFFICIENT USER CHARGES FOR A SAMPLE OF VEHICLES UNDER SPECIFIC CONDITIONS
(US cents per VMT 1981 prices)

Vehicle type	*Location*	*Key parameters*	*Components of efficient prices*: *Pavement repair*	*User costs*	*Adminis-tration*	*Excess delay*	*Air pollution*	*Noise*	*Total*	*Existing average user fees*
Auto (3000 lb GW)	Rural	v/c = .05	-	-	0.3	0.3	-	-	0.6	1.3
Auto (3000 lb GW)	Urban	v/c = .85	-	-	0.7	11.2	1.5	0.1	13.5	1.7
Van or pickup (5000 lb GW)	Suburban or small town	v/c = .55 PCE = 1.0 ESAL = 0.0	-	-	0.5	4.4	0.8	0.1	5.8	1.5
Truck single unit 3-axle (40 000 lb GW)	Small urban	v/c = .35 PCE = 1.2 ESAL = .8	25.6	7.5	0.5	2.2	0.2	0.2	36.2	4.8
Truck combination 5-axle (72 000 lb GW)	Rural interstate	v/c = .15 PCE = 1.2 ESAL = 1.6	8.0	5.9	0.3	0.4	-	-	14.6	9.0

TABLE 4.7 (Cont.) EFFICIENT USER CHARGES FOR A SAMPLE OF VEHICLES UNDER SPECIFIC CONDITIONS
(US cents per VMT 1981 prices)

			Components of efficient prices							
Vehicle type	*Location*	*Key parameters*	*Pavement repair*	*User costs*	*Adminis-tration*	*Excess delay*	*Air pollution*	*Noise*	*Total*	*Existing average user fees*
Truck combination 5-axle (72 000 lb GW)	Urban interstate	v/c = .35 PCE = 1.2 ESAL = 1.6	24.0	16.3	0.3	1.4	3.0	4.0	49.0	9.0
Truck or bus 2-axle (28 000 lb GW)	Urban	v/c = .45 PCE = 1.4 ESAL = .9	37.0	13.4	0.5	4.3	1.6	2.0	58.8	5.0
Truck single unit 3-axle (60 000 lb GW)	Urban collector or local	v/c = .25 PCE = 2.0 ESAL = 4.0	180.0	64.0	0.5	3.1	4.0	8.0	259.6	11.0

TABLE 4.7 (Cont.) EFFICIENT USER CHARGES FOR A SAMPLE OF VEHICLES UNDER SPECIFIC CONDITIONS

(US cents per VMT 1981 prices)

			Components of efficient prices							
Vehicle type	*Location*	*Key parameters*	*Pavement repair*	*User costs*	*Adminis-tration*	*Excess delay*	*Air pollution*	*Noise*	*Total*	*Existing average user fees*
Truck combination 4-axle (100 000 lb GW)	Rural arterial	v/c = .05 PCE = 3.0 ESAL = 27.2	408.0	95.2	0.3	0.3	-	0.2	504.0	5.0
Truck combination 9-axle (105 000 lb GW)	Rural interstate	v/c = .15 PCE = 3.0 ESAL = 1.0	5.0	3.7	0.3	1.2	-	0.1	10.3	9.0

VMT Vehicle miles travelled.
v/c Ratio of average vehicle traffic level to capacity of the road.
PCE Passenger car equivalent units, a measure of road space required by the vehicle.
GW Gross weight.
\- Rounded to zero.

Source US Department of Transportation (1982, E-53,54).

urban road capacity, increase congestion charges, or both. If road capacity is expanded, eventually it could be expected that as congestion costs fell and road expenditure rose, there may be a balance between revenue and expenditure. However, for various reasons governments are reluctant to expand urban roads to satisfy demand. This situation undoubtedly also occurs in Australia. Perhaps partly because they do not wish to expand the urban road system to such an extent, and because the revenue raised would greatly exceed existing levels of road expenditure, which would in turn probably lead to public pressure for more road expenditure, most governments are also reluctant to introduce efficient congestion charges.

Conclusions

The main conclusion that can be drawn from the discussions in this Chapter is that cost recovery studies should be based on thorough research. While United States results could not be expected to be mirrored in Australia and the engineering relationships used in the United States study may still be inadequate, the results of the United States study nevertheless suggest that road damage costs are, for example, far greater than most, if not all, Australian studies have indicated. This suggests that there may be merit in undertaking further engineering research in Australia to establish whether damage costs in this country are similar to those found in the United States.

Perhaps a final remark on the United States study is to note that the charges introduced in the United States were commensurate with the result obtained, at least the results from the equity-based study. The ISC (1986) noted average charges in the United States in 1984-85, including Federal charges, amounted to over A$30 000 per annum for a five-axle articulated truck over 34 tonnes. This compares with charges of about one half of this level from all levels of government in Australia as shown in Chapter 6.

CHAPTER 5 ROAD COSTS AND REVENUES

It was noted in Chapter 2 that the PAYGO approach to cost recovery has been adopted in this Paper. This requires recovery of annual road expenditure and not the economic costs of roads. Nevertheless, one can use efficient pricing principles to allocate this target among road users. These principles were outlined in Chapter 2. What is required under this efficiency approach is first, the identification of short-run marginal (or avoidable) cost and the allocation of this cost in a manner reflecting the extent to which various vehicle types cause it. Second, the balance, if any, of the PAYGO target must also be allocated among vehicle types.

In this chapter the first step will be presented. In addition, the road user charges paid by each vehicle class will be derived. The avoidable cost attributed to each vehicle class and its payments of road user charges will then be compared.

The second step, allocation of the balance of the PAYGO target, will be undertaken in the following chapter together with an alternative equity-based allocation of the whole of the PAYGO target.

ROAD USE DATA

In order to allocate pavement costs and road user revenue it is necessary to identify appropriate road user groups and to adopt a useful measure of output levels.

User groups

Road users can be grouped according to similar characteristics. A basic distinction is between road freight and passenger vehicles. Further distinctions are required, however, in order to provide some meaningful information for cost recovery analysis. Information available in the ABS Survey of Motor Vehicle Usage (SMVU) allows a split in freight vehicles either on the basis of gross vehicle mass or the number of axles for rigid and articulated trucks. Disaggregation on the basis of axle numbers is considered more appropriate given the relationship between axle loads and pavement damage costs. This first level disaggregation divides road vehicles into cars (and light vehicles) and trucks and further divides trucks by number of axles.

For the purposes of applying Ramsey pricing allocations, car use is further divided between use for business purposes and use for domestic (or private) purposes, as the demand elasticities for each are significantly different. For the same reason long-distance bus travel is separately identified. The ten road user categories considered are:

- cars and light vehicles, for business use
- cars and light vehicles, for domestic use
- two-axle rigid trucks
- three-axle rigid trucks
- four-(or more) axle rigid trucks
- four-(or fewer) axle articulated trucks
- five-axle articulated trucks
- six-axle articulated trucks
- more than six-axle articulated trucks
- long-distance buses (three-axle rigid vehicles).

Further disaggregations might apply in a comprehensive pricing scheme based on demand elasticities.

Relative use of roads

The next step in the allocation exercise is to identify and evaluate the level of road use of the various vehicle groups.

Estimates of road use data are presented in Table 5.1. They are only indicative rather than being absolute measures. They cover road use on all roads including local roads.

The output measures presented are those which show the most identifiable relationship with road damage costs, with demand and with revenue payments. The first set of output measures are required for cost attribution using avoidable cost and for the cost-occasioned approach. The second is required for allocations based on Ramsey pricing principles and the third is required in order to allocate revenue on the basis of payments made.

In the case of avoidable cost attribution, equivalent standard axle load (ESAL) is the principal parameter of road damage cost. Aggregate

ESALs are determined by the product of distance travelled and average ESALs. Data on distances travelled are available in the most recent ABS SMVU for 1984-85 (ABS 1987a). The information for 1984-85 has been extrapolated to 1986-87 using new vehicle registrations and estimated growth rates.

Average ESALs were provided from the RoRVL mass and dimension survey (NAASRA 1985). However, the average ESAL figure estimated by the RoRVL study for two axle rigid trucks was based only on those vehicles with dual tyres on the rear axle. These trucks might be expected to have a higher tare mass and to carry heavier loads than two axle vehicles with single tyres. This is confirmed by the data presented in the 1984-85 SMVU which shows a much lower average load for all two axle rigid trucks. The overall average ESAL figure for all two axle rigid trucks is therefore likely to be much lower than that indicated by the RoRVL survey (which was, after all, mainly concerned with heavy vehicles). The average ESAL figure adopted in Table 5.1 is approximately one-half of the RoRVL survey estimate (that is, 0.2 instead of over 0.4).

The calculation of ESALs for each truck in the RoRVL survey was based on the fourth power rule. However, if different powers are used, reflecting different road types, different ESAL results will be obtained. If the power is at least three, then very little difference is made to the final allocations of avoidable cost to trucks in Chapter 6. If a power of two is used, trucks will on average be allocated only about 20 per cent less of avoidable cost. Cars will be allocated much more individually (up to forty times more) but the total allocation to cars will still be small. No studies have suggested a power below two on any roads and many suggest higher powers than four for some road types. The use of a fourth power rule for all roads is unlikely to make more than a marginal difference to the overall allocations. Nevertheless, one should be careful in using the results obtained in this Paper for particular applications, say for a particular road type. The results are broad averages only.

The cost-occasioned approach also requires data on the distribution of gross vehicle mass (GVM) by vehicle type. This information is also provided by the ABS SMVU and the RoRVL survey data.

The allocation based on Ramsey pricing principles requires data on prices, elasticities and output. The output data are essentially tonne-kilometres, passenger-kilometres and, in the case of cars, vehicle-kilometres travelled (VKT). With the exception of passenger-kilometres, which have been estimated by the BTCE on the basis of loading factors, these data were provided by the ABS SMVU.

In order to attribute payments made, the additional road use data required include fuel consumption rates in the case of fuel excise payments and numbers of vehicles in the case of registration and other fees. Vehicle numbers are also required in order to provide information on an average per vehicle basis. These were projected to 1986-87.

TABLE 5.1 ROAD USE DATA, 1986-87

Vehicle type	*Vehicle-kilometres[a] (million)*	*Average ESALs*	*Total ESAL kilometres (million)*	*Passenger- or tonne-kilometres (million)*	*Number of vehicles[a] ('000)*
Cars					
Business[b]	64 136	0.0003	19	..	8 695.6
Private	81 627	0.0003	24	..	
Rigid trucks					
2 axles	6 007	0.20	1 201	9 747	381.7
3 axles	958	1.37	1 313	5 219	45.1
3 axles	610	2.04	1 244	4 360	21.5
Articulated trucks					
5 axles	514	1.62	832	3 611	14.6
5 axles	633	2.40	1 519	7 114	11.6
6 axles	2 604	2.38	6 197	39 277	26.0
6 axles	287	4.27	1 227	9 819	2.4
Long-distance buses[c]	80	1.31	105	2 230	0.3
Total	157 456	..	13 681	..	9 198.4

a. Analysis does not include motor cycles.
b. Business use of cars includes travel to work. Business use represents 44 per cent of total car use and domestic use 56 per cent of total.
c. Previous BTE estimates (do not include charter travel).
.. Not applicable.

Note Owing to rounding, figures may not add to totals.

Sources ABS (1987a). NAASRA (1985). BTCE estimates.

PAVEMENT RESTORATIVE AND UPGRADING EXPENDITURES

The variety of terms used to describe similar concepts in cost recovery analyses is confusing. This problem is compounded when expenditure and cost terms, which are not synonymous, are used interchangeably. As discussed in Chapter 2, expenditure is a measure of what is actually spent, but costs measure the using up of resources, and opportunities foregone as a result of not adopting alternative uses of resources, and are incurred as a function of use, time or some other variable. Costs and expenditure are not necessarily (or usually) equal in a given period. Over the life of a particular road, however, the two may tend towards equality.

This section examines the relationship between the concept of avoidable cost (as a short-run cost concept) and actual road expenditure, particularly that portion termed 'restorative' expenditure. For the expenditure recovery analyses undertaken in Chapters 6 and 7, it is important to distinguish between restorative and upgrading expenditures. It is possible to apportion total annual road expenditure roughly between restorative and upgrading purposes and then estimate how much of restorative expenditures are avoidable with respect to vehicle traffic.

Terminology

For an efficient allocation of costs there is a need to distinguish between short-run avoidable cost and long-run avoidable cost. It was noted in Chapter 2 that an efficient pricing mechanism should only consider short-run marginal cost pricing and that avoidable cost is used as a convenient measure of marginal cost. The balance of costs should be recovered by another mechanism.

Part of the difficulty in distinguishing short-run and long-run costs is in applying engineering terms to economic analysis. Costs are usually measured in terms of engineering requirements which generally do not equate with the categorisation required in economic analysis.

Perhaps the most important distinction required is between engineering concepts of restoration and upgrading of roads. The former largely corresponds with short-run costs and the latter with long-run costs.

Upgrading expenditure is that directed to improving or increasing the capacity of the road asset. It is also referred to as improvement or augmentation expenditure. The capacity increase may be by way of the number of vehicles that can be carried in a given time period, safety, pavement strength or service level. The components of upgrading expenditure include road widening and duplication, pavement strengthening, realignment, extension, adding seals and additional lane provision. As the definitive requirement is an increase in capacity, these expenditures are a measure of long-run costs.

Restorative costs are mainly caused by current users and generally vary with the level of road use. They are the costs of keeping the capacity of the road constant, and can be regarded as short-run in nature. Note that even where road damage is not repaired and no road maintenance expenditure is required, there is still a cost in terms of the using up of the pavement or a diminishing of its capacity. This may be thought of as a loss of opportunity or an increase in costs for some other potential user (for example, an increase in his operating costs). The costs of pavement damage are either the costs of restoration or the loss of benefits (such as higher vehicle operating costs) if there is no pavement restoration. Obviously, these costs may differ significantly from the level of restorative expenditure, particularly the higher vehicle operating costs which are met by vehicle operators. In practice, there may be a combination of both costs since roads are not continuously restored.

Measurement of restorative and upgrading expenditures

The wear and tear cost is measured as the sum of routine maintenance expenditure, resealing (or resurfacing) expenditure, and reconstruction (or rehabilitation) expenditure over the life of the road. These three expenditure items and any other expenditure required to 'maintain' the road asset can be referred to as restorative expenditure. Over an extended period and where there is an efficient maintenance strategy, these expenditures may approximate the short-run (pavement damage) cost. However, in a given year these expenditures are unlikely to equal the road damage costs caused during the year. In fact, expenditure or restoration of the asset in a given year largely repairs damage caused by vehicles in earlier years.

In order to estimate the short-run avoidable cost of road use, restorative expenditure has to be separated from upgrading expenditure.

Isolating the expenditure on restoration from that on upgrading is, however, a difficult task. Upgrading activity is often carried out in concert with reconstruction and resealing. A resealing exercise, for instance, is often undertaken with activities such as road widening, smoothing or realignment, which are upgrading activities. Moreover, activities such as duplication and construction either remove the need for restoring a given road section or result in reconstruction to a level beyond the road's initial capacity. Unfortunately, adequate data representing the level of restorative and upgrading expenditures are not available. However, some indicative data are available in BTE (1984b), BTE (1987a) and NAASRA (1984).

Data on annual pavement expenditure in 1984-85 are presented in Table 5.2. They indicate that almost $3.7 billion was spent by the three levels of government on all Australian roads in 1984-85. One-third of this expenditure was on maintenance as defined in NAASRA guidelines with the balance being construction expenditure. The total road expenditure figures include administrative costs of State road authorities but not the Federal Government or local government authorities.

Total expenditure on arterial roads (including national highways) was $2063 million. Only 24.3 per cent of this ($501 million) was defined as maintenance expenditure, with 75.7 per cent ($1562 million) being construction expenditure. The proportion required for maintenance varies between States and between road types. It mainly represents routine maintenance since all but very short segments of resealing, and all reconstruction work are defined in NAASRA guidelines as construction expenditure. Local road expenditure in 1984-85 was $1600 million of which 45 per cent ($715 million) was maintenance expenditure and 55 per cent ($885 million) was construction expenditure.

Road expenditure in 1986-87 is estimated to total about $4200 million for all roads. This is about the same level in real terms as in 1984-85. Although a detailed disaggregation of this expenditure is not available, a similar proportion of expenditure in each State, between road types and between construction and maintenance activity, has been assumed in this Paper to hold for 1986-87 as in 1984-85. Therefore, it is estimated that routine maintenance expenditure will be about $1400 million in 1986-87.

The higher share of total expenditure represented by maintenance for local roads than for other road types indicates that routine maintenance may be a more important component of the optimal maintenance and investment strategy for lower grade roads. Optimal pavement investment and maintenance strategy is discussed in Chapter 2 and is followed up in the next section as it has implications for road pricing and cost allocation. An alternative explanation for this discrepancy may be that a non-optimal road design strategy is followed for local roads (and perhaps for other roads) due to annual budget constraints and a short planning horizon.

TABLE 5.2 TOTAL EXPENDITURE ON THE AUSTRALIAN ROAD NETWORK, BY ROAD TYPE AND BY STATE, 1984-85
($ million)

Road type	*State*								
	New South Wales	*Victoria*	*Queensland*	*Western Australia*	*South Australia*	*Tasmania*	*Northern Territory*	*Australian Capital Territory*	*Total*
National Highways									
Construction	176.3	83.4	83.8	48.9	37.7	16.7	23.4	0.0	470.1
Maintenance	25.4	8.6	40.1	11.9	12.9	2.7	5.7	0.0	107.4
Total	201.7	92.0	123.9	60.8	50.6	19.4	29.1	0.0	577.5
Rural arterial roads									
Construction	157.0	82.9	118.3	58.1	30.4	33.3	1.8	0.0	481.8
Maintenance	103.2	45.3	64.1	28.7	25.6	8.3	3.4	0.0	278.5
Total	260.2	128.2	182.4	86.8	56.0	41.6	5.2	0.0	760.3

TABLE 5.2 (Cont.) TOTAL EXPENDITURE ON THE AUSTRALIAN ROAD NETWORK, BY ROAD TYPE AND BY STATE, 1984-85

($ million)

	State								
Road type	*New South Wales*	*Victoria*	*Queensland*	*Western Australia*	*South Australia*	*Tasmania*	*Northern Territory*	*Australian Capital Territory*	*Total*
Urban arterial roads									
Construction	256.6	154.3	78.8	61.2	30.7	16.2	2.9	10.0	610.6
Maintenance	43.0	28.6	11.8	9.7	13.2	2.5	0.9	5.0	114.8
Total	299.6	182.9	90.6	70.9	43.9	18.7	3.8	15.0	725.4
All arterial roads									
Construction	589.9	320.6	280.9	168.2	98.8	66.2	28.1	10.0	1 562.5
Maintenance	171.6	82.5	116.0	50.3	51.7	13.5	10.0	5.0	500.7
Total	761.5	403.1	396.9	218.5	150.5	79.7	38.1	15.0	2 063.2
Rural local roads									
Construction	152.1	90.1	144.8	54.0	26.7	35.8	17.9	0.8	522.1
Maintenance	107.8	81.2	83.3	28.7	29.1	15.5	7.8	0.8	354.1
Total	259.9	171.3	228.1	82.7	55.8	51.3	25.7	1.6	876.2

TABLE 5.2 (Cont.) TOTAL EXPENDITURE ON THE AUSTRALIAN ROAD NETWORK, BY ROAD TYPE AND BY STATE, 1984-85
($ million)

	State								
Road type	*New South Wales*	*Victoria*	*Queensland*	*Western Australia*	*South Australia*	*Tasmania*	*Northern Territory*	*Australian Capital Territory*	*Total*
Urban local roads									
Construction	156.1	74.5	61.3	26.8	32.3	5.8	1.0	6.3	364.0
Maintenance	142.8	102.3	53.0	18.4	25.6	11.0	2.2	5.2	360.5
Total	298.9	176.8	114.3	45.2	57.9	16.8	3.2	11.5	724.5
Total road network									
Construction	898.1	485.1	486.9	248.9	157.8	107.8	46.9	17.1	2 448.5
Maintenance	422.3	266.1	252.3	97.4	106.3	40.2	20.0	11.0	1 215.4
Total	1 320.3	751.2	739.3	346.2	264.1	147.9	66.9	28.1	3 663.7

Note Owing to rounding, figures may not add to totals.

Source BTE (1987a).

In order to arrive at an estimate of restorative expenditure, estimates of resealing and reconstruction expenditure must be added to the estimate of routine maintenance expenditure ($1400 million). The Australian Roads Outlook Report (TAROR) (NAASRA 1987) suggested that restorative expenditure amounts to 60 per cent of total expenditure on arterial roads and perhaps an even higher figure for local roads. The Bureaus 1987 roads report (BTE 1987b) also suggests the figure is much higher now than in the past.

In this Paper, the total cost of restoration has been taken as 65 per cent of total road expenditure or $2740 million. This estimate is made up as follows:

- routine maintenance - 34 per cent
- resealing and reconstruction - 31 per cent.

Table 5.3 shows the allocation of the broad categories of road expenditure for both arterial and local roads. The cost of restoration is represented by total expenditure of $4200 million less upgrading and new construction expenditure of $1460 million.

From the estimate of restoration costs, approximately 18 per cent of total road expenditure, around half of the level of routine maintenance, was subtracted to give avoidable cost. The amount subtracted represents bridge repairs and routine maintenance that cannot be attributed to axle loads (for example, mowing median strips, lane marking, repair to guard rails and traffic lights and road damage purely due to weather or floods). The balance, 47 per cent or approximately $2000 million, is attributable to axle load passes over the road system.

It should be noted that these adjustments are realistic only at an overall level and do not apply to particular roads. The assessments for particular road types and for some States (particularly smaller States) may also be less reliable than the aggregate Australian assessment of restorative expenditure. An attempt to apportion total road expenditure into restoration and upgrading expenditure for each of the various road types and for each of ten expenditure components, using US FHA (1984) methodology, is outlined in Chapter 7. A slightly lower estimate of short-run avoidable cost results from that analysis (about $1860 million). In both cases the estimates are fairly rough. More detailed information from State road authorities concerning their road works is needed to refine these estimates.

Dynamic variations

An extrapolated model might also show that over time the proportion of restorative expenditure would increase. This would be partly due to

TABLE 5.3 ESTIMATED TOTAL ROAD EXPENDITURE ON AUSTRALIAN ROADS, BY TYPE OF ROAD WORK, 1986-87
($ million)

Expenditure type	*Arterial roads*	*Local roads*	*All roads*
Avoidable cost			
Routine maintenance due to axle loads	300	360	660
Resealing	250	240	490
Reconstruction	600	250	850
Total	1 150	850	2 000
Non-avoidable cost			
Common routine maintenance	300	230	530
Bridge repair	120	90	210
Upgrading and new construction	830	630	1 460
Total	1 250	950	2 200
Total	2 400	1 800	4 200

Source BTCE estimates.

the gradual completion to an acceptable standard of the major arterial roads, especially National Highways, and to some extent local roads. Thus, a gradual decline in construction requirement would be expected. This could also be partly due to the higher cost associated with maintaining a larger road asset with a higher service level.

It was noted in BTE (1982b) that the United States road funding strategy indicates that proportionally more funds are required to maintain their road system and less for construction purposes compared to Australia. This reflects the fact that the United States has largely completed major new construction programs and so has achieved an acceptable road capacity level. It is now more concerned with maintaining that level. A dynamic cost recovery analysis would take this change in circumstances into account.

In the Australian situation, an acceptable standard is not likely to be achieved for some time. A short-term dynamic analysis is therefore not likely to alter the expenditure allocation position significantly. Upgrading expenditures are likely to be maintained at around current levels until at least 1988-89, although the disbursement of funds among road types and States may be altered (BTE 1984b). The overall proportion of funds attributable to restoration will probably remain around current levels until at least 1988-89.

The implication of these dynamic changes for the cost recovery exercise is that the levels of restoration and upgrading expenditure need to be reassessed regularly. The calculations undertaken in Chapters 6 and 7 would need to be revised to take account of a revised restoration/upgrading split, as well as changes in total expenditure.

Avoidable restorative expenditure

Even given the assumption that the current maintenance or restorative strategy, that is to maintain the existing capacity, is the most appropriate strategy for maintaining roads, the restorative *expenditure* may be quite different from the restorative *cost* for any given year. Further, the amount of restorative costs which are avoidable will be less than the total restorative expenditure since some restorative expenditure cannot be avoided by removing users or groups of users (for example, some road restoration costs such as mowing medium strips, lane markings, etc). In addition, damage caused this year is a cost incurred this year, whereas the expenditure to repair the damage might not be applied until some time in the future.

The three elements of short-run avoidable pavement costs (routine maintenance, resealing and reconstruction) make up the dominant part of restoration costs. It was argued in Chapter 2, that the three costs are by and large attributable to road users. However, as noted above, a small proportion of restorative work, essentially that part dealing with maintenance of road furnishings, signs, signals and so forth, and cleaning and gardening, is not user-related. In addition, a proportion of restorative cost is due solely to weather and climate and natural disasters. Part of administration cost could also be regarded as a fixed cost while some aspects may be road-user related, although not attributable to particular vehicle classes. Of the estimate of restoration expenditure of $2740 million shown in Table 5.3 (that is, total expenditure excluding upgrading and new construction), short-run avoidable cost attributable to vehicles would be of the order of $2000 million in 1986-87.

This compares with the estimate of about $1860 million made in Chapter 7 using the United States study methodology (that is, 44.3 per cent of road expenditure compared to 47.6 per cent). The United States approach is more precise, since it relies on a greater disaggregation of expenditure types but it is not necessarily more accurate. The accuracy of either approach depends on the reliability of the assumptions made. Until a similar study to that conducted in the United States is carried out in Australia, the estimate is only reliable within a fairly broad range.

For this analysis the estimate of $2000 million was taken as the amount which should be recovered in aggregate from road-users to cover avoidable cost in 1986-87. This was therefore the cost recovery target in the avoidable cost recovery analysis undertaken in Chapter 6.

ROAD SYSTEM COSTS

As noted in Chapter 2, the avoidable pavement cost measured above is only one component of the total marginal social cost of road use. Although the main cost recovery analyses undertaken in the next two chapters concentrate on the recovery of this component only, there are good reasons, in an efficiency sense, to see that all social costs are recovered; that is, to ensure that all components of marginal social cost are included in the prices faced by road users.

The causes and implications of this were discussed in Chapter 2. The most obvious reason is to ensure that all sectors, especially those that compete for resources or for a share of a market, are treated both equitably and efficiently. The primary reason for ensuring that all road system costs are included as road prices, is to achieve an appropriate distribution of resources and market shares.

Apart from pavement damage cost, the other main components of costs of road use include:

- congestion
- traffic administration and policing
- noise and air pollution
- accidents among road users
- vehicle operating costs.

Appendix I discusses each of these costs, and the extent to which they increase with increased traffic and can thus be attributed to vehicles using the roads. In Table 5.4 each cost item is divided into that

TABLE 5.4 SOCIAL COSTS OF ROAD USE IN AUSTRALIA, 1986-87
($ million)

	Cost relationship		
Item of cost	*Variable*	*Fixed*	*Total*
Vehicle operating costs[a]	27 615	21 263	48 879
Pavement damage/ road improvement	2 000	2 200	4 200
Accidents	5 520	..	5 520
Administration	400	400	800
Congestion	2 000	..	2 000
Pollution	-	..	-
Total	37 535	23 863	61 400

a. The major part of these costs is caused by and borne by each individual vehicle operator with only a small incidence on other users or the community. Thus, most is a private social cost rather than external social costs.
.. Not applicable.
\- Nil or rounded to zero.

Note Owing to rounding, figures may not add to totals.

Source BTCE estimates, refer Appendix I.

element which does not vary with the amount of other traffic on the roads and that which increases with traffic levels. Most vehicle operating costs and most of the costs of accidents are internalised, that is, they are met by road users. It should be noted, however, that parts of these costs are externalities in that they are not met by the same road users that cause them. An example is the increase in vehicle operating costs of light vehicles due to road damage caused by heavy vehicles.

The costs of pavement damage, traffic administration and policing and some accident costs are met by public expenditure with some recovery of costs from road users. Costs such as congestion and pollution are mostly external to the particular road user and generally do not involve an outlay of expenditure. For instance, congestion causes a time delay for many motorists but the cost of this is mostly in the form of a lost opportunity to do something else. In the case of pollution the damage could be quite significant, involving a resource cost, but the expenditure required to reduce the level of pollution could be small. Some share of pollution costs is, however, currently being met by road users through pollution control devices or more expensive engines in their vehicles.

The existence of congestion costs is implied in upgrading road volume capacity. Although congestion and damage are similar in their direct relationship to road use, damage can be distinguished in that it requires expenditure in the short-term by governments to restore the asset. Congestion, on the other hand, does not diminish the asset and requires no restorative expenditure by governments. Congestion costs should be considered in order to achieve expenditure recovery with minimum distortion of demand patterns, that is as part of marginal cost pricing. However, due to lack of reliable estimates of congestion costs, only road damage costs are included in an assessment of cost recovery.

Most of the costs listed as variable in Table 5.4 represent the short-run avoidable cost of road use. It can be seen from the table that pavement damage forms only a small part of the total of short-run avoidable cost of road use. Note, however, that the bulk of the avoidable vehicle operating costs are internalised (that is, directly faced by each operator). Only a small proportion, estimated to be 3 or 4 per cent of total avoidable vehicle operating costs, are caused by other vehicles via additional road damage. Nevertheless, this small proportion may still be large compared with pavement damage costs.

ROAD USER REVENUE

Road users pay many different charges and taxes to the various levels of government. However, not all of these can be considered as charges for road use or road cost recovery charges. The last section of Chapter 2 outlined several definitions of recovery payments and road-user charges. The choice of definition depends mainly on the purpose of the assessment but is nevertheless largely arbitrary. Appendix II discusses the nature of various categories of revenue raised from charges related to road use, and, in particular, how they relate to the definitions presented in Chapter 2. Based on this analysis, in the first part of this section an assessment is made of the projected government revenue from road use in the year ending on 30 June 1987, for each of the three definitions.

In the second part of this section, the total of road cost recovery revenue is attributed amongst the major user groups. This information is used in the estimates of road cost recovery made in the following two chapters.

Revenue from road users

Government revenue derived from road use has been projected based on revenue receipts reported in the ABS Taxation Revenue publication and supplemented from other sources. The revenue estimates are classified in Table 5.5 according to the three road-user revenue definitions outlined in Chapter 2. The broad definition comprises all payments made by road users on road use related activities whether they are general taxation measures or specific charges but excludes government rent returns. The second definition represents revenue raised from charges which are unique to road users. It excludes general taxation revenue and rent returns, however, it does include excise on motor spirit and diesel as well as petroleum franchise licence fees, which, despite some exemptions, includes a minor contribution from non road-users. This is the definition adopted in Chapters 6 and 7 to assess cost recovery levels. (The reasons for this choice are outlined in Chapter 2). The third definition includes only that part of revenue which is hypothecated to road expenditure.

Payments for the use of road system infrastructure

All payments related to road use are shown in Table 5.5. The total of payments made through road-use related charges in 1986-87 are estimated to have been more than $9000 million. Of this, about $7300 million arose from specific charges which were only levied on road users. The difference was made up from contributions by road users to general taxation. Although all of the revenue from fuel excise has been included, a large proportion could be deducted on the grounds that it is a contribution to general taxation revenue. Revenue from charges such as drivers' licence fees, which are regarded as charges for the traffic administration service provided by governments, rather than for the provision of road system infrastructure, would need to be netted out from a cost recovery calculation relating only to infrastructure costs.

The five remaining revenue items, which total about $7130 million, can be considered as payments for the use of infrastructure. This revenue may be matched against the sum of restorative and upgrading expenditure. Further assumptions are required before specific matching against each of these two expenditure items may be done appropriately.

This estimate of $7130 million has been allocated among nine vehicle categories in Table 5.6 on the basis of estimated contributions. Fuel

TABLE 5.5 ESTIMATED GOVERNMENT REVENUE FROM ROAD USE, BY RECOVERY DEFINITION, 1986-87

($ million)

Type of tax or charge	*All revenue from road use related activities*	*Revenue from charges unique to road users*	*Revenue hypothecated to road expenditure*
Charges on sale of petroleum			
Excise on motor spirit and diesel	5 376.3	5 376.3	1 334.1
Petroleum franchise licence fees	672.0	672.0	350.0
Total	6 048.3	6 048.3	1 694.1
Federal (Interstate) registration	1.5	1.5	1.5
Customs duties			
Motor vehicles and parts	220.0	..	..
Petroleum	20.0	..	..
Total	240.0	..	..
Sales taxes			
Motor vehicles	1 000.0	..	..
Parts and tyres	500.0	..	..
Total	1 500.0	..	..
State motoring charges			
Vehicle registration fees	1 070.0	1 070.0	1 070.0
Drivers' licence fees	170.0	170.0	
Road transport and miscellaneous taxes	10.0	10.0	5.0
Stamp duty on registration	440.0	..	..
Total	1 690.0	1 250.0	1 075.0
Total	9 479.8	7 299.8	2 770.6

.. Not applicable.

Sources ABS (1986). Australian Institute of Petroleum Ltd (1986). Commonwealth of Australia (1986-87). BTCE estimates.

excise payments and franchise licence fee payments are allocated on the basis of aggregate fuel consumption of each vehicle type (ABS 1987a). The allocation of registration fees and taxes among vehicle types is made on the basis of the number of vehicles and estimated average payments made per vehicle. Road transport taxes are allocated on the basis of tonne-kilometres of travel.

The analysis shows that about 75 per cent of contributions to infrastructure expenditure are made by operators of motor cars, with most of the rest being contributed by operators of rigid trucks.

TABLE 5.6 ESTIMATED VEHICLE CONTRIBUTIONS TO ROAD SYSTEM INFRASTRUCTURE COSTS, 1986-87[a]
($ million)

Vehicle type	*Excise on motor spirit*	*Petroleum franchise licence fees*	*Road transport taxes*	*Registration fees and taxes*	*Total contrib-utions*
Cars					
Business	1 924.1	240.5	..	393.7	2 558.3
Private	2 448.8	306.1	..	467.6	3 222.5
Rigid trucks					
2 axles	317.2	39.6	1.5	96.0	454.4
3 axles	87.4	10.9	0.2	21.2	119.8
3 axles	64.4	8.0	0.2	11.7	84.3
Articulated trucks					
5 axles	53.0	6.6	1.0	24.0	84.6
5 axles	79.0	9.9	1.2	17.7	107.8
6 axles	343.7	43.0	5.1	37.0	427.3
6 axles	51.0	6.4	0.6	2.5	60.5
Long-distance buses	7.7	1.0	0.2	0.1	8.9
Total	5 376.3	672.0	10.0	1 071.5	7 128.3

a. Based on the second definition of road user charge.
.. Not applicable.

Note Owing to rounding, figures may not add to totals.

Source BTCE estimates from Table 5.5.

CHAPTER 6 ROAD DAMAGE COST RECOVERY LEVELS

This chapter considers both the overall level of recovery of annual avoidable pavement damage cost in aggregate and by vehicle type for the year 1986-87. As noted in Chapter 5, these costs are approximated by actual expenditure on that share of road restoration works which is due to vehicle traffic.

The first exercise is a straightforward comparison of annual revenues with the level of avoidable pavement damage cost. The second exercise requires an allocation of avoidable pavement damage cost on the basis of relative destructiveness and an allocation of road-use related revenues on the basis of payments made. Given the difficulties outlined in the previous chapters, the estimates are reliable only within a fairly broad range. The avoidable cost measure used is the short-run avoidable cost of a vehicle's use of the road system infrastructure, including pavements and bridges. In this Paper this is taken as damage caused to pavements and bridges by road users and does not include the other social costs mentioned in Chapter 5. The level of avoidable cost was estimated in the previous chapter to be about $2000 million for 1986-87.

OVERALL RECOVERY ESTIMATES

The overall level of recovery involves a simple comparison of the $2000 million estimate of avoidable cost with revenue raised from road-user charges. Road-user charges, as defined in Chapter 5, raised revenue of about $7130 million in 1986-87. The level of recovery of avoidable cost on Australian roads is therefore about 360 per cent.

A simple comparison such as this ignores two important issues. These concern:

- the appropriate allocation of revenues and costs among vehicle types; and
- the level of recovery by vehicle type.

The comparison also ignores recovery of fixed or joint and common costs which is considered in Chapter 7.

The allocation of revenues and expenditures among road users employed in this Paper is broadly in line with the accounting matching principle. This is discussed in most elementary accounting textbooks (for instance, Hendersen & Pierson 1980, 78-81). The aim of the matching principle is to ensure that the appropriate costs are 'matched' against the appropriate revenue when assessing profit. Some minor adjustments were required for this Paper to apply this accounting principle to what is essentially an economic comparison.

RECOVERY BY ROAD-USER GROUP

An analysis of the level of avoidable cost recovery by road-user group indicates which groups are currently paying sufficient road-use revenue to the various governments to at least cover their pavement damage costs.

Allocating avoidable cost among user groups

The estimated level of avoidable cost using the PAYGO approach is accurate only within a fairly broad range and will vary from year to year. The relationship between avoidable (pavement damage) cost and road use is also known only roughly. As noted in Chapter 2 and also discussed in Chapter 5, pavement damage can generally be related to the fourth power of the vehicle's axle loads. The potential for damage is summarised in the ESAL measure presented in Chapter 5.

In the absence of a detailed life-cycle cost analysis of Australian roads, a broadly determined estimate of pavement damage cost by vehicle type is based on a division of the aggregate level of pavement restorative costs due to traffic by the aggregate number of ESAL kilometres travelled. This is the basis of the allocation in Table 6.1. Although imprecise, the allocations indicate the order of magnitude of the pavement damage cost responsibilities of different vehicle types.

For simplicity, this allocation has ignored the problem of allocating the damage costs of bridges which is less a function of ESAL kilometres and more to do with a vehicle's gross mass. This is discussed in more detail in Chapter 7. The allocation here of damage costs to bridges using the fourth power rule is unlikely to make any significant difference to the allocation among road user groups. Bridge damage costs are not a large share of avoidable cost and an allocation by either the fourth power rule or by gross vehicle mass assigns a major share of the costs to the heaviest vehicles.

TABLE 6.1 ROAD DAMAGE COST RECOVERY BY ROAD USER GROUP, 1986-87
($ million)

Road user group	*Pavement damage cost/ expenditure*	*Allocation of variable revenue*	*Contri-bution to balance of road expenditure*	*Allocation of fixed revenue*	*Net contri-bution to balance of road expenditure*
Cars					
Business	3	2 165	2 162	394	2 556
Domestic	4	2 755	2 751	468	3 219
Rigid trucks					
2 axles	176	358	183	96	279
3 axles	192	99	-93	21	-72
> 3 axles	182	73	-109	12	-98
Articulated trucks					
< 5 axles	122	61	-61	24	-37
5 axles	222	90	-132	18	-114
6 axles	906	392	-514	36	-479
> 6 axles	179	58	-121	3	-119
Long-distance buses	15	9	-7	-	-6
Total	2 000	6 058	4 058	1 070	5 129

- Nil or rounded to zero.

Note Owing to rounding, figures may not add to totals.

Source BTCE estimates.

The revenue items in Table 6.1 have been apportioned among vehicle types as shown in Table 5.6. The revenue which varies with road use is presented separately to show a variable contribution to fixed cost. That is, if road use increases or decreases and fixed fees such as registration fees are not adjusted, then the level of cost recovery for that user group will decrease or increase proportionately. The total allocation of variable revenue shown in Table 6.1 ($6058 million) represents total contributions of about $7130 million less registration fees and taxes of about $1072 million shown in Table 5.6.

The results of the analysis imply a pavement damage cost of about 14.6 cents per ESAL kilometre, or about 34 cents per kilometre for a six-axle truck carrying an average load of about 15 tonnes (GVM). This is somewhat higher than similar estimates for 1981-82 made in BTE (1985a) and based on pavement damage cost estimates from the ERVL study (around 5.3 cents per ESAL kilometre). In 1986-87 prices, this estimate would be about 8.2 cents per ESAL kilometre, or about 18.5 cents per vehicle-kilometre for the same six-axle truck. The difference between the 1981-82 BTE estimate of 8.2 cents and the current estimate of 14.6 cents per ESAL kilometre is due chiefly to the fact that the earlier estimates referred to arterial roads only. When the earlier figures are compared with the current estimates for arterial roads only, presented in the last section of this chapter, it can be seen that there is very little difference.

In addition, there are two other factors contributing to a higher estimate for 1986-87; first, an increase in total road expenditure of 18 per cent in real terms over the period and, second, the estimated increase in share of total expenditure being directed to restoration works. The total level of avoidable cost is estimated to have increased from \$600 million in 1981-82 (\$875 million in 1986-87 prices) on arterial roads alone, equivalent to about \$1550 million (in 1986-87 prices) in total on all roads, to \$2000 million in 1986-87: a real increase of 29 per cent. The level of ESAL kilometres is estimated (largely from the ABS SMVU) to have increased from 10 billion in 1981-82 to 13.7 billion in 1986-87: an increase of 37 per cent.

The explanations for the increase in average damage cost per ESAL kilometre highlight the problem of using an expenditure-based approach to estimating avoidable cost, rather than from output-unit cost relationships derived from a life-cycle cost analysis. The former approach is more convenient but lacks precision; the latter approach is more robust but requires a great deal of information.

The specific problem noted here is that the higher levels of expenditure on pavement repairs in 1986-87 may be due to high road damage incurred in earlier years, particularly the years of rapid growth in heavy vehicle use in the early 1980s. In a sense we are now paying for road damage caused by vehicles in previous years. This is a problem of inter-temporality which will persist in any PAYGO approach to road cost recovery.

TABLE 6.2 AVERAGE ROAD DAMAGE COST RECOVERY BY ROAD USER GROUP, 1986-87

($ per vehicle)

Road user group	*Pavement damage cost/ expenditure*	*Allocation of variable revenue*	*Contri-bution to balance of road expenditure*	*Allocation of fixed revenue*	*Contri-bution to balance of road expenditure*
Cars	1	566	565	99	664
Rigid trucks					
2 axles	460	939	479	252	730
3 axles	4 258	2 187	-2 071	470	-1 601
> 3 axles	8 476	3 384	-5 092	545	-4 546
Articulated trucks					
< 5 axles	8 325	4 150	-4 175	1 643	-2 532
5 axles	19 188	7 786	-11 402	1 530	-9 873
6 axles	34 857	15 074	-19 783	1 366	-18 417
> 6 axles	73 523	23 764	-49 758	1 025	-48 734
Long distance buses	51 065	29 320	-21 745	400	-21 345

Source BTCE estimates.

Avoidable cost recovery by road-user group

Tables 6.1 and 6.2 show the estimated level of recovery of avoidable cost by road-user group on all Australian roads for the financial year 1986-87 in total and the average per vehicle respectively. The data indicate that total recovery payments were more than three times the level of the total avoidable cost. The total contribution to common and joint costs (or to pavement expenditure in excess of avoidable cost) was about $4400 million in 1986-87. All of this excess, however, is contributed by operators of lighter vehicles. Motor cars are allocated very little short-run avoidable (pavement damage) cost in this analysis, although the study has not considered non-infrastructure avoidable cost such as traffic administration, pollution and congestion. Indeed, if the analysis was of the level of recovery of road system costs in total, including congestion costs, the cost recovery position for lighter vehicles is quite different.

The smallest rigid trucks are shown in Table 6.1 and 6.2 to be just meeting their avoidable cost, while the three-and four-axle rigid vehicles (with the exception of long-distance buses) have a short-fall of about $170 million on their avoidable pavement damage cost (which is equal to about $1600 and $4500 respectively per vehicle). The long-distance buses operating on regular routes in 1986-87 appear to be under-recovering avoidable cost by about $6.5 million or about $21 000 each. There is some uncertainty with the actual level of under-recovery by long-distance buses, however, due to the lack of available data. Despite this, there seems little doubt that these vehicles did not make a contribution to common and joint costs in 1986-87. This situation is probably true of all such buses (including tour and charter buses), depending mainly on distance travelled.

The major area of concern is the level of under-recovery of avoidable pavement cost by the heaviest freight vehicles. Articulated vehicles failed to recover their avoidable pavement cost by over $750 million in 1986-87. The level of under-recovery per vehicle increases with the size of the vehicle. The 28 000 heaviest articulated vehicles (six or more axles) appear to have an under-recovery of about $600 million on their avoidable pavement cost in 1986-87. This represents over $18 000 for the average six-axle truck and nearly $50 000 for the heaviest vehicles. In fact, the level of shortfall is still large for this group even if all the revenue items from Table 5.5 are included (for example, sales taxes, customs duties and stamp duties).

As noted earlier, the avoidable cost calculated here is based on expenditure rather than actual costs. A PAYGO approach to cost recovery has the anomaly that the level of avoidable cost used, namely restoration expenditure due to vehicle traffic, may vary significantly from year to year. Over a period when ESAL kilometres are increasing, it is highly likely that annual road damage is higher than the annual level of expenditure on restoring the asset. The figures presented above may therefore significantly underestimate actual damage costs in 1986-87 and consequently overestimate the level of cost-recovery of heavy vehicles. This simply points to the need for more research on road damage costs.

Avoidable cost recovery by both vehicle type and road category

It needs to be stressed also that the figures are averages - representing the average for each vehicle type and also the average over all road categories. It was noted in Chapter 4 that the US FHA

(1982) study found that the damage costs per ESAL kilometre differed greatly among road categories. They would also differ greatly among roads of the same category.

Unfortunately, there is very little data on vehicle travel by road category for Australia. Concern has been expressed that the level of charges for articulated trucks shown in Table 6.2 is too high because these trucks travel mainly on arterial roads, which generally have stronger pavements and thus sustain lower road damage. The only information that could be found on vehicle traffic by road category was contained in the NCA study (NCA 1984, 83). NCA estimated, for example, that 93 per cent of the travel undertaken by large rigid trucks and articulated trucks was on arterial roads. The avoidable cost of arterial roads, estimated in Chapter 5 at $1150 million in 1986-87, represents by comparison about 57 per cent of the estimate of total avoidable cost ($2000 million).

In Table 6.3, alternative calculations to those in Table 6.2 are shown based on the NCA traffic estimates. For comparison, a set of estimates is also provided based on greater share of travel of heavier vehicles on local roads than the NCA estimates. It can be seen that the NCA traffic estimates result, as expected, in a smaller average allocation of avoidable cost per vehicle for heavier vehicles than those in Table 6.2 (which are also shown in Table 6.3 for comparison).

It is perhaps surprising that the reduction in avoidable cost shown is not greater for these vehicles. However, the lower share of VKT of the heavy trucks on local roads, is partially compensated for by the higher cost per ESAL kilometre for local roads. For the NCA traffic estimates, the avoidable cost per ESAL kilometre is 8.8 cents for arterial roads compared with 64.9 cents for local roads. In the alternative estimates, the costs are 9.6 cents and 37.7 cents respectively.

Thus, the avoidable cost per ESAL kilometre for local roads is very sensitive to these traffic estimates. It is noteworthy, however, that even using the NCA travel estimates, the avoidable cost per ESAL kilometre for local roads are similar to the figure found in the United States study, which is shown in Table 4.4 (particularly after taking inflation and exchange rates into account).

There is a wide variety of road types, pavement strengths and the like within the category of arterial roads or local roads. However, even less information is available on average ESALs by road type or damage costs for each type of pavement. This simply highlights another problem to be faced in establishing a sound road pricing system.

TABLE 6.3 ALTERNATIVE CALCULATIONS OF AVOIDABLE COST OF EACH VEHICLE TYPE BASED ON ASSUMPTIONS CONCERNING VEHICLE TRAVEL BY ROAD CATEGORY

Vehicle type	*Base case[a] allocation per vehicle ($)*	*NCA traffic estimates*		*Alternative estimates*	
		Percentage of travel on arterial roads	*Allocation per vehicle ($)*	*Percentage of travel on arterial roads*	*Allocation per vehicle ($)*
Cars	1	65	1	65	1
Rigid trucks					
2 axles	460	70	807	70	568
3 axles	4 258	80	5 829	70	5 251
> 3 axles	8 476	93	7 371	80	8 002
Articulated trucks					
< 5 axles	8 325	93	7 263	85	7 885
5 axles	19 188	93	16 678	85	18 106
6 axles	34 857	93	30 354	85	32 954
> 6 axles	73 523	93	63 959	85	69 436
Long-distance buses	51 065	93	44 486	85	48 295

a. All vehicles assumed to travel 54 per cent of annual distance on arterial roads and 46 per cent on local roads.

Source BTCE estimates.

There will always be difficulties with averages, particularly those involving the fourth power rule. Even the NCA estimates of vehicle travel by road type are only broad figures being obtained by comparing two very different data sources (the NAASRA Roads Study (1984) for travel on arterial roads and the ABS SMVU (1982) for total vehicle travel).

CHAPTER 7 ANNUAL ROAD COST/EXPENDITURE RECOVERY

In this Chapter, annual road expenditure recovery calculations are presented for Australia for the financial year 1986-87. In considering recovery of annual expenditure as distinct from recovery of avoidable and other costs, this Chapter follows the PAYGO approach to cost recovery. This approach was outlined in Chapter 2 and, as noted there, it has a number of shortcomings. The PAYGO approach is, however, a pragmatic approach and the one usually adopted by governments both in Australia and overseas.

In allocating expenditure to different user groups, two approaches are used. The first is the Ramsey pricing approach which allocates expenditure above avoidable cost/expenditure among road users on the basis of demand elasticities. This is a second-best efficiency approach in that it is, theoretically, the most efficient approach given that there is a constraint that all road expenditure must be recovered from road users in the year in which it is incurred.

The second approach is presented for purposes of comparison. This is an equity approach based on the cost-occasioned methodology adopted in the United States[1] cost allocation study (US FHA 1982). It is a disaggregated average cost approach to expenditure allocation.

Although other allocation approaches have been used in various road cost/expenditure allocation studies, these two have, in theory, the most clearly defined rationales.

In the final section of this Chapter, the cost/expenditure recovery estimates for each approach are compared.

TOTAL EXPENDITURE RECOVERY BY ROAD-USER GROUP: ECONOMIC EFFICIENCY APPROACH

In 1986-87 road construction and maintenance expenditure by the three levels of government is estimated at about $4200 million. With revenue from road users estimated at about $7130 million, given the definition adopted in Chapter 5, there is an over-recovery of $2930 million. The level of expenditure recovery is therefore about 170 per cent.

In Chapter 6, estimates were made of the level of charges being paid by operators of the various vehicle types and estimates of the avoidable cost of their use of roads. In order to complete the picture and assess the total cost/expenditure recovery level for each vehicle type, an allocation of the balance of total road expenditure above avoidable cost/expenditure among road users is required. In this section this allocation will be undertaken using economic efficiency principles.

In many cases of public pricing of goods or services economic efficiency objectives are constrained by other objectives. These constraints might include: meeting a given revenue target (for example, the PAYGO target); maximising revenue from road users; or not pricing at short-run marginal cost (for example, by not including a congestion charge). In such cases the constrained efficiency approach is referred to in the literature as a 'second-best' approach.

There are two parts to this Ramsey pricing allocation of the annual expenditure target. The first is the attribution of short-run avoidable cost as this is what individual road users should pay to ensure an economically efficient use of roads. This attribution was done in Chapter 6. The second part is the allocation of any imposed additional recovery target. In 1986-87 total expenditure exceeded avoidable cost by $2200 million.

The Ramsey pricing formula used to allocate this expenditure among users was:

$$FAC_i - MC_i = \frac{-k.Po_i}{Eo_i}$$

where FAC_i is the fully allocated expenditure target for road use i;

MC_i is the short-run marginal cost of road use i;

k is a constant which is set to achieve the recovery target;

Po_i is the original or existing price of road use i (this is explained more fully in the text); and

Eo_i is the price elasticity of demand for road use i (which is normally negative).[1]

---

1. The elasticity of supply is not considered since the expenditure to be allocated is the expenditure on the supply of infrastructure; that is only road users, not suppliers, are to be charged. A further assumption is that Po_i and Eo_i, the initial or existing prices and elasticities, are in the same ratio as the final (or post-Ramsey) allocation prices and elasticities.

Some simplifications are required in order to apply this formula in practice. For instance, there are no market determined prices of road use and accordingly there are no corresponding estimates of levied road use price elasticities. In addition, the charges and taxes that are currently levied do not reflect the marginal cost of road use (including congestion cost), which is ideally the starting point in a Ramsey pricing scheme. Marginal (or avoidable) pavement damage cost was found in the previous chapter to be very low for cars, but was estimated to be very large for heavy trucks. The elasticities which would apply if corresponding prices were charged are not known.

In a simple case where the government wishes to tax an item such as a light bulb, the tax is normally levied on the wholesale price at a particular percentage rate. As noted, there is no wholesale price for road use and so a proxy must be used. Road transport prices were used in this study. Given that in most cases road transport is sold on a basis such as tonne-kilometre or passenger-trip, the prices of these were used. It does not matter what units of output are used provided the price is then multiplied by the annual output. Thus, for trucks, an average freight rate per tonne-kilometre was used as the price. A different price was used for large and for small trucks. For buses, an average price per passenger-kilometre was used. For cars, the unit of price used was an estimate of the variable cost to the owner of driving for one kilometre.

For the purpose of the Ramsey pricing allocation, road users were divided into five vehicle categories. These were:

- articulated trucks
- rigid trucks
- long-distance buses
- cars for business purposes (including travel to work)
- cars for domestic and leisure purposes.

Market segmentation on alternative bases to vehicle categories could also be considered. For instance, allocations could be among those groups of vehicles: travelling in different areas, say, city and rural areas; travelling on different roads; or travelling at different times. In order to differentiate markets in this way, it is necessary not only to identify the respective road users but to establish their demand patterns including the road prices they face and the respective price elasticities of demand. Focusing on five road user groups is a simplification of what could be quite a detailed disaggregation.

Ramsey pricing could also be undertaken as a two-part pricing scheme involving a fixed and a variable component. This would be in addition to the price based on short-run marginal (avoidable) cost. The reason for this is that the road use decision essentially involves two parts. First, there is a decision on whether or not to 'enter' the system. The price that is currently charged for this, apart from the private costs, is essentially the price of registering a vehicle. The second decision concerns the level of use of the system. Current government charges varying with use include fuel excise, fuel franchise fees and the variable tolls and charges.

In allocating costs using a two-part avoidable cost Ramsey pricing scheme, the two aspects of the road use decision are treated separately. Two-part Ramsey pricing minimises the 'distortion' to vehicle registration decisions and to road use decisions, which occurs from charging a price which differs from short-run marginal cost. For a small increment to price, the minimum distortion is where, at the higher price, for each of the user categories considered, the ratio of registrations to road use remains the same. For large adjustments, prices need to be structured so as to result in as small a decline in both usage and vehicle registrations as possible. A balance may need to be struck and the calculations of the appropriate charge may be quite complex.

Due to the difficulty in establishing prices and relevant elasticities in the detail required, only a single-part Ramsey pricing allocation is undertaken here.

Elasticity values

Although the elasticities of demand may vary greatly from user to user within each category, to further segment road use and identify the appropriate weighted-average elasticities is complex. A five-part segregation was adopted as a reasonable compromise.

Even with only five vehicle categories, it is impossible to precisely identify weighted-average price elasticities of demand for road use. Instead, the approach used was to identify a range of elasticity values for each of the five user types. The ranges were relatively small and all vehicle groups are assumed to be on average fairly inelastic in their demand for road use. What is more important for the Ramsey pricing allocation is the relative price-elasticity ratios for the five different vehicle groups. If it can be said with certainty that one group has the least elastic demand at a given price, then allocating this group a slightly greater price than for other groups, will cause less distortion to market activity than if prices were set at the same amount above each group's short-run marginal cost. Further refinements to demand-based pricing can be made as more information becomes available.

Information deficiencies concerning elasticities can be reduced over time as responses to price changes are monitored. A process of price searching is common in the private and public sectors. A similar exercise could be tried with road pricing.

The elasticities used in the allocations are shown in Table 7.1. The mid-range elasticities are short-run estimates which are based on a range of studies, particularly the TEC (1981) study. While certainly not ideal, they are all that is currently available. The values shown should be regarded as indicative of the range of price elasticities of demand for road use, and not estimates of the absolute values. The range shown is roughly from 50 per cent of the mid-range value to 50 per cent above.

The results of the analysis based on these elasticity figures should, in turn, be regarded as indicative only. Much more information is needed about the demand patterns, and thus the elasticities, of different road users, before much confidence can be placed in the accuracy of Ramsey pricing allocations.

Prices

As k is set according to the recovery target, the only additional information required is Po_i, the original price of road use i at which the elasticities apply. As noted earlier, average freight rates and coach fares were used as the bases of truck and bus prices. The relative transport prices in 1986-87 for the five types of activity identified are also shown in Table 7.1.

The representative price used for heavy freight vehicles is based on a broad weighted average of Australian Road Transport Federation (ARTF) rates. The representative price for long-distance buses is based on the lowest Melbourne-Sydney rate and, although prices on all routes vary considerably, most journeys are priced near this level.

Use of cars, for a given level of vehicle ownership, is mainly priced through fuel costs. The fuel price in 1986-87 was taken as 56 cents per litre. Given an average fuel consumption of 0.125 litres per

TABLE 7.1 PRICES AND ELASTICITY VALUES USED IN ALLOCATION OF EXPENDITURE ABOVE AVOIDABLE COST

User category	Prices at which elasticity values apply	Elasticity values: Least elastic	Mid-range	Most elastic
Heavy freight vehicles[a]	5c/Tkm[b]	-0.06	-0.12	-0.18
Light freight vehicles	20c/Tkm	-0.07	-0.15	-0.23
Long-distance buses	4c/pax-km[c]	-0.10	-0.18	-0.26
Cars, business use	7c/km	-0.06	-0.13	-0.20
Cars, domestic use	7c/km	-0.08	-0.19	-0.30

a. All articulated trucks.
b. Tonne-kilometre.
c. Passenger-kilometre.

Source BTCE estimates.

kilometre (ABS 1987, Table 22), the representative price of using a car is about 7 cents per kilometre. It should be noted that there are other relevant running costs not included in this price.

Some initial results showed that the allocation of costs above avoidable cost was not very sensitive to changes in the representative price. The main controlling variable is the elasticity value used. This is evidently due to the higher order of magnitude of the numerator (price) relative to the denominator (elasticity) in the Ramsey pricing formula.

Ramsey pricing allocations

With five road user groups identified, each with three elasticity values representing points on a range of possible demand elasticity values, there are 243 (that is, three to the fifth power) sets of Ramsey allocations that can be made. These in turn represent an infinite range of sets of Ramsey allocations. Such a range simply reflects the range of elasticity values assumed.

After establishing the respective values of k required to achieve the recovery target, the resulting sets of prices and allocations were determined.

The range of allocations and respective prices are presented in Table 7.2. The three intermediate sets represent Ramsey allocations (and prices) when, for all five types of road use, demand is the most elastic expected, the least elastic expected, or the mid-range expected value. The Ramsey allocation (and respective price) will be lowest for each user category when its value of elasticity of demand is the highest expected, while for each of the other categories demand is the most inelastic that would be expected. Conversely, the allocation will be highest for a particular user group when its value of elasticity of demand is the lowest expected, while for each other category demand is the most elastic that would be expected.

The range between highest and lowest allocation for each category is extensive because of the range of elasticity values used. What should be noted about the Ramsey allocation is that where the ranking of road user groups by elasticity to price ratio is maintained, the Ramsey allocation (per unit output) follows the same ranking and is maintained. Even if the elasticities are not known with certainty, if groups can at least be ranked according to price:elasticity ratios, then it can be shown that allocating at least slightly more costs per unit of output to the group with the most inelastic demand is likely to achieve a more efficient distribution than some other allocation, provided the same prices and elasticity values apply fairly widely within each group. More refinement of groups of users may need to be identified to ensure charges are based as close as possible on elasticities of demand, particularly if the elasticities varied widely within each group identified.

Fully allocated expenditure

Table 7.3 shows fully allocated road expenditure outcomes for the financial year 1986-87. The avoidable cost/expenditure attribution is that made in Chapter 6. The Ramsey allocation of expenditure above avoidable cost is based on the mid-range elasticity value for each user group. There are numerous other possible allocations depending on the assumptions of price elasticity of demand. The allocation set chosen gives only one possible interpretation. However, if the ranking of groups according to price:elasticity ratios is as implied in Table 7.1, then other possible Ramsey allocations will still achieve virtually the same proportional distribution among user groups.

TABLE 7.2 RANGES OF POSSIBLE RAMSEY PRICES AND ALLOCATIONS, 1986-87

Vehicle type	Lowest[a]	*Intermediate* All groups lowest E	*Intermediate* All groups mid-range E	*Intermediate* All groups highest E	Highest[b]
Heavy freight vehicles					
Price (cents per Tkm)	0.31	0.79	0.86	0.89	1.79
Allocation ($m)	185	473	516	530	1 072
Light freight vehicles					
Price (cents per Tkm)	0.92	2.71	2.76	2.77	6.75
Allocation ($m)	112	329	335	337	1 819
Long-distance buses					
Price (cents per passenger-km)	0.42	0.38	0.46	0.49	1.27
Allocation ($m)	3	8	10	11	28
Cars, business					
Price (cents per km)	0.43	1.11	1.12	1.12	2.11
Allocation ($m)	275	711	715	715	1 357
Cars, domestic					
Price (cents per km)	0.29	0.83	0.76	0.74	1.59
Allocation ($m)	234	678	623	607	1 294

a. Calculations are based on the assumption that the price elasticity of demand for the vehicle class in question is the lowest value in Table 7.1 with the elasticities for all other vehicle classes the highest value in the table. More detail on the formulas used and the calculations is contained in BTE (1985a).
b. The reverse of note 'a' applies in this column.

Source BTCE estimates.

TABLE 7.3 FULLY ALLOCATED ARTERIAL ROAD EXPENDITURE, 1986-87

Vehicle type	*Avoidable cost/ expenditure ($m)*	*Ramsey allocation*[a] *($m)*	*Fully allocated road expenditure ($m)*	*Fully allocated road expenditure ($ per vehicle)*
Cars				
Business	3	715	718	157
Private	4	623	626	
Rigid trucks				
2 axles	181	269	450	1 178
3 axles	176	36	212	4 698
> 3 axles	177	30	207	9 648
Articulated trucks				
< 5 axles	120	31	152	10 376
5 axles	225	61	287	24 789
6 axles	916	339	1 255	48 279
> 6 axles	184	85	269	110 147
Long-distance buses	15	10	25	83 109
Total	2 000	2 200	4 200	..

a. Assuming all user groups have intermediate demand elasticity values.
.. Not applicable.

Note Owing to rounding, figures may not add to totals.

Source BTCE estimates based on Tables 6.2, and 7.2.

Vehicle cost recovery

Recovery payments totalled about $7130 million in 1986-87. This estimate is based on the second definition in Table 5.5. A comparison of the fully allocated expenditure and the revenue from road-use charges is presented in Table 7.4.

TABLE 7.4 COMPARISON OF FULLY ALLOCATED ROAD EXPENDITURE AND COST RECOVERY CONTRIBUTIONS, 1986-87

	Fully allocated expenditure		*Cost recovery contributions*		*Over or under recovery*	
Vehicle type	*($m)*	*($/veh)*	*($m)*	*($/veh)*	*($m)*	*($/veh)*
Cars						
Business	718	187	2 558	669	1 840	480
Private	626	133	3 223	662	2 596	533
Total	1 344	157	5 781	665	4 437	508
Rigid trucks						
2 axles	450	1 178	454	1 190	4	11
3 axles	212	4 698	120	2 657	-92	-2 033
> 3 axles	207	9 648	84	3 929	-122	-5 704
Articulated trucks						
< 5 axles	152	10 376	85	5 793	-68	-4 620
5 axles	287	24 788	108	9 316	-179	-15 497
6 axles	1 255	48 279	427	16 440	-828	-31 865
> 6 axles	269	110 147	60	24 789	-208	-85 229
Long-distance buses	25	83 109	9	29 720	-16	-53 776
Total	4 200	..	7 128	..	2 928	..

.. Not applicable.

Note Owing to rounding, figures may not add to totals.

Source BTCE estimates based on Table 5.6 and Table 7.3.

Only cars, both for business and domestic use, and the smallest rigid trucks are shown to be recovering their share of fully allocated road expenditure. The largest trucks contribute about $30 000 per vehicle less than their share of fully allocated road expenditure, while for long-distance buses the shortfall is in the order of $54 000 per vehicle. The results may vary, of course, depending on the relative prices and elasticities used in the allocation formula. The allocations do not change significantly, however, if the relative price:elasticity ratios are similar to those assumed in Table 7.1.

The figures suggest that motor cars are over-recovering their share of fully allocated road expenditure.

ALLOCATION OF COSTS AMONG VEHICLE TYPES USING COST-OCCASIONED METHODOLOGY

In this section, an alternative to the avoidable cost plus Ramsey pricing approach is presented, following on the equity-based approach used in the United States cost allocation study (US FHA 1982). The allocation of costs among vehicle types attempted here, using the cost-occasioned methodology, is far simpler than that undertaken in the United States study. However, it does illustrate how a more detailed study could be undertaken. At various stages, comments are made on how the analysis could be improved.

As with the efficiency approach, this approach will be based on recovery of total road construction and maintenance expenditure in 1986-87. However, because the essence of the cost-occasioned approach is to allocate different elements of road expenditure according to cost responsibility, a greater level of disaggregation of expenditure is required. Information is required on each cost item and by road type since different attributes of different road types (for example, average strength of pavement) will produce different relative cost responsibilities. In addition, each expenditure item represents a different share of total expenditure for each road type.

This level of detail was not so necessary in the efficiency approach since avoidable cost was allocated by only one method (that is, by ESAL kilometres). However, to be more precise, the efficiency approach should also be further refined by disaggregating costs and allocating each cost item making up total avoidable cost/expenditure by a separate allocation formula (for example, ESAL kilometres for pavements, gross vehicle mass and axle spacing for bridges) as will be undertaken below. The difference in final outcome is not large since bridge repair costs are small compared with pavement restoration costs. With more information, gained through engineering research, the methodology could be refined. For example, as noted in Chapter 4, the United States study adopted different relationships from the fourth power rule for different manifestations of pavement damage such as various forms of pavement cracking. The overall results were, however, little different from those using the fourth power rule.

Road expenditure items

The first step was to divide total road expenditure into smaller items reflecting the broad categories of road expenditure. In this exercise the emphasis was on identifying those elements making up the total of avoidable cost/expenditure, as well as identifying groups of items for which vehicle cost responsibility would need to be calculated on clearly differing bases. In the United States study the broad categories were:

- new pavements
- rehabilitated pavements
- structures
- grading
- miscellaneous.

These were further divided into more elements. The NCA study used the broad NAASRA classifications:

- new works
- duplication
- reconstruction
- new seal
- new gravel form
- new bridges
- resurfacing
- road maintenance
- bridge maintenance.

The approach adopted for this analysis took account of both of these, plus availability of data and, mcre importantly, the need to distinguish short-run avoidable cost from other costs. The categories adopted were:

- new pavements and duplication
- the upgrading element of reconstruction
- new bridge construction
- the restoration element of reconstruction
- resurfacing and resealing
- bridge reconstruction
- traffic-related element of routine maintenance

- bridge maintenance
- common element of routine maintenance
- administration.

The first three items are long-run costs, the next five represent total short-run avoidable cost and the last two residual, common or joint costs.

The classification corresponds broadly to the NAASRA classification and essentially only differs from the United States classification by not containing a specific item relating to geometric costs (for example, road or lane widths and steepness of grades) for which little information is available for Australia.

Allocation of road expenditure among road categories and vehicle types

The next step involved allocating current road expenditure among these items for each road category. This is shown in Table 7.5. This relied chiefly on the BTE's 1984 Road Study (BTE 1984), the TAROR report (NAASRA 1987) and advice from local government engineers and State road authority engineers. For national roads and rural arterial roads, this information was supplemented by data contained in the Bureau's database developed (from the NAASRA data bank and other sources) for the Bureau's 1987 road study. However, this is an area which requires further research, particularly over controversial issues such as the percentage of routine maintenance caused entirely by weather or other climatic conditions. For this item, the NCA, Travers Morgan and United Kingdom studies all adopted the argument that if, for example, trucks were removed from the road system, the level of routine maintenance would not fall dramatically. Thus, the NCA study, for instance, allocated only 15 per cent of routine maintenance to trucks.

The United States study adopted a different argument. It argued that if a heavy vehicle is driven on a road made more susceptible to damage by weather or other environmental effects, the operator is fully responsible for the damage: the damage only occurs because he chooses to use the road (US DoT 1982, E-22). The United States' study only allocates as residual costs those costs that are truly independent of traffic (for example, traffic signal operating costs, median strip mowing costs, etc). In the United States' study, the item 'rehabilitated pavement', which includes routine maintenance, was allocated 94.9 per cent to vehicles according to engineering relationships and only 5.1 per cent allocated as a residual. However, as was noted in Chapter 4, the damage relationships in the United

TABLE 7.5 ROAD EXPENDITURE IN AUSTRALIA, BY ROAD CATEGORY AND EXPENDITURE ITEM, 1986-87

($ million)

Expenditure item	*National roads*	*Urban arterial roads*	*Rural arterial roads*	*Urban local roads*	*Rural local roads*	*All roads*	
New construction and duplication	87	264	53	26	41	471	
	(15)	(31)	(6)	(3)	(4)		
Upgrading element of reconstruction	81	111	107	255	268	821	(36)
	(14)	(13)	(12)	(30)	(26)		
New bridges	58	26	62	26	31	202	
	(10)	(3)	(7)	(3)	(3)		
Restoration element of reconstruction	145	43	160	128	124	599	
	(25)	(5)	(18)	(15)	(12)		
Bridge reconstruction	6	26	18	26	31	106	
	(1)	(3)	(2)	(3)	(3)		
Pavement resealing or resurfacing	35	51	107	119	113	425	(44)
	(6)	(6)	(12)	(14)	(11)		
Traffic element of routine maintenance	41	119	134	119	196	608	
	(7)	(14)	(15)	(14)	(19)		
Bridge maintenance	12	26	27	26	31	120	
	(2)	(3)	(3)	(3)	(3)		
Common element of routine maintenance	29	60	89	128	196	501	
	(5)	(7)	(10)	(15)	(19)	(12)	
Administration	87	128	134	..	..	348	
	(15)	(15)	(15)			(8)	
Total	580	850	890	850	1 030	4 200	
	(100)	(100)	(100)	(100)	(100)	(100)	

.. Not applicable.

Note Figures in parenthesis are percentages.

Source BTCE estimates.

TABLE 7.6 BASIS OF ALLOCATION OF ROAD EXPENDITURE ITEMS AMONG VEHICLE TYPES, BY ROAD CATEGORY, 1986-87
(per cent)

	Allocation method											
	National roads				*Rural arterials*				*Urban arterials*			
Expenditure item	*ESAL km*	*VKT*	*VKT★PCU*	*VKT★GVM*	*ESAL km*	*VKT*	*VKT★PCU*	*VKT★GVM*	*ESAL km*	*VKT*	*VKT★PCU*	*VKT★GVM*
New construction and duplication	..	30	70	..	..	20	80	..	..	50	50	..
Upgrading element of reconstruction	60	20	20	..	60	20	20	..	60	20	20	..
New bridges	..	40	30	30	..	40	30	30	..	40	30	30
Restoration element of reconstruction	100	..	..	..	100	..	..	..	100	..	..	..
Bridge reconstruction	..	60	20	20	..	60	20	20	..	60	20	20
Resealing or resurfacing	100	..	..	..	100	..	..	..	100	..	..	..
Traffic element of routine maintenance	100	..	..	..	100	..	..	..	100	..	..	..
Bridge maintenance		60	20	20	..	60	20	20	..	60	20	20
Common element of routine maintenance	100	..	..	..	..	100	..	..	..	100	..	..
Administration	100	..	..	..	..	100	..	..	..	100	..	..
					Rural local roads				Urban local roads			
New construction and duplication					..	10	90	..	..	20	80	..
Upgrading element of reconstruction					60	20	20	..	60	20	20	..
New bridges						40	30	30	40	30	30	
Restoration element of reconstruction					100	..	..	..	100	..	..	..
Bridge reconstruction					..	60	20	20	..	60	20	20
Resealing or resurfacing					100	..	..	..	100	..	..	..
Traffic element of routine maintenance					100	..	..	..	100	..	..	..
Bridge maintenance					..	60	20	20	..	60	20	20
Common element of routine maintenance					..	100	..	..	..	100	..	..
Administration					..	100	..	..	..	100	..	..

VKT★PCU = VKT weighted by passenger car units (1 for cars, 1½ for light rigid trucks, 2 for heavy rigid and articulated trucks).
VKT★GVM = VKT weighted by GVM but only for articulated trucks and rigid trucks with GVM of at least 2½ tonnes.
.. Not applicable.
Source BTCE estimates.

States study took account of the interaction of vehicle traffic and weather. A fourth power rule was not adopted in all cases. Nevertheless, as noted earlier, provided that on average the power is at least two, trucks will be allocated most of the rehabilitation costs.

The approach adopted here, as in Chapter 5, was to allocate about one-third of routine maintenance as a common or joint cost due solely to weather. This is somewhat higher than the United States allocation because it was felt that for local roads in Australia the residual cost element could be fairly high. The residual share adopted for local roads was about 50 per cent compared with 16 per cent for arterial roads.

It should be noted that administration costs for local roads are shown as zero. This is because administration expenditure is shown separately for local government in BTE (1987a) and is not included in the road expenditure figures. Their inclusion does not affect significantly the final allocation of costs/expenditure to each vehicle type.

The next step was the allocation of the various costs among vehicle classes. This is shown in Table 7.6. It involved some element of judgement and is an area where much more research is needed.

New pavements

The allocation of the first two items of roadworks, namely new pavements or upgrading of pavements, among vehicle types, was based on United States results, which were in turn based on the uniform removal-incremental method. The United States study found that overall 34.6 per cent of new pavement costs could be considered common and the balance attributed to vehicles.

The allocation of attributable costs among vehicle classes was performed by hypothetically and uniformly removing vehicle classes and calculating costs saved using design equations incorporated in the EAROMAR-2 computer simulation model. In many States of the United States these attributable costs are allocated on the basis of ESALs and in fact, the United States approach basically comes down to this. This is both simpler and intuitively easy to understand when one notes that road pavements are designed for a given number of ESAL passes.

While the use of ESALs to allocate the attributable element of new pavement costs is not thought likely to produce results that differ significantly from the United States allocation, there is another factor on which there has been a great deal of disagreement. This is whether distance should be included as a factor.

The European Economic Community guidelines allocate all fixed costs without taking distance travelled into account. Other factors such as mass and axle configuration (a proxy for ESALs) are used in part, but they are weighted by vehicle numbers, not distance travelled. The ISC (1986, 501) notes that the New Zealand Working Party formed to review charges endorsed this approach, but in the final decision a distance weighting was incorporated in the calculations of appropriate charges.

The argument would seem to turn on whether a vehicle travelling many times over a given road should pay a greater share of fixed costs than if it travelled only once over the road. Would an appropriate charge be a usage charge or an entry fee?

It was noted in the previous section that Ramsey pricing should take both aspects into account - the number of entrants into the system and the total level of road usage. The cost-occasioned approach methodology is not, however, sufficiently rigorous or precisely defined to answer the question unambiguously. This is a problem with all equity-based methods: they involve a large element of judgement.

The approach adopted in this study was to include distance, and thus the factor used to allocate attributable costs for upgrading was ESAL kilometres. The remainder in each case was treated as a residual and allocated by VKT. A distance factor was included on the basis of the following argument. When the design for all roads is taken into account, in total for Australia, the total level of ESAL kilometres is what is important, not whether a few vehicles pass over the road system many times, or many vehicles only a few times. If all vehicles were to use a given road twice as often, it would need to be designed to a higher standard (that is, for twice as many ESAL passes).

Part of the problem is one of timing. The PAYGO approach looks only at one year's traffic, whereas the roads in the system are of various ages and were designed for various lifetimes. As noted in Chapter 2, it is preferable to use life-cycle analysis rather than the PAYGO approach and allocate costs rather than expenditure.

The problem becomes a little further complicated when residual costs are considered. The United States' study allocated these costs by vehicle-miles travelled. Other studies have used distance travelled but some have weighted this by passenger car equivalent units (PCUs). The NCA study used four different methods. The use of distance for residual costs is even further open to debate than is its use for attributable cost. It seems truly arbitrary what method is used. The approach adopted here is to use VKT.

One final point worth noting in relation to new pavement costs is that other methodologies considered by the United States' study team allocated an even greater share of costs to heavy trucks than the approach finally adopted. One alternative approach, based more fully on the road test equations calculated in American Association of State Highway Officials (AASHO) studies would have allocated considerably more costs to the heaviest articulated and rigid trucks.

New bridges
For new bridge construction it was considered that gross vehicle mass multiplied by distance travelled was a more appropriate allocation procedure than ESALs since damage to bridges is in part based on expected loads, irrespective of the number of axles. The key factor in bridge design is the total load on the bridge and where it occurs relative to the centre of the bridge span. Thus, gross mass and the spacing of axles (or more correctly the largest expected axle load spacing combinations or bending moments), are the important variables to consider, not ESALs.

The United States' study adopted a modified version of the uniform removal - incremental method used for pavements. The approach assigned gross vehicle mass key significance. Vehicles with gross mass less than 2.5 tonnes are largely ignored and vehicles above 15 tonnes are divided into further categories to assess more carefully the influence of heavier vehicles. The study found that 65 to 91 per cent of new bridge costs did not vary with vehicle mass but that the heaviest vehicles were responsible for a significant share of those that did. Counting both attributable and the allocated share of residual costs, vehicles over 37.5 tonnes were attributed 5 units of cost per vehicle-mile travelled compared with 0.67 units for small cars. Trucks in total were allocated 35 per cent of total bridge costs. Trucks plus pick-ups and vans were allocated 52 per cent of total costs and cars, 46 per cent, with the balance allocated to motor cycles and buses.

The approach adopted in the present study allocates 30 per cent of bridge costs by VKT weighted by gross vehicle mass for vehicles with a GVM above 2.5 tonnes. This would include all articulated trucks and rigid trucks with three or more axles. The average GVM for two axle rigid trucks is 6.18 tonnes and it was assumed that 80 per cent had a GVM of at least 2.5 tonnes. All cars were ignored in this calculation. This figure of 30 per cent of bridge costs was chosen on the basis that about 30 per cent of new bridge costs were allocated to trucks in the United States study, as was noted in Chapter 4. The remaining 70 per cent of new bridge costs were allocated 40 per cent by VKT and 30 per cent by VKT weighted by passenger car units, thus largely falling on cars. The latter weighting was to account mainly for the width of bridges. Here again more research is needed to refine this procedure.

The allocation of bridge costs resulted in trucks being assigned about 38 per cent and cars about 63 of total new bridge costs. These results are close to those obtained in the United States study. In contrast, the NCA study allocated about a quarter of new bridge costs to trucks.

A similar debate to that for new pavements concerning the use of distance travelled can be mounted for new bridges. The differences in final outcomes of the two approaches are significant. Vehicles that travel more than the average distance for vehicles included in the allocation (that is those over 2.5 tonnes GVM), would be allocated less if a distance factor was included. A sensitivity analysis showed that if distance was removed from the allocation factor for both new pavements and new bridges, the final allocation of cost to the average six axle articulated truck would be about $9000 less per annum ($230 million less for 26 000 vehicles).

Restoration expenditure

In the United States' study, pavement restoration costs were allocated using road damage relationships which took account of the interaction of the environment with vehicles. The result was that cars were allocated only 15 per cent of pavement restoration costs. In the alternative efficiency approach a single relationship was used based on ESAL kms. No doubt this would have allocated even less to cars if adopted in practice.

The approach adopted in this study was to allocate all reconstruction and resealing costs by ESAL kilometres but to separate from traffic-related routine maintenance an estimate of routine maintenance costs due wholly to the environment or which was common to all vehicles (for example, operating costs of traffic lights). This is in line with the method advocated by Fwa and Sinha (1986). Traffic-related costs, which represented 66 per cent of total routine maintenance, were allocated by ESAL kilometres and the balance of routine maintenance by VKT, as for other residual costs which were classified as administration costs.

Bridge repair costs were treated as a residual cost in the United States study on the basis that no strong relationships with traffic could be found. In earlier United States studies the incremental method was used which assigned a greater share of costs to heavy vehicles. The method adopted in this study was basically to use VKT but to weight this partly by PCU (20 per cent) and GVM (20 per cent). Overall trucks are allocated about 25 per cent of bridge reconstruction and maintenance costs. This is a little lower than that in the NCA study.

Residual costs, as noted earlier, are allocated by Vkt. The United States' study used this method but the NCA study divided residual costs into common and joint costs, the former being allocated by VKT weighted by PCUs. Joint costs were allocated in that study by four different allocation methods as noted earlier.

Results

Table 7.7 shows the details of characteristics for each vehicle type for each of the four allocation measures and how these were derived from raw data. Data on VKT was derived from the 1984-85 ABS SMVU but was updated to 1986-87. The PCUs per vehicle were those used in the NCA study and are in line with those adopted in the United States' study. Average gross vehicle mass for each vehicle type was obtained from the SMVU. Average ESALs for each vehicle type were obtained from the RoRVL mass and dimension survey conducted for the RoRVL study. Averages for each State were weighted by VKT in each State to obtain an Australian average for each vehicle type.

One modification was, however, made to the RoRVL results. In the case of two-axle rigid trucks, the RoRVL survey only covered vehicles with dual rear tyres. This was thought likely to result in an overestimate of average ESALs for this vehicle class since a large proportion of these vehicles have only single rear tyres. This was confirmed by calculating average ESALs from SMVU figures on average loads and tare masses. Accordingly, average ESALs for this vehicle class were reduced from 0.39 to 0.20.

The results of the analysis are presented in Table 7.8. The table indicates the share of total road expenditure distributed by each allocation method and shows the total attribution to each vehicle class and per vehicle in each class. While the final results are essentially indicative, further refinement would require a much more detailed study than attempted here.

Allocation of costs by both vehicle type and road category

As with the allocation of avoidable cost in Chapter 6, costs under the equity approach should ideally be allocated by both vehicle type and road category, that is, by taking into account vehicle travel on particular road types. In Table 7.9, alternative estimates of average

TABLE 7.7 ESTIMATED VEHICLE CHARACTERISTICS, 1986-87

Vehicle type	*VKT (million km)*	*Average ESALs per vehicle*	*PCUs per vehicle*	*GVM (tonnes) per vehicle*	*ESAL kms (million)*	*PCU*VKT (million)*	*GVM*VKT (million)*
Cars	145 763	0.0003	1	1.33	43.7	145 763.0	193 864.8
Rigid trucks							
2 axles	6 007	0.20	1.5	5.00	1 201.4	9 010.5	30 035.0
3 axles	958	1.37	1.5	14.00	1 312.5	1 437.0	13 412.0
> 3 axles	610	2.04	1.5	19.30	1 244.4	915.0	11 773.0
Articulated trucks							
< 4 axles	514	1.62	2	20.24	832.7	1 028.0	10 403.4
5 axles	633	2.40	2	26.54	1 519.2	1 266.0	16 799.8
6 axles	2 604	2.38	2	29.10	6 197.5	5 208.0	75 776.4
> 6 axles	287	4.27	2	41.70	1 225.5	574.0	11 967.9
Long-distance buses	80	1.31	2	15.25	104.8	160.0	122.0
Total	157 456	..	..	..	13 681.7	165 361.5	365 252.3

.. Not applicable.

Source ABS (1987). ISC (1986). NAASRA (1986).

TABLE 7.8 ALLOCATION OF TOTAL ROAD EXPENDITURE IN AUSTRALIA, BY VEHICLE TYPE, USING A COST-OCCASIONED METHODOLOGY, 1986-87

($ million)

	Share of total expenditure allocated by					*Number of vehicles*	*Cost per vehicle*
Vehicle type	*VKT*	*ESAL kms*	*PCU*VKT*	*GVM*VKT*[a]	*Total*	*('000)*	*(dollars)*
Cars	1 409.1	7.4	238.1	0.0	1 654.5	8 695.6	190
Rigid trucks							
2 axles	58.1	202.1	14.7	18.5	293.5	381.7	769
3 axles	9.3	220.8	2.3	8.3	240.7	45.1	5 337
> 3 axles	5.9	209.4	1.5	7.3	224.0	21.5	10 420
Articulated trucks							
< 5 axles	5.0	140.1	1.7	6.4	153.2	14.6	10 491
5 axles	6.1	255.6	2.1	10.4	274.3	11.6	23 636
6 axles	25.2	1 042.8	8.5	46.8	1 123.2	26.0	43 201
> 6 axles	2.8	206.2	0.9	7.4	217.3	2.4	89 056
Long-distance buses	0.8	17.6	0.3	0.8	19.4	0.3	64 737
Total	1 522.1	2 302.0	270.1	105.8	4 200.0	9 198.8	..

a. Allocation by GVM*VKT carried out only for vehicles greater than 2.5 tonnes GVM (see text).
.. Not applicable.

Source BTCE estimates.

avoidable cost per vehicle are presented, based on the NCA estimates of vehicle travel on arterial and local roads plus an alternative set of travel estimates in line with Table 6.3. As with Table 6.3, the results are little different from the base case where travel is, by implication, assumed to be in proportion to costs for arterial and local roads. Again it should be stressed that the travel estimates are little more than guesswork.

TABLE 7.9 COMPARATIVE ALLOCATIONS OF TOTAL ROAD EXPENDITURE (COST-OCCASIONED APPROACH) FOR EACH VEHICLE TYPE BASED ON ASSUMPTIONS CONCERNING VEHICLE TRAVEL BY ROAD CATEGORY, 1986-87

		NCA traffic estimates		*Alternative estimates*	
Vehicle type	*Base case[a] allocation per vehicle ($)*	*Travel on arterial roads (per cent)*	*Allocation per vehicle ($)*	*Travel on arterial roads (per cent)*	*Allocation per vehicle ($)*
Cars	190	65	192	65	194
Rigid trucks					
2 axles	469	70	1 217	70	866
3 axles	5 337	80	7 311	70	6 465
> 3 axles	10 420	93	9 000	80	10 687
Articulated trucks					
< 5 axles	10 491	93	9 065	85	9 743
5 axles	23 636	93	20 406	85	21 973
6 axles	43 201	93	37 302	85	40 165
> 6 axles	89 065	93	76 833	85	82 873
Long-distance buses	64 737	93	55 952	85	60 066

a. All vehicles assumed to travel on arterial and local roads in proportion to costs on these roads (arterial 55 per cent: local 45 per cent).

Source BTCE estimates.

COMPARISON OF THE RESULTS OF THE AVOIDABLE COST/RAMSEY PRICING APPROACH AND THE COST-OCCASIONED APPROACH

Table 7.10 summarises the results of each of the two approaches outlined in this Chapter in their allocation of total road expenditure among the various vehicle types.

The most interesting feature of Table 7.10 is the similarity of results between the two approaches. While the efficiency-oriented approach assigned a large share of expenditure above avoidable cost/expenditure to trucks on the basis of value of freight carried, the cost-occasioned approach assigns a large share of construction and upgrading expenditure to trucks because of their requirement for stronger roads and bridges. Both approaches assign almost all road damage costs to trucks.

TABLE 7.10 COMPARISON OF ALLOCATION OF ROAD EXPENDITURE AMONG VEHICLE TYPES USING THE AVOIDABLE COST/RAMSEY PRICING APPROACH AND THE COST-OCCASIONED APPROACH, 1986-87

($ per vehicle)

	Allocation of total road expenditure using	
Vehicle type	*Avoidable cost/ Ramsey pricing approach*	*Cost-occasioned approach*
Cars	157	190
Rigid trucks		
2 axles	1 178	769
3 axles	4 698	5 337
> 3 axles	9 648	10 420
Articulated trucks		
< 5 axles	10 376	10 491
5 axles	24 788	23 636
6 axles	48 279	43 201
> 6 axles	110 147	89 056
Long distance buses	83 109	64 737

Source BTCE estimates.

Again it should be stressed that caution should be exercised in the use of these figures. They are averages for each vehicle type over all road categories. The cost allocated to each venicle type would vary greatly with distance travelled, particular loads carried, category of road used and even different road types and designs within each road category.

CHAPTER 8 IMPLEMENTATION OF MORE EFFICIENT ROAD PRICING

This chapter discusses some of the practical aspects of implementing a more efficient road pricing system. It considers the feasibility of implementing a more efficient system of road pricing, both practical considerations and social, political and constitutional constraints.

A proposed three-part pricing system, which takes these issues into account is outlined. In doing this, the chapter draws together the theoretical outlines of road cost recovery and road pricing discussed in Chapter 2. The findings from, and comments on, the various studies reviewed in Chapters 3 and 4, and the results of the cost recovery analyses undertaken in Chapters 5, 6 and 7, are used to discuss some of the implications of efficient road pricing in Australia.

The question of the feasibility of proposed changes influences the question of whether it is worthwhile to adjust the road pricing. The costs and benefits of the required adjustments are outlined, although this requires an assessment of the economic loss which results from the current arrangements.

Some broader concerns about the distribution of economic gains and losses and changed road funding responsibilities are also discussed.

FEASIBILITY OF MORE EFFICIENT ROAD PRICING

Although the need for a more efficient set of charges has already been argued, it is also necessary to show whether such charges could be implemented in practice.

This section outlines the practical requirements of more efficient road user charges and discusses the technical, social (and political), legal and financial constraints to such a pricing system and to full road cost recovery. In summary, the points covered are:

- an outline of the required structure of charges;
- the technical practicability of implementing more efficient charges;

- a proposed three-part pricing system;
- implementation approach in the face of political and social (and constitutional) constraints;
- implications for road freight rates; and
- uniform national charges.

Required structure of charges

The pricing theory outlined in Chapter 2 has essentially two components. The first is that to improve economic efficiency, both the structure and level of charges should be related to short-run marginal cost. The second feature required for efficiency is that, where there is a requirement for full annual expenditure recovery, and this is not able to be achieved by short-run marginal cost pricing (perhaps including a congestion charge), any additions to price should be set so as to cause the least distortion to market activity.

In addition to the two aspects of the efficiency criteria for optimal prices, there are two other criteria which are sometimes overlooked in economic studies. These are administrative simplicity and equity. These three criteria are discussed in detail below.

Structure of cost-based prices
In order for prices to efficiently ration resources, they are required to be direct rather than indirect. A charge for road damage should be clearly perceived as such and not form part of an overall charge for roads (or for general revenue). Road users should be able to perceive that the charges being levied represent the costs of road use and make their road use decisions accordingly. If they are not faced directly with the costs, they may demand excessive use of the road system. This would cause an overuse of road resources.

As discussed in Chapter 2, road damage is a function of several variables. For a particular vehicle using a given pavement, the cost of road damage caused varies with distance travelled (or the number of times a given section is traversed) and with axle loads. For a given vehicle mass, pavement damage will be lower the more axles the vehicle has. Axle loads depend on both the number of axles and gross mass of the truck (and more correctly, the distribution of that mass over the axles). Since gross mass is the sum of tare mass, which is largely fixed, and the load carried, damage to roads can be said to be a function of the load carried for a given truck. As the extent of these variables (type of truck, loads and distance travelled) is within the control of the road user, a pricing, mechanism should take these factors into account. Of all the available forms of road pricing a mass-distance charge is the most appropriate for recovering road damage costs, provided that it is appropriately structured for vehicles with different axle configurations. In the longer term, this may affect the choice of vehicle, for instance, encouraging operators to use trucks with greater numbers of axles.

Such a strategy presupposes that other decisions made by road users are also based on prices that reflect short-run marginal cost. Many safety devices, such as improved braking systems, adequate suspension systems, underride bars and so on, add to the vehicle's tare weight. Thus, there may be some disincentive to invest in these devices as they reduce the available payload. This is especially the case with irregular entrants to the industry who do not perceive the same cost structure as regular operators. While it is not suggested that a mass-distance charge should be adjusted for vehicles with more or less safety features, it is necessary to ensure that minimum safety standards are adhered to.

Actual road damage, in terms of, say, road roughness and the cost of repairing it, is also likely to be greater, for a given level of traffic, on lower quality pavements. Where road users have a choice about which road to use, they should be encouraged to use the road which involves the least total resource cost. Thus, where possible, the structure of charges should vary with road quality. This might mean that some roads will be less used by heavy vehicles (although other roads will have higher usage) with consequences for further investment in such roads. Where charges accurately reflect the costs caused, this not only encourages the most appropriate use of the existing road system but also, under certain conditions, the most appropriate investment in upgrading the system.

Structure of demand-based prices

As noted in Chapter 2, in the absence of broadly based short-run marginal cost prices including congestion charges and charges to cover other externalities, it is unlikely that the total level of annual road expenditures will be recovered.

Any charges to recover the balance of expenditure will also influence road user demand patterns, no matter what method of recovery is employed. If it is required that such impact on demand be minimised, that is, that the distortion from pricing at other than short-run marginal cost be minimised, then this is achieved in theory by using Ramsey prices. The rationale behind this was discussed in Chapter 2 and the methodology was employed in Chapter 7.

The structure of demand-based prices requires that the overall market for road use be broken down into discrete sub-markets, differentiable on the basis of their demand functions and demand elasticities. The appropriate segregation needs to be investigated in some detail and will evolve over time and with experience. On the basis of the limited evidence available, it appears that business users may be less elastic in their demand than non-business users and that long-distance freight operators are more elastic in their demand for roads than short-distance operators, particularly those in city areas. However, if ever Ramsey pricing were to be applied to road cost recovery, much more research would be needed to establish better estimates of demand elasticities.

The demand-based part of the charge might be levied through both fixed and variable fees, say, an annual registration fee and fuel levies, depending on the relative elasticities of each. There is no necessity, as suggested by Kolsen and Docwra (1987, 69), that 'costs which do not vary with use' should be recovered using a fixed annual charge. A variable charge, smaller but more frequent, may distort demand less than a large fixed charge. The combination of fixed and variable charges which least distorts demand should be employed. This might mean that upgrading and administration costs be recovered partly through registration and partly through fuel excise payments.

Administrative simplicity

Administrative simplicity requires that the pricing system as applied, should not be more trouble than it is worth. From the point of view of the various governments and their road authorities, it should not be too difficult to apply. Also, if the pricing scheme is to be successful, it is necessary that any prices be easily understood, and by and large, be accepted, albeit grudgingly, by road users. The road maintenance charge that applied until June 1979, for instance, eventually became very unpopular as it was costly for operators and governments to collect and because evasion and avoidance were widespread. It was also viewed as unfair as there were many exemptions.

Equity

There is no unique definition of what is equitable. However, the equity criterion is often interpreted by various interest groups to mean that any currently held advantage should not be lost, no matter how inappropriate or inefficient it might be.

Although equity is a matter of judgment, there appears to be a widespread view that neither the horizontal nor vertical equity requirements are violated if all users are required to recover, as a minimum, their avoidable cost, as long as this is the case for all users in each mode. Thus short-run marginal cost pricing can be efficient and still regarded as equitable. It is in the recovery of fixed costs, or rather costs other than short-run marginal cost, that equity and efficiency criteria may produce different results.

Practicability of required structure

The discussion in Chapter 2 suggested that where the PAYGO approach has been set as an overriding constraint, the appropriate form of road pricing system consistent with economic efficiency principles would be a multi-part charge. It would consist of:

- a correctly structured mass-distance charge perhaps forming part of an annual registration fee;
- a fixed charge, also part of an annual registration fee; and
- a variable charge such as a fuel excise fee.

The first component encourages the most efficient use of roads with respect to pavement damage, while the latter two combine to achieve full expenditure recovery without significantly affecting the level of road use achieved by market conditions.

It was argued above that the first part of the charge could be consistent both with economic efficiency and with equity goals. The structure of the latter two parts would depend on which of these two criteria was judged to be more important.

The three-part system should not be unduly complex to administer. The only real difference from current charges lies in the structure of the mass-distance charge. It would require schedules of charges to be established for different vehicle types and the annual reading of hubodometers. However, given that vehicles must in any case be registered each year, the additional administrative cost of a mass-distance charge should be small.

The current system of road-user charges employed in Australia includes fuel excise and fuel franchise fees, vehicle registration fees and an array of minor road-user charges mainly employed in specified local areas.

Fuel excises are charged at a Federal level and most States charge a fuel franchise fee. A share of Federal fuel tax revenues is hypothecated to the financing of road construction and maintenance. One way of restructuring current charges to fit the three part charging system outlined, could include restructuring all fuel taxes to cover new construction or upgrading expenditure rather than funding both construction and maintenance. The Federal excise could be used to fund upgrading that was deemed to be in the national interest. The

State charges could be set and administered by the State authority that has the responsibility for the provision of other roads.

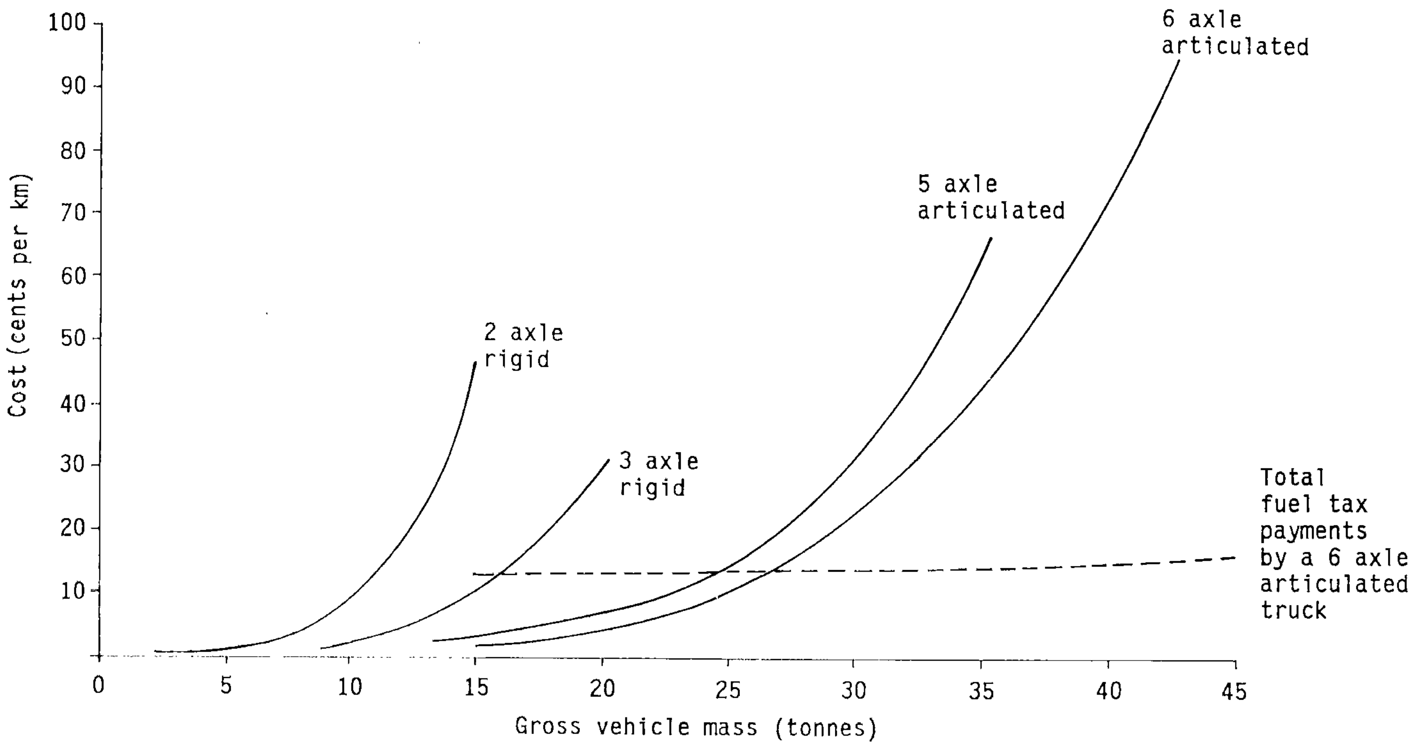
Annual registration fees are also employed by all States to fund the range of road expenditures. These could be restructured to help recover new construction, upgrading and administrative expenditure. They also could be set and administered by the road construction authority in each State.

These two charges, registration fees and fuel taxes, or even annual registration charges alone, could thus be used to recover new construction, upgrading and administrative expenditure and common variable costs, with a mass-distance charge used to recover short-run marginal cost. This would enable a closer connection between charges levied and costs which would be more understandable than the current system. Alternatively, a combination of fuel taxes and a mass-distance charge could be used to recover short-run marginal cost and a combination of fuel excise and registration fees used to recover the balance of annual road expenditure. Under this structure, however, the charge to recover marginal cost is not as closely related to the incidence of these costs.

Both of these alternatives would be practical since they involve little change in the basic charging mechanisms from those used currently, with the exception of the introduction of a mass-distance charge. The main change is to relate fixed charges more to fixed costs and variable charges more to variable costs.

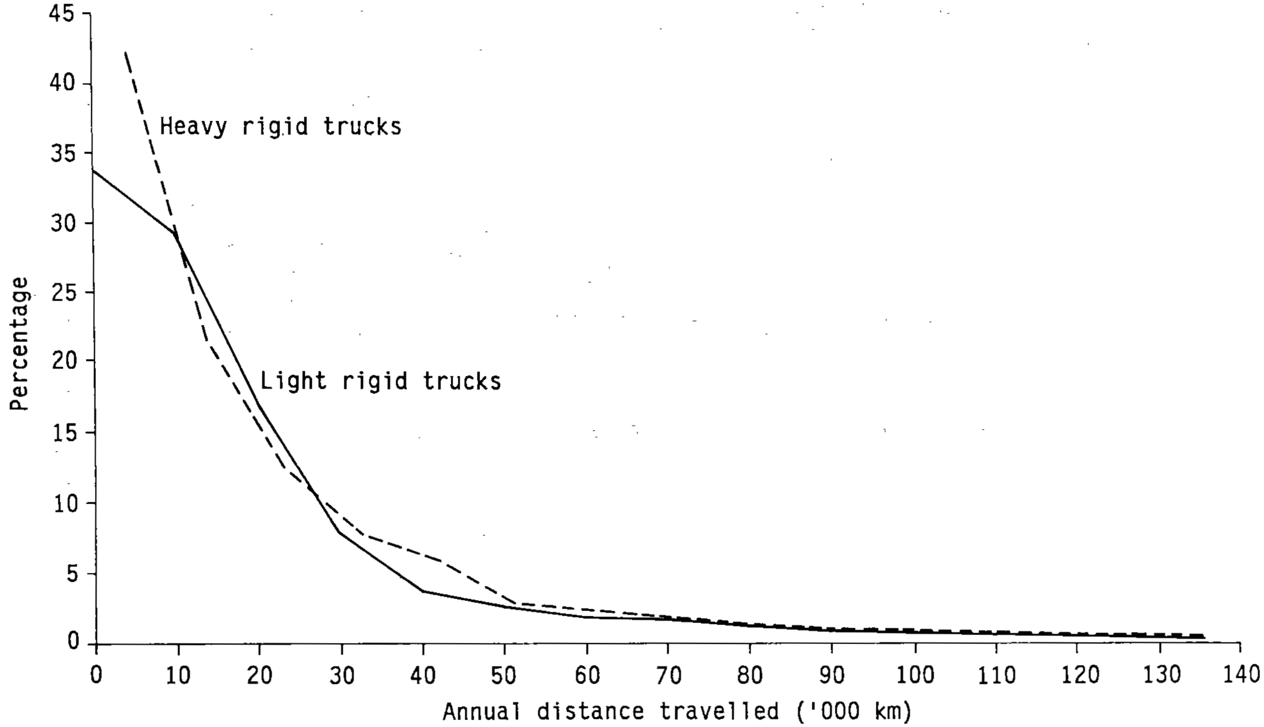
Figure 8.1 demonstrates the relationship between road damage costs for typical truck configurations and different levels of fuel taxation. The road damage costs are based on results of the analysis in Chapters 6 and 7. Road damage costs rise much more steeply with vehicle mass than does fuel consumption for a vehicle of given axle load. This is because pavement damage increases with the fourth power of the axle load whereas fuel consumption is a function of the vehicle's rolling resistance. Fuel excise on its own is therefore an inappropriate mechanism for recovering pavement damage cost.

The damage costs and fuel tax revenue shown in Figure 8.1 are estimates per kilometre. Total costs and revenues will depend on distance travelled. Data provided by the ABS show that there is a large variation in annual distances travelled by all vehicle types. This is demonstrated in Figures 8.2 and 8.3.



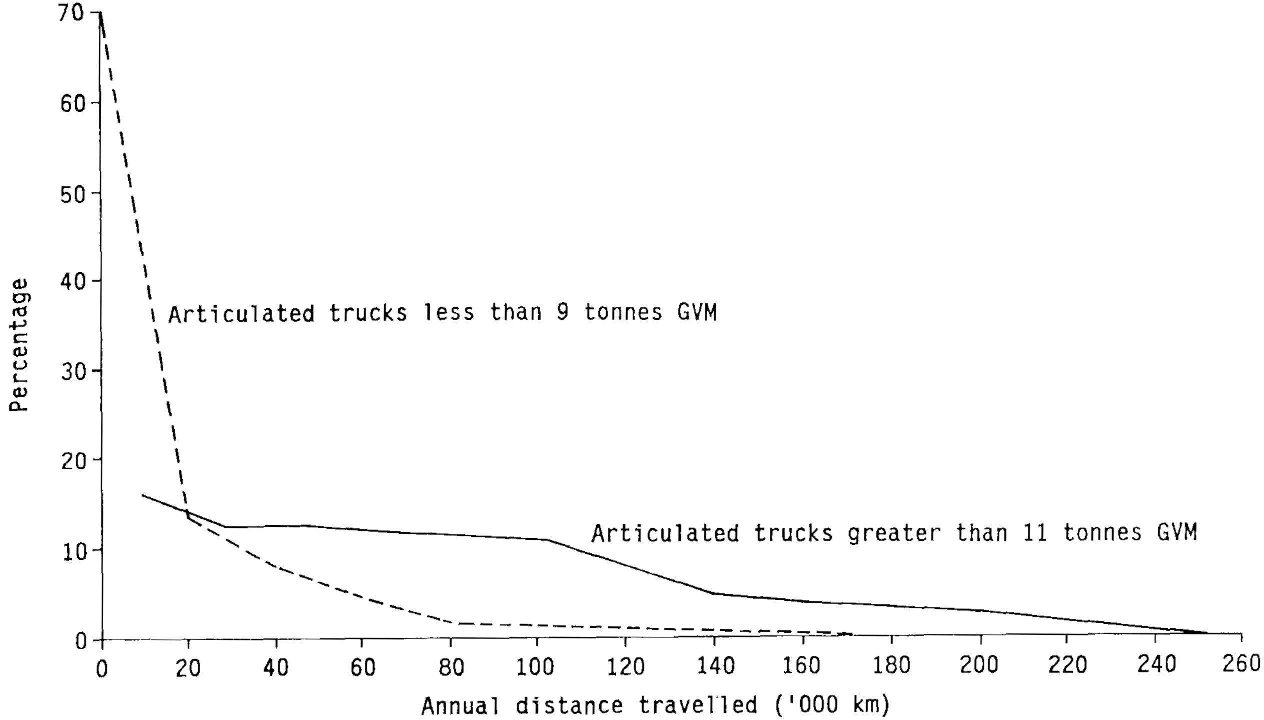
Source BTCE estimates.

Figure 8.1 Road damage costs for various truck types and fuel tax payments by a typical 6-axle articulated truck at current fuel tax rates



Source ABS (1984).

Figure 8.2 Distribution of annual distance travelled by rigid trucks



Source ABS (1984).

Figure 8.3 Distribution of annual distance travelled by articulated trucks

Figures 8.1 to 8.3 demonstrate that for a given road type any system of charges designed to recover road damage costs needs to be related to:

- distance travelled;
- gross vehicle mass (or with load on a given tare mass); and
- axle configuration.

Thus, whether or not fuel taxes are employed, a mass-distance charge is also required.

Distance
In order to take into account distance travelled, a distance-measuring device such as a hubodometer or tachograph is required. At present such devices are expensive (costing up to $1000). Given current registration charges they are not warranted. However, if charges at the levels suggested in Chapter 7 were to be introduced, then an expense of this level might be warranted. A fixed charge could be set, calculated on a large annual distance, say 250 000 to 300 000 kilometres, and voluntary use of hubodometers by operators encouraged with a rebate being allowed for smaller distances travelled.

Given the fact that operators of two-axle rigid trucks are, as a group, currently meeting their road damage costs, most of these trucks may not need to have the devices fitted. There is less reason for any mass-distance charge to be levied on operators of the lighter two axle rigid trucks if current fuel taxes remain. These trucks represent the great bulk of trucks. In New Zealand, vehicles weighing less than 3.5 tonnes do not pay a separate road damage charge. Of course, if the mass-distance charge were to replace fuel taxes as a means of recovering part of total pavement damage costs, the need for hubodometers for these vehicles might remain.

The alternative adopted in the United States is for a fixed fee based on average distance travelled. This form of charge does not encourage efficient use of roads since it does not discourage over-use of the road system. It may also be considered inequitable since operators of vehicles which travel less distance and do less damage pay the same as operators of vehicles which travel larger distances and do greater damage. The scheme was introduced in the United States because, although mass-distance charges were favoured as a mechanism for recovering road damage costs, there were concerns that hubodometers were not reliable. The fixed tax is also administratively simpler to implement. Recent New Zealand experience, however, demonstrates that hubodometers are acceptably reliable. The system could also be made administratively easy, requiring only an annual reading of the device at the time of vehicle registration renewal or alternatively, whenever vehicles are stopped for weighing.

Vehicle mass

The variation in vehicle loads is a more difficult problem. Because of imbalances in freight flows between cities or other back-loading problems (for example, deliveries, quarrying operations) there is a substantial amount of empty running or part-loading of vehicles. Additionally, there is a substantial amount of over-loading by many vehicle operators. Thus, the legal maximum limit does not adequately measure vehicle loads. The average gross vehicle mass for six-axle articulated trucks is around 30 tonnes compared with the legal limit of 41 tonnes in most States. Because road damage increases so greatly with vehicle mass for a given truck, a charge based on average or legal maximum mass will only approximate road damage costs for a proportion of vehicle travel and will not encourage efficient vehicle loading practices. In terms of Figure 8.1 this charge would be a point on the curve for each vehicle type rather than a schedule following the curve.

Ideally, the charge should vary with the vehicle load on each trip. This could be achieved by requiring operators to report to checking stations at the beginning of each trip, with heavy penalties for non-compliance, or the compulsory fitting of on-board weighing devices or scales which are connected to a recording mechanism. Such devices currently exist and the scheme is feasible. However, acceptability within the industry has not yet been investigated. An experiment is being conducted in the United States in which on-board transponders transfer details such as vehicle mass to magnetic loops in the road way. This information is in turn fed by cable to a central computer. The Road Traffic Authority in Victoria is currently employing the feasibility of such a system for Australia. The system could offer other advantages such as vehicle location for trucking companies.

An alternative suggested by the industry has been the idea of a nominated mass. This applies in the United Kingdom and New Zealand. Under this approach operators would pay a charge based on a nominated maximum mass (or load) for their vehicle. They would be required to obtain a permit for any trips on which they intended carrying a larger load, up to the legal limit. Fines for overloading would apply to and be based on the nominated mass. Of course, some form of external identification would be required on the vehicle to guide load enforcement officers at weighbridges and on the roads. Also, to avoid undue complexity only a few mass levels would be allowed and permit costs would need to include administration costs.

This latter scheme may have some merit. It would be much simpler to administer and be less costly than the use of on-board weighing devices although not as closely related to marginal cost. A small trade-off would be involved between economic efficiency and administration expense. The nominated mass scheme would still, of course, involve some administrative costs and perhaps make the policing of over-loading more difficult. However, the industry has accepted that higher penalties for over-loading offences would be justified in exchange for the reduction in charges for some operators and the greater level of trust placed on these operators.

Axle configuration

This third factor is the easiest to incorporate in the mass-distance charge. All that is required is a charging schedule for each vehicle axle configuration. While there are many vehicle types, the variety of axle configurations is fairly limited and it would not be difficult to calculate appropriate schedules with computers. The key element of the schedules is that the charges vary with total combined axle loads and roughly follow the fourth power rule.

Road quality

It was noted earlier that the amount and cost of road damage varies with quality of pavements. However, without the aid of electronic measuring devices, it is probably not feasible to apply different weight-distance charges to vehicles travelling on roads of different quality. With the aid of such devices there would probably only need to be four or five categories of road type with differential road prices in order to appropriately influence road use.

In general, however, it must be conceded that it is not possible to set charges exactly equal to short-run marginal cost for every road user for every trip. Compromises may need to be made, largely by way of setting charges based on average damage caused to different road types or the average loads carried by different truck types. Distance and axle-configuration can be accounted for, but at present, actual loads carried on each trip cannot be accurately measured by the type of road travelled on. To the extent that charges cannot be exactly related to short-run marginal cost by road type, the full gains from efficient pricing cannot be achieved. It is to be hoped that these other factors may be addressed as the technology for gathering the information on actual loads carried and type of road used becomes available.

A system of electronic identification of vehicles is currently being developed in the United States. The Heavy Vehicle Electronic Licence

Plate (HELP) project is a system capable of automatic collection of truck location, weight and classification data. Australian road authorities are monitoring these developments, but practical implementation is some way off.

In the absence of such electronic devices, two adjustments to an 'average' price for all roads could be made.

First, where it could be demonstrated by an operator that a certain percentage of a particular vehicle's travel was on certain inter-capital national highways, a rebate could be applied. This would be justified as pavement damage cost is lower on many such routes.

Second, some local routes which are used for specific purposes, such as logging roads, or routes to quarries, building sites and so on, could easily employ a special rate. When a particular route was predominantly used by a single operator or for a single purpose it would be justified on the basis of the higher damage levels occurring on such roads. Some schemes of this type have been employed on some roads in Australia.

Possible three-part pricing system for 1986-87

A possible pricing structure, based on 1986-87 estimates from Chapters 5 to 7 and discussed in Appendix III, is outlined in Table 8.1. The estimated revenue obtained from the scheme is slightly greater than the PAYGO target of $4200 million. However, there are many uncertainties in the statistics, and undoubtedly, user patterns would change somewhat when such a scheme was introduced (for example, car usage might increase and truck usage decrease, thus altering the allocation of construction costs). In addition, the target will change each year, so there will need to be some trial-and-error in setting charges under such a scheme. The calculations in Table 8.1 are averages for all roads, local as well as arterial.

Compared with the estimates of current charges provided in Table 7.4 there are some significant increases for some road users while other road users would pay significantly less. The potential losers would be expected to react to such change as the recent truck blockades suggest. In this context the social and political constraints to such change are outlined.

Implementation of efficient prices, subject to social and political constraints

The road transport industry would be, in the short-term, the main potential loser if efficient road prices were implemented 'overnight'.

TABLE 8.1 POSSIBLE THREE-PART ROAD PRICING SYSTEM TO RECOVER TOTAL ROAD EXPENDITURE, 1986-87

	Damage charge element of registration fee		*Demand-based*			
Vehicle type	*Charge*[a] *($/vehicle)*	*Revenue ($ million)*	*Fuel taxes*[b] *($/vehicle)*	*Fixed element of registration fee ($/vehicle)*	*Revenue ($ million)*	*Total revenue ($ million)*
Cars	..	..	172	..	1 500	1 500
Rigid trucks						
2 axles	470	178	320	500	310	488
3 axles	4 300	156	820	500	60	216
>3 axles	8 800	162	1 200	500	27	189
Articulated						
< 5 axles	8 300	118	1 400	2 000	49	167
5 axles	20 000	220	2 600	2 000	52	272
6 axles	34 500	918	5 000	5 000	260	1 178
> 6 axles	69 000	197	7 400	10 000	42	239
Long-distance buses	45 000	16	11 500	10 000	6	22
Total	..	1 965	..	..	2 306	4 271

a. Based on average ESALs per vehicle and average distance for the class, calculated at 14.8 cents per ESAL km.
b. Based on tax of 9 cents per litre for both motor spirit and automotive distillate.
.. Not applicable.

Source BTCE estimates.

Although the structure of the charges is unlikely to be opposed by the road transport industry, the level will be. Following the NRFII and RoRVL studies, industry groups accepted the need for properly calculated charges. However, the RoRVL study and the recent ISC Report (1987) have both suggested only modest increases in charges. Even these levels have met with some industry resistance. The calculations in Chapter 7 and charges in the United States of America, United Kingdom and New Zealand indicate that for the heaviest vehicles charges should be raised substantially. The top of the charging schedule would have to be very high indeed. Table XIII.1 of the ISC Report (1986-499) shows that New Zealand charges range up to almost NZ 60 cents per kilometre for some vehicles loaded within the legal limit. Over an annual distance of 250 000 kilometres this amounts to NZ$150 000 per annum. While this is an extreme, typical charges for trucks in New Zealand were estimated at the equivalent of A$20 000 to A$35 000 per annum in 1985 (ISC 1986, 250) and currently amount to around NZ$45 000 per annum for a 41 tonne six-axle articulated vehicle travelling 100 000 kilometres. This charge is, however, designed to recover fully allocated road expenditure and not just road damage costs.

Obviously, the introduction of charges more in line with road damage costs would need to be gradual and properly structured to allow the industry to adjust. In the short-term, small input cost adjustments allow users to respond by changing road use and other inputs gradually, and with only small output price adjustments. Small incremental changes to costs, aimed specifically at reflecting the way costs were caused, may therefore cause less social and industrial problems than large and sudden change. In the long-term, changes in input costs will require time to plan for changed investment requirements. Operators need time to replace their current vehicles with vehicles more suitable to their freight task, having in mind the potential for reducing pavement damage costs. Typically, trucks have a life time of about 10 years. The industry will also need time to adjust to any increased competitiveness from rail transport which results from changes in relative prices.

A gradual introduction of a new road damage charge would also allow time for gradual reassessment of cost-recovery levels. It is pointless, though, for any more studies to be conducted until there is agreement on the basic methodology to be adopted. Even when such agreement is reached, there will still be a large number of areas of uncertainty concerning costs, traffic/road damage relationships, economies of scale and so on, for Australian roads. Overseas results, such as those obtained in the United States, need to be calibrated for Australian roads and conditions.

Time is also required to explain the principles on which the new charges are to be based and to assess the impact of the charges. Much has been made of the lack of information on demand elasticities and cross elasticities with rail. A gradual introduction of the scheme focusing on the pricing structure rather than the price level, should enable a better assessment of demand functions and demand elasticities by analysing the effect on demand of the changes in the charges.

There has been argument in the past as to the legality under Section 92 of the Australian Constitution, of imposing road user charges on vehicles engaged in interstate trade. It is not intended to engage in a legal discussion in this Paper, except to note that recent High Court decisions such as the recent decision concerning South Australian crayfish imported into Tasmania, suggest a relaxing of views expressed by the Court in the 1950s. It is likely that section 92's provisions would not be seen to imply that interstate trade should be free from appropriate regulation or free from recovery of resource costs if these are applied in a non-discriminatory manner. It is therefore probable that charges to recover not only road damage but also new road construction costs would be upheld in the High Court.

Implication of increased road charges for road freight rates

If a more efficient road pricing system were to be introduced, there would be a significant impact on road freight rates. A charge for road damage of around 15 cents per ESAL kilometre as suggested in Chapters 5 and 6, implies a charge for a fully laden (38 tonne) six-axle articulated truck of about 55 cents per kilometre. This compares with current registration charges and fuel exise payments which amount to about 25 cents per kilometre. Thus, an efficient charge would be about 30 cents per kilometre higher than current charges. This would be even more if trucks were required to recover a share of costs above avoidable cost.

With other vehicle operating costs amounting to around 80 cents per kilometre, that is, total operating cost of a little above $1, the increase would be about 30 per cent over current costs. Thirty cents represents over 1 cent per tonne-kilometre for a 23-tonne load. For operators utilising the recently introduced 41-tonne limit the increases in total vehicle operating costs would be a little higher; pay the higher road costs being partly cancelled by a larger payload. For the average six-axle truck, representing 2.38 ESALs, the increase in charge works out at over 1 cent per net tonne-kilometre.

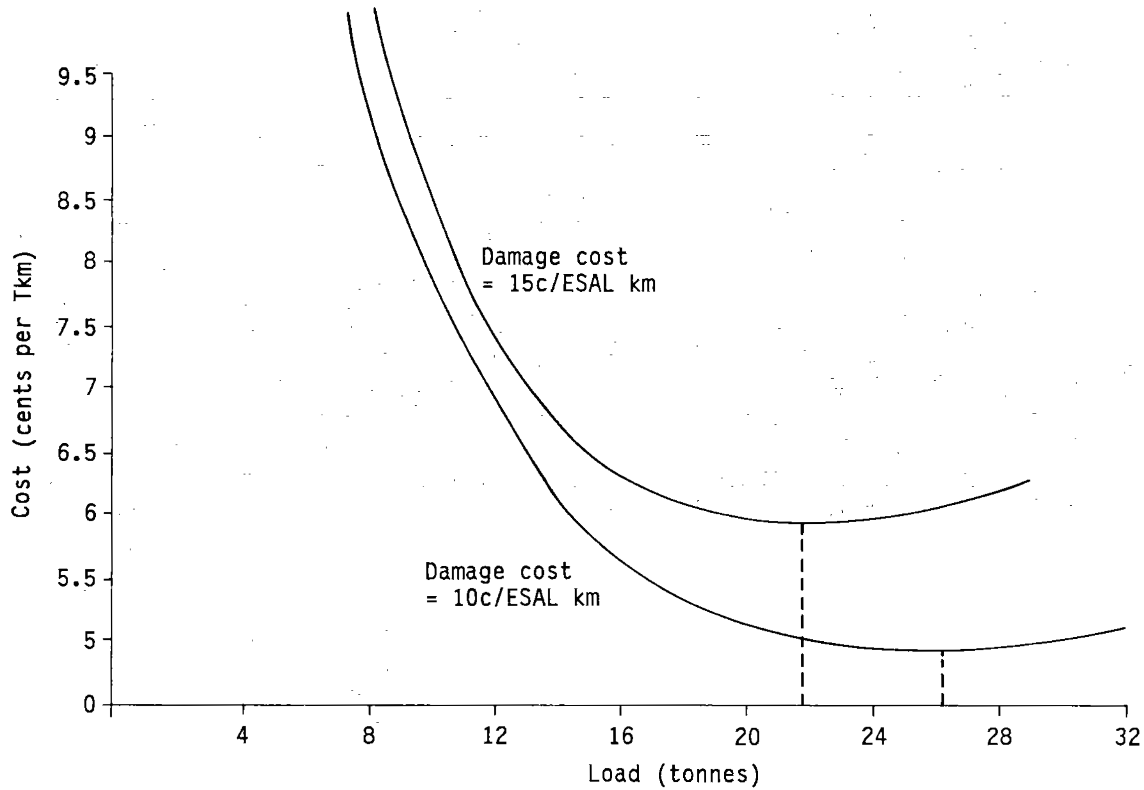
Of course, other elements of marginal (pavement damage) cost are not included in these calculations. The chief one of these is the increase in operating costs for other vehicles, due to use of pavements made rougher by trucks as they pass over the road. The United States efficiency study examined earlier, research undertaken by the World Bank (1985) and the RoRVL study, all suggest these costs are of a similar magnitude to road damage costs.

Figure 8.4 shows that if the operator is required to pay a damage charge of 15 cents per ESAL kilometre, the average cost per net tonne-kilometre (load carried multiplied by distance) will increase marginally if the load is increased from 23 to 26 tonnes, as implied by an increase in gross mass limit from 38 to 41 tonnes. In a competitive market, operators will maximise profit at the output level that minimises average cost. Thus, if the industry is competitive (and price is forced down towards minimum average cost), operators will generally not find it profitable to avail themselves of the higher limits. As well, if it is not profitable for the operators, it will not be beneficial to society at large, since society also has to bear other costs (such as accidents, pollution and higher vehicle operating costs for other users).

If increased vehicle operating costs for other users are included in the analysis, the results may indicate that it is not economically efficient to allow the higher limits on many arterial roads.

This line of reasoning casts doubt on the results of the RoRVL analysis and suggests that, in fact, a mass limit of 38 tonnes for a six-axle articulated truck may be too high on average for the current Australian road system. It may be that only on the better quality arterial roads in Australia can a 41 tonne limit be justified. The corollary is that even 38-tonne vehicles may be causing enormous damage to most local roads despite the fact that they may use them less than arterial roads, an argument which has been advanced by local government associations.

An average increase in road use charges of between one and two cents per tonne-kilometre, if reflected in freight rates, is likely to have some impact on the competitive position of road transport with regard to rail. The reaction of railways to an increase in road freight rates should depend on the elasticity of demand faced by them for competitive traffic. For some traffic, it may be more profitable to respond with higher rail freight rates, for others it may be more profitable to increase market share.



Note Truck tare mass assumed to be 15 tonnes.

Source BTCE estimates.

Figure 8.4 Average cost per tonne-kilometre for various loads on a 6-axle articulated truck if full road damage costs included

Of course, road transport operators may complain of the disadvantage they would suffer compared with rail. However, they did not consider the disadvantage suffered by rail when vehicle limits were increased. A balance obviously needs to be struck. One possibility is to offer even higher mass limits in return for full cost recovery, subject, of course, to safety considerations. If there exists a more rational road pricing system in which charges are related to road damage costs and therefore, *inter alia*, to vehicle axle loads, limits may no longer remain an economic issue.

Uniform national charges

The analysis in Chapters 5 to 7 was based on Australia-wide data. However, road types, road conditions, traffic levels, costs of roadworks and a host of other factors will differ from State to State. Thus, road damage costs per ESAL kilometre will vary from State to State.

From an economic efficiency viewpoint, the price set for road use should be related as closely as possible to actual road damage costs (ideally, even by individual road). However, the necessary information for setting charges with this degree of precision is currently not available. The administrative difficulties of setting a range of charges would also be greater. Broad average charges will therefore need to be set, undoubtedly, at a uniform level within each State. However, net benefits may be maximised, *a priori*, by setting different limits in each State.

In practice, it may nevertheless be desirable for charges in each State to be reasonably similar to discourage distortions in decisions regarding industry structure between States. For example, location of industries in areas close to State borders could be influenced by the states' road user charges. Even decisions as to the State in which a factory might be established could be so influenced. States could compete for industry through lower road user charges that did not clearly reflect lower road resource costs.

In general, where there is a constraint to achieving efficient prices, as there is in the supply of roads, some judgment will be required if the prices are not to distort decision making. In the absence of market-based prices, it is possible that uniform national charges will have the most neutral effect on investment decisions. Thus the benefits of maximising economic efficiency may be influenced by practical considerations.

BENEFITS OF CHANGES IN ROAD PRICING LEVEL AND STRUCTURE

The changes implied in the charging system presented above are certainly significant. For some operators total operating costs could increase by up to 30 per cent. The effect of this on their profitability and the total road freight task depends on the elasticity of demand of the goods being transported. If, as suggested in the Ramsey pricing exercise in Chapter 6, demand is fairly inelastic, the overall effects may be small.

In the case of the 'flag bearer' of the long-distance road transport industry, six-axle articulated trucks, the three years from 1982 to 1985, saw a compound growth of about 20 per cent per annum in tonne-kilometres of freight carried. With the increase in charges of the level discussed above, this growth rate may decline. Some freight will be switched to competing industries such as rail transport, communications or storage industries. On the other hand, the increased road freight rates should also encourage an increase in rail freight rates on unprofitable rail traffic as part of an overall package to reduce rail freight deficits. The increases in charges implied by the results of the analysis in Chapter 7 are not large compared with current freight rates (of the order of 1 to 2 cents per net tonne-kilometre compared with current freight rates of around 5 to 7 cents per net tonne-kilometre). Accordingly, there may only be a minor structural alteration in the Australian transport industries in terms of modal tasks. The level of adjustment in the long-run depends on the long-run cross elasticities of demand between the road sector and competing industries as well as the elasticity of demand of shippers. As so many factors other than price are influential in determining road freight demand, the cross-price elasticities are probably not overriding. However, the question at issue here is whether or not the cost of the structural change is significant compared to the gains in greater transport efficiency.

Of course, structural adjustment in any sector of the economy involves some redistribution of costs and benefits. Governments must balance the possible redistribution effects with the efficiency gains likely to be achieved and consider what, if any, compensatory actions are required.

Costs of adjustment

Generally speaking the costs will include those which may arise from:

- loss of earnings to particular operators;
- loss of business to particular operators as a result of higher road freight rates; and

- industry resistance to the higher charges.

These are discussed in general terms below.

Loss of earnings to operators
The recent increase in the allowable mass limit for six axle articulated trucks, from 38 to 41 tonnes, has been partly matched in New South Wales and Victoria by increases in truck registration charges for these vehicles. The increased fees are but a fraction of that required for full recovery of additional road damage costs from heavy vehicles. Nevertheless, they were resisted by heavy vehicle operators on the grounds that an increase in costs would 'squeeze' the industry, making it more difficult to operate profitably. There is little evidence, however, to suggest that existing operators could not pass on to customers an increase in costs of the order indicated. In fact, some of the industry organisations have unofficially spoken of complaints from operators that there is nothing in the higher vehicle mass limits for them and that all the benefits will accrue to shippers. However, they argue that operators will be forced to utilise the higher limits to remain competitive. If proper charges were made on all heavy vehicles without exemptions, then all freight rates would increase. In the unlikely situation that the industry is unable to pass on cost increases by way of freight rate (and passenger fare) increases, then this problem needs to be addressed directly, rather than by avoiding appropriate input cost increases.

The existence of exemptions from existing charges for some operators of heavy vehicles upsets the competitive balance and is seen to be inequitable by many operators. Exemptions, for instance, were one of the causes of industry resentment to the road maintenance charges in the 1970s. It has been estimated that at the time the charges were abolished, exemptions applied to over 40 per cent of operators of heavy vehicles (Webber, Both and Ker 1978, p 305).

Currently, exemptions apply on fuel excises and other fees to a wide range of operators of heavy vehicles. Biggs and Anderson (1987, 649) noted that exemptions are currently offered to various classes of vehicle owners. These include 'farmers, prospectors, pensioners, government departments, crocodile hunters, charitable organisations, religious organisations, beekeepers, stock transporters, the defence forces and numerous others'.

Exemptions allow potential competitors to carry, in some cases at higher resource costs to the nation, road freight in direct competition to the existing road transport industry. Much farm produce, defence force freight and so on might be more efficiently carried by the existing road transport industry. For example, fewer trucks might be needed for the task. Many farm trucks are idle for much of the time. Any equity arguments for exemptions are of course a matter for governments to weigh up.

The paradox is that higher road user charges, if applied without exemptions, may increase the freight task required of the mainstream road transport industry and so increase its ability to recover overhead costs. There would not necessarily be any loss of earnings to road transport operators.

Loss of business
There are two principal sources of evidence to support the contention that the role of the mainstream road freight industry may actually increase if exemptions and subsidies were discontinued, despite higher charges.

First, as already noted, there has been a very substantial growth in numbers of heavy vehicles using Australian roads. Although the number of articulated trucks has grown by between 3 and 4 per cent per annum in the ten years since 1976, the growth has been much higher in the heavier of those trucks, especially six-axle articulated trucks. Vehicle-kilometres travelled have grown from a total of about 1000 million in 1975-76 to over 3500 million in 1986-87 for five, six and more than six axle trucks. Another output measure, tonne-kilometres of travel, has increased from about 13 700 million in 1975-76 to 56 200 million in 1986-87 for the same trucks (ABS SMVU for 1976 and 1985 extrapolated to 1986-87). Most of this growth has occurred on six-axle articulated trucks.

Although some of this growth is due to an increase in the overall freight task, much of it is due to winning a larger share of total freight at the expense of the rail sector. If both modes increase charges uniformly (in the case of road freight due to implementation of road damage charges, and in the case of rail freight in order to reduce rail freight deficits and in response to higher road freight rates), then there will be little impact on the modal split. The road freight task would not decline relative to rail freight.

The second piece of evidence is that regarding elasticities of demand for road freight. While such evidence is quite sparse, results of studies such as that by the University of Tasmania's Transport Economics Centre (1981) indicate an inelastic long-run demand for road freight. Although it is necessary to do much more research before elasticities can be more precisely quantified, the evidence strongly indicates that demand for road freight is responsive to a range of factors besides price. What data is available on these elasticities suggests that the demand for road freight is sufficiently inelastic to gradually absorb the price increases necessary to achieve efficient cost recovery, without causing a significant decline in that industry. If properly introduced, the road damage pricing scheme will only slow the rapid growth of the road transport sector, mainly by reducing the rate of transfer of the freight task from the rail to the road sector.

Resistance to change

The 'Razorback' blockade of 1979 and the recent truck blockades demonstrate that parts of the road transport industry are capable of organising industrial action to protest over perceived inequities.

These disputes, however, were based on a range of issues. Central to these in 1979, was an inability of many drivers to make an adequate return on their investments and labour. The road haulage industry was, and remains, highly competitive and in the recessed economic conditions of the time, long-distance operators were squeezed between higher costs and an inability to substantially increase rates. Causes of the 1979 dispute were discussed by Kolsen and Docwra (1979). Adding to the grievances was the large scale evasion and exemptions of the road maintenance charges by some operators which allowed them to undercut rates.

In order to achieve acceptance of the proposed road damage charge, the structure of the charge and the timing of its introduction should be well known in advance and implemented after consultation with the industry. There should be no exemptions to the charges. Evasion of the charges could be almost completely precluded if they were to form part of legal registration charges. The issue of avoidance of correct payments, like that of many taxes and charges, is related to policing and severity of fines.

There is certainly evidence that the broader community is concerned about the level to which road freight is subsidised (refer Sydney Morning Herald 15 July 1987, p. 5, and 17 July 1987, p. 12). To some extent the strong support that the Razorback dispute attracted from the wider community in 1979 seems to have been diminished. The recent blockades received far less community support than did the 1979 dispute.

Benefits from adjustment

The benefits from the implementation of appropriate road-user charges lie mainly in the increased efficiency of the road transport industry and indirectly in competing modes of transport. The direct benefits arise when the road pricing system encourages behaviour which reduces the cost of road damage. A long-run benefit may occur if prices then influence the type of investment in vehicles and roads which lowers this cost.

The Australian road transport industry is widely regarded as being an efficient mover of freight. However, the industry itself cannot be said to be an efficient user of national resources if it does not meet all of its resource costs. As argued in Chapter 2, unless it meets its costs one cannot be sure the benefits from its use of roads are at least equal to the costs. If they are not, the resources used should be directed into other more profitable areas.

Specifically, in the absence of a pavement damage cost recovery charge, the more marginal tasks undertaken by heavy freight vehicles must be questioned. The marginal tasks are those which it is only just considered worthwhile carrying out, although they may be difficult to identify. It is open to question whether all freight tasks carried by heavy vehicles should be undertaken or whether it would be better for some other mode, such as rail transport, to undertake some of these tasks.

The distribution of the freight task between modes is distorted to some degree by inefficient pricing. Pricing and cost recovery arrangements of all modes must be considered.

Rail cost recovery levels are likely to improve as a result of higher road prices for road freight operators. For instance, there will be greater scope for rail price increases. Alternatively, a relatively higher price for road transport may attract some freight back from road to rail or simply decrease the rate of transfer of freight from rail to road. A combination of price and freight task adjustments is perhaps the most likely. A large scale transfer of the freight task from road to rail is unlikely since full cost recovery for heavy trucks implies an increase in charges of only about 1 to 2 cents per tonne-kilometre of freight. This is about 20 to 40 per cent of current freight rates. If implementation of full cost recovery is made gradually, the increments to freight prices will be quite small. For this reason, it is probable that full road cost recovery will simply slow down the transfer of long distance freight from rail to road.

Theoretically, rail should be more efficient than road in the carriage of long-distance bulk freight. To take full advantage of its technical advantage rail must be efficient in its operations. In the long-run, both modes must face and set efficient prices and achieve full cost recovery. Efficient allocation of the freight task requires an efficient pricing structure for both modes.

With the information currently available, it is not possible to accurately assess the full benefits which would accrue from efficient road prices. Studies in the United States have indicated that savings could be in the order of thousands of millions of dollars (Small and Winston 1986, and United States Department of Transportation 1982).

DISTRIBUTIONAL AND FUNDING CONSIDERATIONS

In the analyses in Chapters 5 to 7, the road transport sector was segmented by vehicle type rather than income level. Therefore, the conclusions do not take income levels into account. Some individuals with lower incomes may pay more for road use than others with higher incomes but only if they make more use of the road system. This results partly from the cost side. With marginal cost pricing, those who cause greater costs pay more, irrespective of their income level.

With the Ramsey pricing exercise, however, a more subtle issue arises. The use of Ramsey pricing rules in this study is based on the assumption of a constant marginal utility of money for every individual, (as is most applied microeconomic theory). Thus, it is assumed that everyone obtains the same additional level of utility from receiving an additional dollar of income. Alternatively, the payment of a dollar results in the loss of the same level of utility for every individual. The total of everyone's utility is assumed to determine society's welfare function. The statement that Ramsey pricing rules enable the least reduction in society's welfare for a given level of road taxation is based on these utility assumptions.

There may also be some circularity in the Ramsey pricing approach. The reason a given individual's elasticity of demand for road use may differ from that of another individual may partly reside in his having a different marginal utility of money. Of course, it could simply be explained by the revealed preference argument; he simply obtains a different level of utility from the use of the road.

What this argument leads to is a questioning of whether Ramsey pricing does lead to maximum (or minimum reduction of) welfare in the face of a constraint to marginal cost pricing. One can certainly hypothesise cases where an individual with a very inelastic demand curve could nevertheless suffer a larger loss in welfare from charges based on Ramsey pricing than an individual with an elastic demand curve.

The distributional consequences of Ramsey pricing (or even marginal cost pricing) are not known *a priori*. One can only have a broad degree of confidence that they do, in fact, maximise society's welfare. The same argument obviously applies, and perhaps with even more emphasis, on other pricing bases.

The likely initial distributional consequences of efficient road pricing are to reduce road user payments by motorists and increase the payments of operators of heavy vehicles. In addition, other income transfers are also likely. Those paying less would likely include:

- private motorists; and
- taxpayers subsidising railway deficits.

Those paying more would likely include:

- those purchasing goods carried by road, particularly goods with a high transport content; and
- those purchasing goods carried by rail.

It is likely, though, that most individuals in society will actually fall into most or all of these categories.

The overall size of all these transfers could be large. The analysis in Chapter 7 suggests that operators of heavy vehicles collectively might pay an additional $1 billion or more in charges, if an efficient pricing system were introduced. The balance to this is perhaps a budget or general taxation saving of $1 billion.

Intergovernment funding responsibilities

One issue not addressed so far, is which level of government will levy the road damage charge. Under the Australian Constitution, the States have primary responsibility for intrastate trade and for roads. By far, the larger share of revenue from a road damage charge will be raised from operators of State-registered, as against interstate, vehicles. Thus, the States stand to gain a large increase in revenue (if they do not reduce charges on the private motorist) and the share of total road funding raised by the States could increase significantly.

Of course, the Commonwealth may not wish to reduce its financial role in road funding. However, if it continues to fund roads at current levels, the total level of funds available for road works as a result of the introduction of more efficient road-user charges, will increase significantly (from $4200 million to perhaps over $5000 million in 1986-87 terms). There is a large potential for some of these additional funds to be spent on road works of dubious economic merit rather than those with a high benefit-cost ratio.

A more significant issue arises with local government road funding. Part of the revenue raised from the road damage charge would relate to travel on, and thus damage caused to, local roads. Currently, there is no mechanism by which an appropriate share of the revenue from the road damage charge could be returned to those local government authorities whose local roads suffered damage. Such a mechanism would presumably require detailed traffic surveys. Alternatively, State governments might agree to accept full funding responsibility for the maintenance of local roads. Some reorganisation of current Federal-State-local government financial arrangements might be required in return. This may occur, for example, through a corresponding cut in untied financial assistance grants. The level of maintenance cost of local roads (defined broadly to include all local road asset restoration) was estimated in Chapter 5 to be over $900 million in 1986-87. This represents about 18 per cent of the total level of local government budget expenditure.

Hypothecation and road supply

One of the issues that always arises when considering increased, or new, road user charges is that of hypothecating, or earmarking, the additional revenue to roadworks. Surveys of public opinion, such as that recently conducted by NAASRA for its TAROR report, show that those who pay are concerned that the charges be earmarked. Most are much more prepared to pay if this approach is adopted.

A charge such as the road damage charge, which is closely related to the cost of road works, is likely to attract public pressure for full hypothecation. Of course, economic theory would suggest that any road suffering road damage should nevertheless only be repaired if it is economically justified to do so. Some roads may have been over-designed and may justify some level of deterioration. However, in general it is likely that hypothecation of the revenue will become a prerequisite for acceptance of the charge by operators of heavy vehicles.

The problem, alluded to earlier, of operators having to pay more in Australia, compared with, say, the United States, because our roads are not as good (not as strong), is a serious one. Undoubtedly, the introduction of a road damage charge will not only result in pressure for hypothecation of the revenue, but also pressure for better roads, with subsequent lower damage costs.

Clearly, in Australia there are significant economic returns to be gained from selective improvement of much of our road system, particularly arterial roads. Bureau of Roads, NAASRA and BTE studies over the past 20 years have consistently demonstrated this.

In New Zealand road users have been given some direct input into the road investment decision process. Such a process in Australia would likely generate pressure on governments and road authorities to invest efficiently. Road users, when confronted with the full costs of road investment, may question the merit of the level of investment in some parts of our road system, particularly local roads, but seek more funds for heavily used roads, which are mainly the arterial roads. Even State road authorities, if they were to be held more accountable and required to operate more in line with a profit-maximising, efficiency-oriented business undertaking, would question much current road expenditure. Undoubtedly, this would focus on local roads and many rural roads where current standards are difficult to justify on economic efficiency grounds. The questions which may be asked are: 'What is the gain from efficient pricing if road investment is inefficient?' and, 'Is there much to be gained from establishing a funding nexus between revenue and expenditure, while there is a fundamental failure in the investment process?' Users may ask why they should be forced to meet the costs of roads which they do not use (for example, very lightly trafficked local and rural roads) or roads which are designed inappropriately. Indeed, the results of this study should point to the need to consider the way in which roads are supplied, rather than simply focusing attention on road users.

A more rational and efficient road pricing system is an important aspect in the maximisation of benefits from the limited resources available for roads. The introduction of such a system may stimulate discussion of, and action to improve, both road usage and the other side of the coin, efficient road investment.

CHAPTER 9 CONCLUDING COMMENTS

This Paper has outlined the basic pricing principles and their application to road pricing and investment. It has reviewed some of the more important Australian studies of road cost recovery as well as aspects of the United States' road cost allocation study (US FAH 1982 and 1984) and the extent to which these adhere to the principles outlined. The Paper has outlined both the avoidable cost/Ramsey pricing method of assessing the level of road cost or road expenditure recovery and an alternative cost-occasioned method. Estimates of the level of road cost recovery in 1986-87 are presented, based on each of these methods. A further purpose of the Paper was to consider the practical benefits and constraints to full cost/expenditure recovery.

The avoidable cost/Ramsey pricing approach adopted in Chapters 6 and 7 was based on economic efficiency principles. It was used to determine indicative levels of overall road expenditure recovery as well as short-run avoidable (pavement damage) cost expenditure recovery on Australian roads by user group. This approach was compared with a cost-occasioned equity approach in Chapter 7.

It was noted in the Paper that the avoidable cost/Ramsey pricing approach suffered from a number of shortcomings compared with a theoretically optimum approach to efficient road pricing. For instance, according to the theory, prices should be set at short-run marginal (avoidable) cost, but in practice governments require road users to meet the total level of annual road expenditure, including expenditure on road construction. This is termed the PAYGO approach. Under this approach short-run marginal cost is approximated by the level of expenditure on road works which can be directly attributed to vehicles using the road. The balance of annual expenditure is regarded as common or joint and is allocated accordingly among all vehicles.

Another limitation of the PAYGO approach is its narrow coverage of expenditure. Significant costs of road usage such as congestion, accident and pollution costs are excluded since they generally do not involve a direct expenditure outlay by governments. They are nonetheless significant costs to the community.

Despite these constraints, it is argued that the approach outlined will lead to greater efficiency in the allocation of resources to roads. To the extent that some users are currently not meeting their road damage costs, the pricing system proposed in the Paper should also be more equitable.

The three parts of the efficiency based analyses were:

- the assessment and allocation of avoidable cost/expenditure,
- the allocation by Ramsey pricing principles of expenditure in excess of avoidable cost/expenditure; and
- the assessment of the level of recovery payments both overall and by user group and road type.

The three components of the avoidable cost/expenditure were identified as:

- routine maintenance
- resealing
- reconstruction.

The analysis in Chapters 3 and 4 suggests that the measurement of avoidable cost of pavements in the various road cost recovery studies is inadequate. Of the three studies reviewed in this Paper, the work of Webber, Both and Ker (1978) was assessed as giving the most reasonable assessment of short-run avoidable cost, although some adjustments can be made to improve the reliability of the estimates.

A life-cycle cost analysis might provide a more accurate estimate of avoidable cost but the information required to do this is not currently available. An estimate based on current expenditure on Australian roads provides an indicative measure. It is estimated that around two-thirds of annual road expenditure is required for restorative purposes with about two-thirds of this, in turn, being due to damage caused by trucks. There is very little pavement damage caused by motor cars. The avoidable cost/expenditure so derived, about $2000 million in 1986-87, was allocated among all vehicle categories on the basis of relative road damage. It is recognised that this estimate of avoidable cost is fairly rough. Much more research and data gathering by State and local road authorities are required to refine it.

Most other studies have produced lower levels of avoidable cost than this estimate. One reason for this lies in the adoption in this Paper of the approach that only the damage that is common and joint, or wholly due to weather, should be allocated broadly among all users. In particular, pavement damage caused by vehicles, even though compounded by the interaction of weather and vehicle use, is attributed fully to the operators of the particular vehicles responsible for the damage. The inclusion of local roads in the analysis will also cause a higher estimate of avoidable cost than analyses which only consider arterial roads. Generally, maintenance and restoration make up a much greater proportion of costs on local roads than on arterial roads.

Since annual road expenditure in 1986-87 is well in excess of the estimate of avoidable cost, an additional mechanism is required to allocate the balance of road expenditure among vehicle types. The economic efficiency approach to the allocation of this expenditure is based on Ramsey pricing.

Studies using different allocation approaches have indicated very different levels of cost recovery in Australia. Even those cost recovery studies (such as two of those reviewed in Chapters 3 and 4) which have used the Ramsey pricing approach have also indicated a large range of outcomes. This reflects, in some cases, an incorrect application of Ramsey pricing rules and, more generally, the difficulty in determining robust estimates of the price elasticity of demand for road use. It is sensible, therefore, when using Ramsey pricing to conduct sensitivity analyses on the elasticity values and the allocation outcomes. The results of such an analysis in Chapter 7 indicate that the expenditure allocation, and therefore the recovery levels of different user groups, are reasonably sensitive to the relative elasticities assumed.

The alternative method of cost allocation presented in Chapter 7, which was based on the United States cost-occasioned approach, produces similar overall results to the efficiency approach. Operators of heavy vehicles are still shown as being responsible for a much greater level of costs than they pay in road-user charges.

In undertaking this analysis, a problem occurs in determining which payments made by road users should be matched against road cost or expenditure to assess the level of recovery for each vehicle type. A number of definitions of road-user charges are presented although the choice is, to a degree, arbitrary. It depends largely on the purpose for which the estimates are to be used. The definition adopted in the

Paper lies between the broad definition used in the Nicholas Clark and Associates study and a narrower definition which includes only hypothecated road charges.

The merit of the foregoing research must lie in its general applicability within the existing economic and political system. An appropriate allocation and pricing system is ideally one which is correct in theory and workable in practice. It was shown in Chapter 8 that there are some practical and social constraints to efficient road cost allocation and pricing. Nevertheless, it was argued that a practical compromise should lead to efficiency gains. It was acknowledged that some sectors of the community would be worse off as a result of higher charges for road usage but that the losses could be lessened by a gradual implementation of a properly structured road pricing scheme.

The results of this Study have indicated that:

- The level of avoidable cost is significant compared with the level of annual road expenditure.
- The amount of annual road expenditure allocated to various vehicle categories using the Ramsey pricing approach is reasonably sensitive to the assumed relative demand elasticities.
- The avoidable cost of trucks overall, and in particular the heavier articulated vehicles, greatly exceeds their road cost recovery contributions (given the definition of recovery payments adopted and the estimated avoidable cost levels).

The avoidable cost recovery analysis by road-user group indicates that while motorists pay much more than their avoidable road damage cost, operators of heavy trucks are contributing less than their avoidable cost and that the shortfall per vehicle increases with vehicle size. The operator of an average six axle articulated truck contributes about $18 000 per vehicle less than his assessed share of annual avoidable cost. It was noted that even if the broad definition of a road-user charge was used, operators of the heavier articulated trucks would still be shown to be paying much less than their avoidable cost.

It was stressed in the Paper that the estimates of avoidable cost are broad averages over all roads in Australia. Undoubtedly, there is a large variation in road damage costs per ESAL kilometre among the various types and quality of roads and among States. The stronger the pavement the less the damage done to it by each ESAL kilometre. Caution must be exercised in the use of the broad average results, especially in applying the results to particular road types or particular States. While the average damage cost per ESAL kilometre found was 15 cents, it could be less than half this for some roads and more than twice this for others. This is consistent with the results of the United States 1982 road cost allocation study.

A further qualification made in this Paper, referred to earlier, is that the avoidable cost figure of 15 cents per ESAL kilometre represents the charge that is needed to be levied to recover expenditure on restoring the road system in 1986-87 in line with the PAYGO approach. However, if the expenditure in that year is not equal in amount to the required restoration, then the real level of restoration cost per ESAL kilometre may be higher (or lower). In addition, the need for restoration is chiefly the result of road use in previous years. Thus, the figure calculated does not truly represent the actual average level of road damage costs caused by vehicles using the road system in 1986-87. This amount may be much higher.

Overall there is more than full recovery of total road expenditure under some definitions of relevant revenue. However, this is due to the high level of contribution from motorists. Using a mid-range set of demand elasticities, the operators of the heaviest trucks are shown to be under-recovering their fully allocated cost by about $30 000 per vehicle in 1986-87.

Given the revenue definition adopted in this Paper, motorists contributed significantly more than their share of fully allocated cost under both the expenditure allocation methods outlined in the Paper. Indeed, motorists contributed more in 1986-87 than the total amount of road expenditure.

The discussion of pricing theory (Chapter 2) and its broad applicability (Chapter 8) indicates that the form of road use charge is also important in determining allocative (and productive) efficiency. The structure of charges designed to recover avoidable costs should allow road-user prices to vary closely with road costs. Road damage cost is a significant component of the costs of road use. As noted above, other social costs are also significant and should be included in any broadly based road cost recovery analysis.

It is suggested that a more appropriate road pricing scheme would include a vehicle registration charge that was structured to be closely related to road damage costs. In particular, it should vary with distance travelled, preferably through the use of distance-measuring devices and should be related to vehicle mass and axle configuration. Such a scheme operates in New Zealand. Ideally, the charge should also be related to the type of road on which the vehicle is travelling. However, at this stage, the technology to achieve this is still being developed.

Combined with the variable registration charge, a fuel tax, and perhaps also a fixed element of registration charge, could be used to recover total annual road expenditure.

It is recognised that the introduction of a road damage charge would need to be gradual, especially as it could entail a large increase in annual road charges for operators of heavy vehicles which would need to be passed on by way of higher freight rates.

There will be benefits in introducing an efficient road pricing scheme. These arise from restricting road use to those users who derive a net value from using it. Only those who derive benefits at least equal to the costs they impose on the system, should be encouraged to use the road network. For this reason it is necessary that no exemptions for road charges be allowed. (This will also serve to help achieve acceptance of appropriate pricing levels and structure. It is quite possible that appropriately structured and gradually introduced road damage charges will benefit many road transport operators). Additionally, this will lead to reduced levels of road damage and therefore, greater net benefits.

A resulting benefit is that higher charges for heavy trucks should enable railways to charge higher rates and so lead to a reduction in railway deficits. Of course, this should not remove the need for the railways to improve their efficiency. The overall result should be a more efficient land transport system with each mode carrying traffic for which it is best suited. The cost to the taxpayer and motorist of railway deficits and road damage will therefore be reduced.

The Paper also points to the need to consider the way in which roads are supplied, particularly the extent to which road supply responds to revealed user requirements. Typically road cost recovery studies imply that roads are not used properly without the same implications being applied to road supply.

The analysis in this Paper has been primarily aimed at demonstrating the appropriate cost-recovery methodology, illustrating problems with the studies reviewed and discussing the economic consequences of non-efficient road pricing. Although the results presented are indicative only, it would appear that road pricing in Australia is not optimal. There would be advantage to be gained for both productive and allocative efficiency of the transport sector from an efficient road pricing system.

APPENDIX I SOCIAL COSTS OF ROAD USE

INTRODUCTION

The social cost of road use includes the opportunity cost to society of resources used, as well as the value of any loss in welfare or increase in costs which the activity causes. In the case of road use, social costs include both private costs (those borne by road users) and costs external to users but affecting other groups in the community.

This appendix discusses five different social costs of road use, apart from pavement damage cost, and sets out estimates of their relative magnitude in terms of short-run avoidable cost and total cost. Such a distinction is important because it allows the short-run avoidable social cost to be identified and equated to a certain price or charge which will encourage economic efficiency. That is, road users' decisions will be socially optimal because the charge will correctly reflect the avoidable social cost (that is, the social opportunity cost) of road use.

Whilst this appendix primarily covers short-run avoidable cost (as an approximation to short-run marginal cost), an estimate of total cost is also established. The ideal situation would be to establish a functional relationship between road usage for each vehicle and all marginal costs, but in most cases only rough relationships or orders of magnitude can be established. There are enormous econometric problems in obtaining reliable estimates, therefore the discussion in this appendix is necessarily general and indicative.

As mentioned in Chapter 5, the social costs discussed here include:

- vehicle operating costs
- traffic administration and policing
- accidents among road users
- congestion
- noise and air pollution.

VEHICLE OPERATING COSTS

The Use of NIMPAC Technical Report, which is part of the NAASRA Roads Study, points out that vehicle operating costs (VOCs) 'form the primary quantifiable component of road user costs, and are largely internalised by road users' (NAASRA 1984b, 17). Road users as a group both cause and bear the costs of operating their vehicles. However, each road user, in causing damage to road pavements, increases the operating costs of other users. Thus, the costs are internalised to users as a group but not entirely to the individual user responsible for the cost.

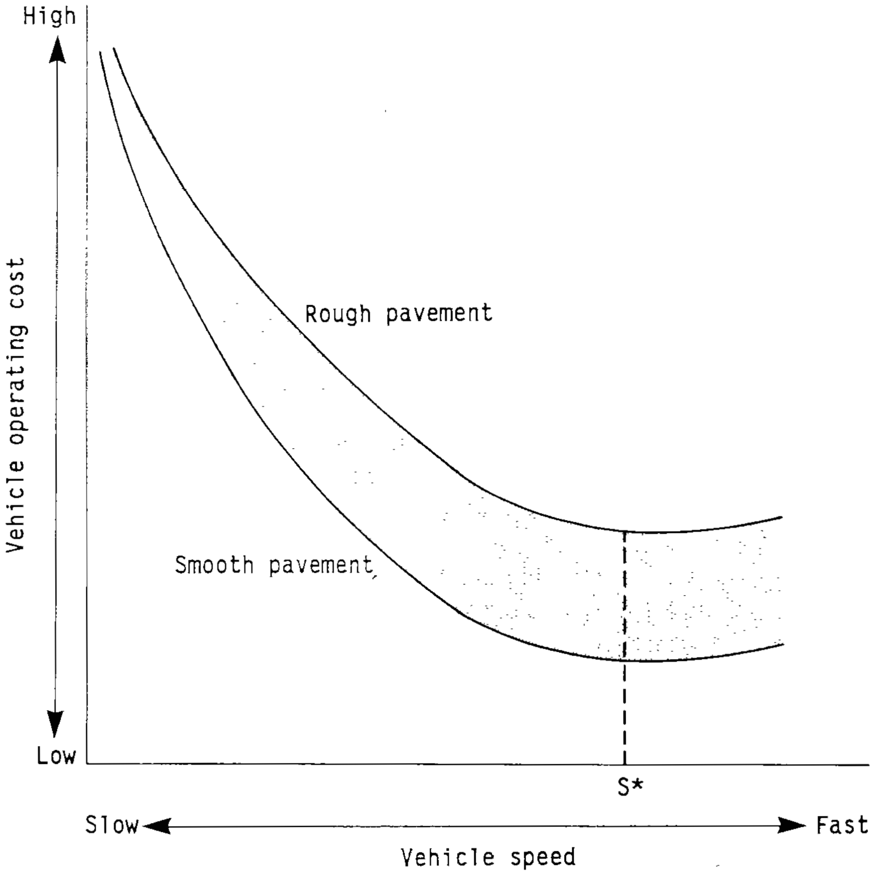
There are four key components of VOC:

- fuel and oil
- tyres
- maintenance
- annualised capital.

Analysis and estimation of VOCs are useful in general because VOCs are a significant part of the total road-user costs. However, there is a shortage of data on VOCs of road transport vehicles.

VOCs for a particular vehicle, primarily depend on speed. However, the roughness, grade and curvature of the road pavement, as well as many other factors, also influence VOC. Figure I.1 shows the combined effect of speed and roughness on VOC. The figure indicates that, up to a point, the faster the vehicle travels and the smoother the pavement condition, the lower are the possible user costs per vehicle-kilometre. Beyond the point S* it would seem that excessive speed incurs increasing VOC, mainly due to increased fuel consumption.

The United States study (US FHA 1982) points out that, while the impact of surface condition on user costs is significant, the empirical basis for relationships developed to date is weak. There are many complicating factors which cannot be captured in a simple relationship such as the one depicted in Figure I.1, which only depends on speed and pavement roughness. For example, a rough pavement (at some point) will reduce speed and thus reduce fuel consumption while increasing vehicle wear. However, the problem is determining where declining fuel consumption from lower speed is offset by higher fuel consumption caused by bouncing and swaying on rougher roads. Additionally, the longer the pavement is left damaged (that is, no maintenance is carried out), the higher are the cumulative VOCs of other vehicles subsequent to the one which caused the damage.



Source NAASRA Technical Report T-7, April 1984.

Figure I.1 The combined effect of speed and roughness on vehicle operating cost

From this it is clear that VOCs cannot be totally explained by speed, but that they are also a function of factors such as:

- surface type
- pavement condition
- horizontal alignment
- volume to capacity ratio (that is, congestion)
- average speed for the vehicle type.

The NAASRA study distinguishes between surface categories as follows:

- unpaved (that is, natural surface, earth formed)
- unsurfaced (that is, gravel or crushed rock pavements)
- surfaced (that is, prime or flushed seal, bituminous or cement concrete).

Pavement condition relates directly to road roughness. The major explanatory variable in the NAASRA model for road roughness is the age of the road (that is, the roughness of the road increases as it gets older). Of course, offsetting maintenance and resealing work has to also be taken into account.

As the United States study (US FHA 1982) points out, a reduction in pavement condition results in increased vehicle wear, fuel and other VOCs as well as increased travel time, accidents and even discomfort. The effect on VOCs (and user costs in general) of such reductions in pavement condition depends on the number of vehicles using the road section and the length of time until the damaged road is restored (that is, maintenance work is carried out). In addition, the passage of heavier axle loads tends to exacerbate an already damaged pavement condition but, as the United States study highlights, the effects of axle loads on user costs are complicated by the multi-dimensional nature of pavement quality and by the interactive effects among user costs.

Changes in horizontal alignment causes negligible change in VOCs. Effects on congestion are discussed separately.

As mentioned earlier there is a shortage of data on VOC. Some BTCE estimates for different types of vehicles are presented in Table I.1. The costs are split into fixed and variable components, with a labour cost component being included for trucks. In all categories the payments for registration, third party and comprehensive insurance and legal liability have been omitted to avoid double counting with respect to estimates of factors such as accident costs which are discussed separately. The estimates for the fixed annualised capital were calculated by multiplying the per vehicle annualised capital cost estimate in each case by the number of vehicles in that category. Variable costs (fuel, tyres and maintenance) were measured as a cents per kilometre cost. For trucks, labour costs were measured per truck hour and split into wages and on-costs, calculations being based on a 40-hour week.

TABLE I.1 ESTIMATED VEHICLE OPERATING COSTS, 1986-87
($ million)

Vehicle type	*Annualised capital*	*Fuel and oil*	*Tyres*	*Main-tenance*	*Wages*	*On-costs*	*Total*
Cars							
Small 4-cylinder	4 111	2 124	312	1 969	..	..	8 516
Medium 4-cylinder	6 842	3 523	484	2 418	..	..	13 267
Family 6-cylinder	5 874	3 281	345	1 684	..	..	11 144
Luxury 6-cylinder	3 359	657	139	458	..	..	4 613
All cars	20 186	9 585	1 280	6 529	..	..	37 580
Rigid trucks							
2 axle	1 325	648	50	235	6 403	942	9 603
3 axle	418	181	28	70	754	112	1 563
All rigid trucks	1 743	829	78	305	7 157	1 054	11 166
Articulated trucks							
<5 axle	260	157	22	60	251	37	787
5 axle	271	200	34	78	260	38	881
>6 axle	777	939	181	374	633	95	2 999
All articulated trucks	1 308	1 296	237	512	1 144	170	4 667
Total	23 237	11 710	1 595	7 346	8 301	1 224	53 413

.. Not applicable.

Source BTCE estimates.

An interesting pattern is clear from Table I.1. Annualised capital cost as a proportion of total VOC increases with car size (for example, 48 per cent for small four-cylinder cars and 73 per cent for luxury six-cylinder cars). However, the larger cars spend proportionally less on fuel (14 per cent for luxury six-cylinder cars versus 25 per cent for small four-cylinder cars) and maintenance (10 per cent for luxury six-cylinder cars and 23 per cent for four-cylinder cars). Fuel, oil and maintenance represent such a small proportion of total VOC for luxury cars because annualised purchase costs are so high on luxury cars.

Figure I.2 shows graphically the proportion of VOCs for the three main vehicle types. It indicates that car operating costs represent the largest proportion of total VOC, approximately 70 per cent ($37 580 million).

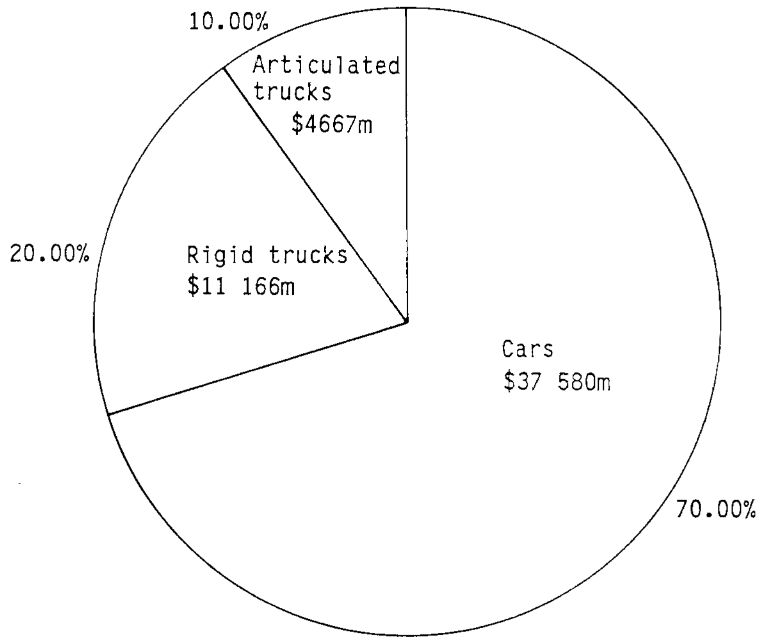
Rigid trucks represent approximately 20 per cent of total VOC ($11 166 million). Articulated trucks account for a further 10 per cent ($4667 million).

Trucks with more than two axles have a large portion of their VOC represented by annualised capital (30 per cent for five-axle articulated trucks and 14 per cent for two-axle rigid trucks). This reflects the sizeable jump in retail cost of trucks with more than two axles.

From Table I.1 a breakdown of VOC into fixed and short-run avoidable costs is possible, the former being represented by annualised capital and the latter by fuel and oil, tyres, maintenance, wages and on-costs. This breakdown, which is shown in Figure I.3, is important because it indicates what proportion of total VOCs are directly related to road use. In this case, the short-run avoidable component of VOC amounts to over $30 000 million.

The relationship between these short-run avoidable VOCs and road roughness (due to an increased number of ESALs) is of particular interest. Since negligible damage to roads is attributable to cars, trucks will be the major contributors to increases in road roughness and the resulting increases in VOCs.

The multi-dimensional nature of VOC and the inter-relationships between many of its components, make it difficult to set up a *functional relationship* which explains the increase in VOC due to an increase in roughness caused by an additional vehicle using the road. To properly capture changes in VOC, many, if not all of the factors listed in Table I.2, would have to be included in an explanatory model. Mathematically, this task is extremely complicated. This problem is compounded by the fact that some of the causal relationships between factors are not fully known or understood.



Source BTCE estimates.

Figure I.2 Vehicle operating cost by vehicle type, 1986-87

It is therefore very difficult to estimate the additional VOC due to the increased roughness caused by an extra vehicle using the road. The problem of aggregate estimation is even more complex.

Abelson (1986) points out that the two main problems in estimation of VOC are:

- isolating the effects of road conditions; and
- that established cost relationships are out of date in terms of today's vehicles due to technological changes.

This is certainly the case for the two main sets of estimates of VOC in Australia. The NIMPAC model, which has cost functions which were established between 1968 and 1973, is used for rural roads. The standard formulae used to estimate VOC in urban areas, rely heavily on parameter estimates of Both and Bayley (1976).

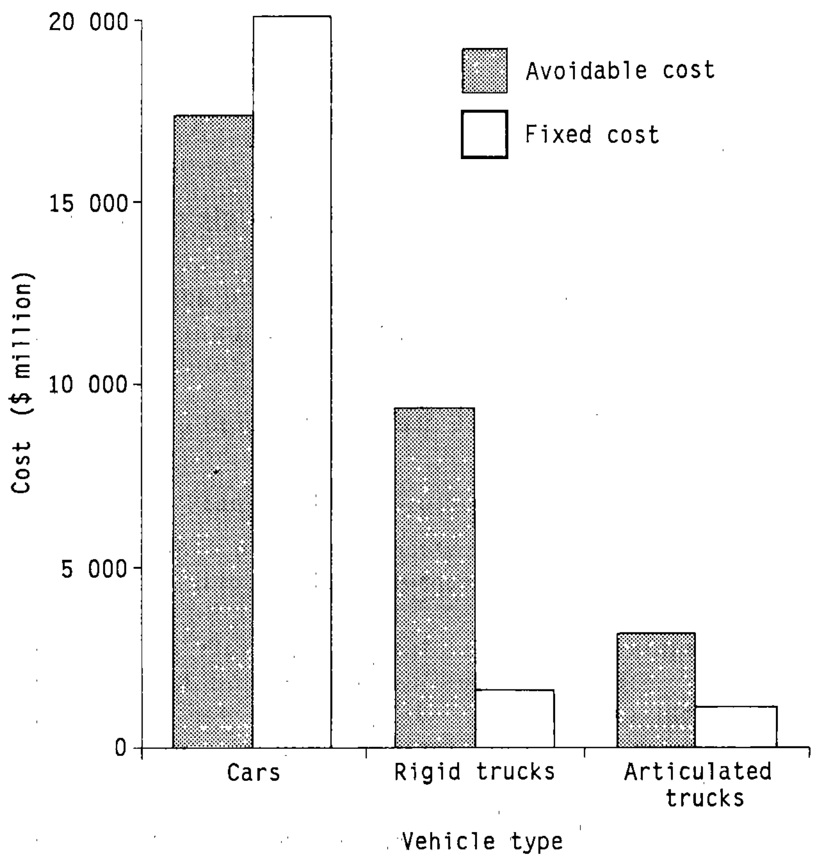
As Abelson points out, the NIMPAC estimates highlight two things: first, that improvements in road surfaces and conditions result in a reduction in VOC, but that these savings may be partly offset by increased VOC due to increased speed; and second, that increased congestion and grades 'significantly' increase VOC, but that changes in road curvature does not. Table I.3 (adapted from NIMPAC results shown in Abelson 1986) shows the percentage of VOC saved from moving from a worse road to a better road for various road and vehicle types.

The standard formulas used to estimate VOC in urban areas in Australia are:

For surface roads : $C = A + B/V$
For freeways : $C = C_0 + C_1V + C_2V^2$

where

C = cents per kilometre
V = kilometres per hour
and A, B, C_0, C_1 and C_2 are constants (parameters which vary with vehicle type).



Source BTCE estimates.

Figure I.3 Indicative vehicle operating cost, 1986-87

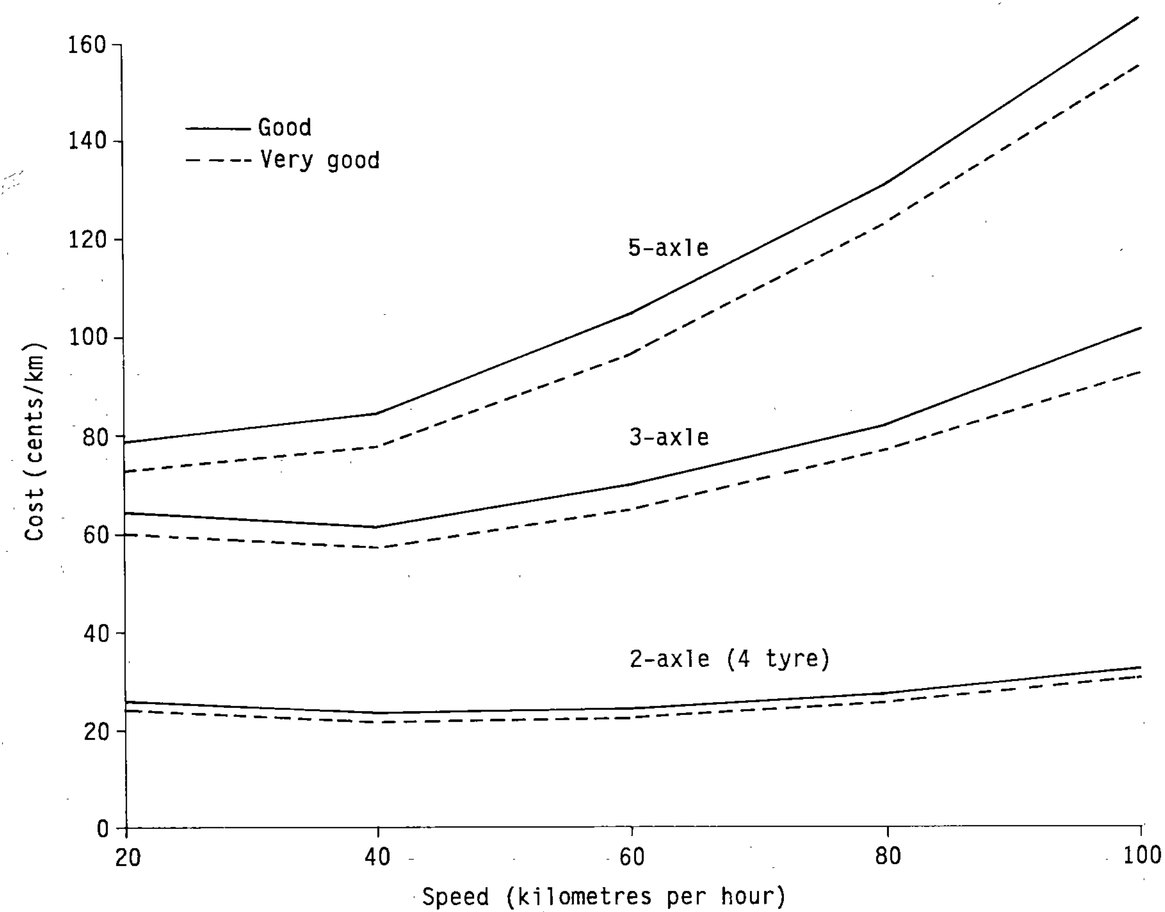
TABLE I.2 FACTORS INFLUENCING VEHICLE OPERATING COSTS

Factor	*Fuel and oil*	*Tyres*	*Maintenance*	*Annualised capital*
Pavement type	x	x	x	x
Pavement roughness	x	x	x	x
Geometric features of the road	x	x	x	
Congestion	x	x	x	
Volume capacity ratio (VCR)	x	x		
Traffic composition	x	x		
Average operating speed	x	x		
Axle loadings and configurations	x	x		
Type, size and pressure of tyres	x	x		
Suspension systems	x	x	x	
Timeliness and level of maintenance	x	x	x	x
Environmental factors	x	x		
Acceleration/ deceleration	x	x	x	
State of tune of vehicle	x	x	x	x
Gross vehicle weight	x	x		
Age of vehicle	x	x	x	x
Fuel and oil prices	x			
Tyre price		x		

Source BTCE estimates.

Abelson, using the NAASRA recommended values for the parameters, found that the VOC and speed relationship on freeways is U-shaped, with VOC first falling and then rising with increases in speed.

Despite the difficulties outlined, the studies that have attempted to measure this, at least give an indication of what could, be expected. Figure I.4 shows that the NIMPAC results, listed in Table I.3, of VOC savings from moving from a good to very good surface road, are in the order of 7 to 8 per cent.



Source Abelson (1986).

Figure I.4 VOC savings of moving from a good to a very good road condition

TABLE I.3 AVERAGE VOC SAVINGS BY MOVING FROM A WORSE TO A BETTER ROAD CONDITION

(per cent)

Road condition change		*Vehicle type*			
From	*To*	*Cars*	*2-axle trucks*	*3-axle trucks*	*5-axle trucks*
Earth	Poor gravel	21	26	24	22
Poor gravel	Good gravel	12	14	13	12
Good gravel	Poor surface	13	15	14	12
Poor surface	Good surface	13	13	13	14
Good surface	Very good surface	7	7	8	8

Source Abelson (1986).

Using this approach and VOC savings estimated in the RoRVL study, approximately 3 to 4 per cent of avoidable VOC (that is about $900 to $1200 million in 1986-87) is due to increased road roughness. This was arrived at with the assumption that, for the whole spectrum of road types in Australia, an average 'good' road becomes a 'bad' road in six years, and assuming that no maintenance or restorative work is carried out at all.

This is an additional amount of avoidable pavement damage cost to the $2000 million estimated in Chapter 5 of this Paper. That is, the true total may be closer to $3000 million in 1986-87. It has not been allocated among road users and included in the cost recovery estimates for several reasons. First, it is only indicative of nature; the true amount may be quite different. Second, like congestion, it is already internalised to road users as a group (although probably being a cross-subsidy from motorists to heavy vehicle operators) and they are paying for it indirectly. Third, the nature of the trade-off between savings in vehicle operating costs and higher road maintenance expenditure is not perfectly clear and is probably not being optimised.

More detailed discussion on VOC is contained in BTE (1982c), Abelson (1986) and various NAASRA and ARRB reports.

TRAFFIC ADMINISTRATION AND POLICING

Costs considered under this heading include traffic administration, traffic facilities (that is, traffic lights, line markings, street signs and so on) and police services related to traffic. These are generally the range of items considered by the McDonell Enquiry (1980). Many costs of traffic administration and policing are fixed. To the extent that these costs vary in a direct or indirect way with the level of road usage, they should be included in efficient road use charges.

Once again, however, data problems arise. In Australia's case, each State classifies costs differently. Also, while some figures appear in one State's reports, they do not appear in others. Aggregation of many expenditure items is widespread and many expenditures do not appear in road-related budgets. Nevertheless, some estimates of these expenditures, as far as level of road use is concerned, are available. These are summarised in Table I.4.

Although Auditor-General's and State Road Authority annual reports include figures for 'police costs' these usually do not indicate the proportion which is directly related to road traffic. This was indicated in the Travers Morgan report (1985) prepared for the South Australian Road Cost Recovery Study. The estimates presented in that report were extrapolated to provide Australia-wide estimates for 1986-87.

TABLE I.4 ESTIMATED TRAFFIC ADMINISTRATION, POLICING AND TRAFFIC FACILITIES COSTS, 1986-87
($ million)

Cost	*NSW*	*Vic*	*Qld*	*SA*	*WA*	*Tas*	*Total*
Payment for police service	152	124	78	41	51	14	460
Payments to traffic facilities fund	56	46	29	15	19	5	170
Adminis-tration	50	41	26	14	17	5	153
Total	258	211	133	70	87	24	783

Source BTCE estimates.

The figure for the traffic facilities fund for New South Wales is from the 1985-86 Auditor General's Report. Estimates for other States were obtained by allocating the total estimated cost in proportion to the number of vehicles in each State.

Due to the difficulty in obtaining a definitive break-up into fixed and short-run avoidable costs, the summary table (Table I.7) presented at the end of this appendix shows only a total figure.

Other costs and/or expenditures which could be included under this heading include public court costs related to traffic enforcement, liability litigation, public costs of accidents, retrieval of stolen vehicles, and so on. To some extent, some of these are discussed elsewhere in this appendix.

ACCIDENT COSTS

Accident costs are also part of the avoidable cost associated with road use.

While most of the accident costs are internalised, there are other associated costs which are not. The Federal Office of Road Safety (1983) uses two broad categories: personal costs, and community costs. The former are costs borne by the road crash victims and their families. Community costs involve those costs which are borne by the community as a whole (including many non-road users), and includes some expenses of government and some private community service bodies.

A further disaggregation can be made. Road crashes involve ex-post (that is, after the accident) and ex-ante (that is, before the accident) costs. BTCE (1988) includes some estimates of annual ex-post costs for 1986-87 using an adjusted income method:

- loss of earnings ($946 million);
- vehicle damage ($1618 million);
- hospital and medical services ($213 million);
- court and legal costs ($165 million);
- insurance administration ($305 million);
- accident investigation ($115 million);
- losses to others ($35 million); and
- traffic delays ($253 million).

Ex-ante costs (some of which have been included in the cost recovery calculations) are the costs of reducing and/or preventing crashes. They include: better roads, safety signs, traffic lights, traffic legislation, road traffic law enforcement personnel, safety standards, and so on. These costs are harder to isolate from general road construction and maintenance costs. They are generally provided for through normal road funding arrangements.

Table I.5 shows the total costs of various types of road accident in Australia in 1986-87 to be over $5500 million. This amount represents an economic cost to the Australian community equal to approximately 2 per cent of Gross National Product.

The United States study states that, since the marginal cost of an accident of a particular vehicle is the extra accident cost that arises from adding that vehicle to the traffic stream, then 'each vehicle should pay the costs that could be avoided were that vehicle to be removed from the stream' (US FHA 1982, E-37). This involves calculating the marginal accident cost of that additional vehicle and using this to set the efficient 'road accident' price.

Accident costs are related to congestion levels, the type of vehicles in the traffic stream, the speed at which vehicles are travelling, the condition of the road surface and driver behaviour. Trying to estimate the cost of an accident while allowing for such relationships is extremely difficult. For example, each type of damage arising from

TABLE I.5 ESTIMATED TOTAL COSTS OF VARIOUS TYPES OF ACCIDENTS, 1986-87
($ million)

Type of accident	*Cost of accident*
Where a fatality occurred	1 283
Where there was a critical injury	177
Where there was a severe injury	884
Where there was a moderate injury	1 271
Where there was a minor injury	883
Where there was only property damage	1 022
Total	5 520

Source BTCE estimates.

an accident would have to be incorporated in a marginal cost calculation. Furthermore, some of these damage costs have valuation problems. The United States study (US FHA 1982) states that for major personal injury and fatalities, the basis for evaluation is quite obscure and the private insurance system may ignore some costs and misjudge others. On the other hand, the private insurance system seems to adequately cover costs of restoration in regard to damage to private property and minor personal injury.

There is also some question over whether public property damage (and other public costs) should be covered in total damage costs. Such costs are often not covered in damage payments. This is also frequently the case for the cost of many of the public services provided.

The United Kingdom Government considered whether or not to charge users for the public costs of accidents. The Government rejected this approach arguing that double taxation would emerge. Road users were already paying part of public accident costs in national insurance payments and charging road users would discriminate against them, relative to other industries which did not have to pay for the costs they cause to the public. However, Fowkes et al. disagree with this line of argument pointing out that:

> There is no doubt whatsoever that these costs are part of the marginal social cost of road transport and *should* be treated as such... (Fowkes et al. 1984).

For efficiency to be satisfied, public property damage should be covered in total damage costs. Resource costs are involved in repairing public or private damage and these should be charged directly.

When only one vehicle is involved in an accident (for example, a vehicle running into a tree), expected cost to those involved is the same as the marginal cost. In this context, the insurance premium may reflect this expected cost of the accident. Subsequently, there is no difference between the cost to the driver and the cost to society, assuming that the insurance covers all costs.

However, when two or more vehicles are involved in an accident, the marginal cost is the total cost of the accident. This somewhat counter-intuitive result, stems from the principle of paying for all costs that could be avoided were either of those vehicles not using the road. The liability for the accident is not important in this context. The accident could have been avoided by either driver staying off the road. Consequently, at the margin (that is, deciding to use the road at that time) the cost of the accident is equal to the total cost. Ideally, however, an efficient road user charge for road accidents, should reflect the fact that there is a degree of causality in accidents. Calculation of an efficient charge should also take risk into account.

As noted earlier, the level of traffic and congestion has a bearing on accident costs. For example, fatalities are less likely in slow moving, congested traffic streams. In such an environment the number of accidents will most likely increase but the cost per accident may be lower.

Another relationship which could be included, is that, as the size of the car increases, so does the cost of the accident, all other things being equal. However, this will vary depending on the type of vehicle, the mix of vehicles in the traffic stream and the compatibility of this mix. For example, adding a light vehicle to a traffic stream of mainly larger and heavier vehicles would make it more prone to greater damage costs resulting from an accident.

Attempting to incorporate all the above relationships in a marginal accident cost relationship is fraught with difficulties. These problems range from valuing the loss of a human life to allocating the damage costs of a multiple vehicle accident. The United States' study omitted its marginal accident cost calculations stating that 'the results are small in magnitude and not especially plausible' (US FHA 1982, E-37).

CONGESTION COST

Congestion cost is a measure of the value of additional resources used because the system is utilised beyond its designed capacity level. Usually, the most substantial component of increased resource costs due to congestion on roads is time delay cost. Other components of congestion cost may include higher vehicle operating cost, higher traffic administration cost and higher accident cost. Generally, congestion is influenced by the nature of the speed-flow relationship on roads and the speed-cost relationship for vehicles.

Congestion costs are mostly internalised to all road users, as a group, in that they cause and bear the costs of congestion. However, it is important to note that each individual road user does not bear the full costs of the time delays and so on, that he imposes. The South Australian Road Cost Recovery Study points out that, congestion costs are not very useful as far as the cost recovery debate is concerned, because they are 'internal to the road user sector as a whole' (Travers Morgan 1985, 78). However, 'if economic road pricing in urban areas were to become a policy issue, then it would be valid to consider charging road users as a means of achieving more optimal levels of traffic flow. In that case, the correct approach would be to charge all road users in the areas at times of interest, the difference between the average and marginal congestion costs, defined as the marginal external congestion cost'. In this way, the avoidable cost of congestion is internalised to the decision-maker. In this manner, marginal cost pricing incorporating congestion cost is used to achieve optimal congestion levels in order to influence an economically efficient allocation of resources.

The Travers Morgan study (1985) attempted to quantify congestion cost on a per vehicle-kilometre basis, this being equal to the difference between the total cost of travel per kilometre in uncongested circumstances and the total cost of travel in congested circumstances. This was expressed in the form:

$$\text{Total congestion cost per vehicle-kilometre} = \frac{T}{S_a} - \frac{T}{S_f} \qquad (1)$$

Where,

T = value of time savings (\$/vehicle/hour),
S_a = average speed (kilometre/hour),
S_f = free flow speed (kilometre/hour).

Such a relationship is multi-dimensional. Average speed and free flow speed are affected by such things as peak period flow, capacity and width of lanes.

Marginal social cost is equal to the additional private cost of making the trip at the existing level of congestion plus the marginal external congestion cost. The Travers Morgan study (1985) expressed this as:

$$MC = C + X \frac{dC}{dX} \qquad (2)$$

Where,

C = the additional cost of the trip at current congestion levels,
X = peak period capacity, with $X\frac{dC}{dX}$ equal to the marginal external congestion cost.

There have not been any recent studies aimed at estimating the total level of congestion cost in Australia. Consequently, only a rough estimate can be made of the magnitude of these costs. One guide would be to extrapolate from the current level of expenditure on urban arterial roads in Australia since it has been demonstrated in many studies (for example, the various roads studies of the BTE and NAASRA), that more than the current level of expenditure on these roads can be justified on benefit-cost grounds. A major benefit of improving or maintaining urban arterial roads is reduced travel time.

The current level of expenditure on urban arterial roads is of the order of $900 million. Recent road studies (for example, BTE 1984b) have shown high benefit-cost ratios (many over 4 to 1) for urban arterial road works, much of the benefits being due to reduction in congestion. As well, there is congestion on other roads (particularly on many urban local roads being used as sub-arterials as noted in BTE, 1987b). Assuming an average benefit-cost ratio of 2 to 1 for urban arterial roads, plus some congestion on urban local roads, would indicate total congestion costs of the order of $2000 million per annum. This is, of course, a speculative figure, but nevertheless is a guide to the order of magnitude of congestion cost, vis a vis other social costs of road use.

Table I.7 allocates the total estimated congestion cost of $2000 million as a short-run avoidable cost because congestion by its very nature is avoidable.

BTE (1985b) points out that there is little evidence in Australia to suggest that congestion has become worse in recent years. A decision to introduce a congestion pricing scheme in Australia would itself require a benefit-cost analysis. For example, a system such as the electronic monitoring system of Hong Kong, with its high implementation and administration costs, must imply high benefits from lower congestion levels. In contrast, a scheme such as the Singapore system of area licences and increased parking charges, with its lower cost, could be justified by a much lower level of benefits per unit of cost. However, whilst these systems may work well, their success is largely due to the unique geographical circumstances of Hong Kong and Singapore. Similar systems in a city like Sydney, for example, may simply move the congestion elsewhere because of the city's expansive spatial distribution and scattering of other business districts and regional centres (for example, Parramatta, North Sydney and Chatswood).

Australian cities, as a whole, have not suffered the chronic congestion problems of many cities overseas. However, there are now indications that this situation will change in the future. For example, the proposed construction of the Sydney Harbour Tunnel and the Monorail, highlight the fact that Sydney has reached a stage where it must look at a variety of alternative proposals to alleviate its growing congestion problems.

A pricing scheme with the aim of rationing congestion levels should also be included amongst any list of proposals regarding congestion. It is possible that some high-profile projects to alleviate congestion would not be considered worthwhile if congestion was properly priced. However, a pricing scheme will most likely be supplementary to other congestion-reducing measures. The revenues (and costs) from pricing congestion act as an incentive to provide such measures (for example, increased road capacity, tunnels, bridges, buses, park-and-ride systems, car pooling networks and so on).

NOISE AND AIR POLLUTION COSTS

Pollution costs are reflected in health, materials, vegetation and discomfort costs and are a negative externality. As with other externalities, the aim is to internalise these costs so that individuals and producers will take them into account in decision-making. Ideally, taxing the source of the pollution according to the amount of damage caused will reduce the externality to a socially efficient level. However, attribution of the cost among vehicles is not clear.

Exhaust from road vehicles is the most significant aspect of air pollution in relation to road use. Rattray and Robinson (1986) point out that the main source of carbon monoxide and lead particles in exhaust gases comes from petrol engines. Vehicles operating on diesel fuel emit 'considerably less' of these compounds, even though they emit ten times as much smoke and other particulate pollution.

It has been estimated that transport (of all kinds) in the United States was responsible for only 7 per cent of particulates and 3 per cent of sulphur oxides in 1975. Abelson (1986) goes on to state that the health effects of carbon monoxides, hydrocarbons and nitrogen oxides are particularly unclear, although there is a definite illeffect on people with cardiovascular and respiratory problems. Due to the uncertainty about the relationship between health standards and traffic, and because of the small proportion of particulates and sulphur oxides attributable to road use, attempting to cost and price the health effects of road traffic may not be a very precise exercise.

Noise pollution (that is, tyre noise, engines, braking, horns and so on) is difficult to cost because of the subjective nature of what an acceptable noise level is. The cost of such noise, in terms of its effect on health and comfort, becomes much more a matter of judgment.

Noise levels are determined by the interaction of traffic flow, vehicle characteristics, composition of speed variables with topographical and meteorological factors. There are also many other fairly subjective considerations in trying to establish the cost of noise levels. These include, for example, interference with conversation and sleep, headaches, nervousness, hearing loss and reduced benefits from television and hi-fi equipment.

Reducing noise levels at the source may be the most cost-effective approach to take. Other avenues which could be taken might be to erect sound barriers or insulate buildings, but in many cases the costs are prohibitive.

The United States study (US FHA 1982) also highlights the degree of non-linearity in the relationship between pollution and damage costs. For example, adding one extra vehicle to an already noisy street may result in little marginal damage even though the average impact might be high. The United States study also points out a possible 'dose-response' relationship where some percentage of the population is highly sensitive to impact while other groups are largely insensitive. Such a situation would mean that charging one particular price might not reflect the real cost of damage resulting from pollution to certain individuals.

Noise is measured by decibel units (db(A)). This measure relates to the responses of the human ear to noise. The McDonell Report (1980) points out that it has been widely accepted that the following noise levels should not be exceeded for more than 10 per cent of the time during the day:

- Country areas 40 db(A)
- Suburban areas 45 db(A)
- Busy urban areas 50 db(A).

Various studies have attempted to estimate the cost of noise and air pollution by considering the effects on property values. United States figures for noise pollution suggest a 0.4 per cent fall in market value of properties per decibel unit above what is deemed to be the acceptable level of noise.

One study on noise pollution was conducted into noise levels in the city of Wollongong and three sites in the Metropolitan area of Sydney for the McDonell Enquiry (1980). The results show that a great proportion of medium and heavy trucks operate at high and, in many cases, 'unacceptable' noise levels. In such a situation, heavier trucks should pay proportionally more to cover the full marginal social cost of the noise pollution, if an efficient charge were to be levied.

Fowkes et al (1984) point out that alternative modes of transport to road vehicles, such as rail and water transport, have much lower environmental costs. Thus, not pricing for noise and air pollution causes a relative distortion. It does not discourage the use of heavy vehicles and especially larger bulk vehicles and will tend to increase the environmental cost imposed upon society beyond the point where there are net benefits.

From a theoretical point of view, a zero level of noise and air pollution is not the most efficient result. Instead, the optimal situation is when the discharge of pollution is reduced to a level where the marginal cost of pollution and the marginal cost of pollution control are equal (as at R, in Figure I.5). Such a situation is more likely to come about if these environmental costs are priced. There is then an incentive for users to reduce the damage costs by whatever means to optimal levels.

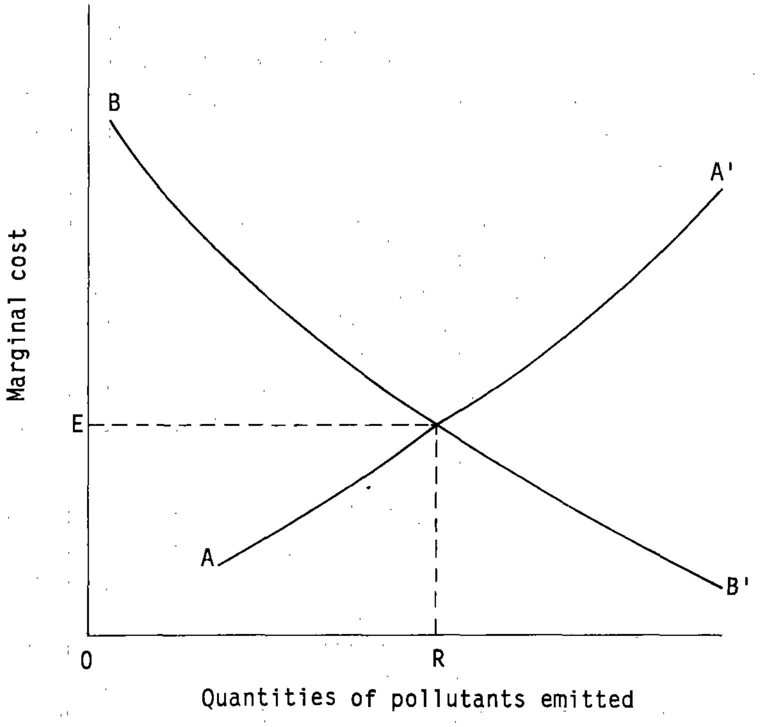
Pollution control cost figures presented in Table I.6, are based on an estimate obtained from the New South Wales' State Pollution Control Commission for costs associated with the enforcing of environmental standards for vehicle operations. Amounts for other States were allocated on the proportion of vehicles using the roadways in those States. At the least they form a lower bound to estimated pollution costs. If a recent estimate was available for health and discomfort costs due to pollution, the figures presented in Table I.6 may well be an order of magnitude or more higher. Due to this constraint, there is no indicative measure of pollution cost to include in Table I.7 which summarises the (non-road expenditure) social costs of road use.

TABLE I.6 ESTIMATED ROAD VEHICLE POLLUTION CONTROL COSTS, 1986-87
($ million)

NSW	*Vic*	*Qld*	*SA*	*WA*	*Tas*	*Total*
0.9	0.8	0.5	0.3	0.3	0.1	2.8

Source BTCE estimates.

All road-user pollution costs are avoidable because, like congestion costs and most accident costs, they arise directly as a result of users' decisions to use the road system.



where,

- AA' represents the marginal cost of one extra unit of waste discharge;
- BB' represents the marginal cost of reducing discharge of waste by one unit.

Figure I.5 Marginal cost of pollution and marginal cost of pollution control

TABLE I.7 SUMMARY OF ESTIMATED SOCIAL COSTS ASSOCIATED WITH ROAD USE, 1986-87

($ million)

Costs	*Short-run avoidable costs*	*Fixed costs*	*Total*
Vehicle costs			
Cars	17 394	20 186	37 580
Rigid trucks	9 423	1 743	11 166
Articulated trucks	3 359	1 308	4 667
Total	30 176	23 237	53 413
Accident costs			
Administration, policing and traffic facilities	na	na	783
Pollution (noise and air)	na	..	na
Congestion	2 000	..	2 000

na Not available.
.. Not applicable.

Note Owing to rounding, figures may not add to totals.

Source BTCE estimates.

OVERVIEW OF SOCIAL COSTS

Table I.7 presents a summary of estimates of five social costs of using the road system which are discussed above (that is, excluding pavement expenditures). The costs are broken up into estimated short-run avoidable cost and fixed cost.

From Table I.7 it is quite clear that over half of all VOCs are avoidable in the short-run, and are the largest of all the social costs listed. Consequently, they represent the largest proportion of social costs in relation to total road-user costs. The short-run avoidable components of VOC, traffic administration and policing, accident, congestion and pollution costs, with the addition of the $2000 million avoidable pavement damage cost estimated in Chapter 5, may roughly indicate that the total marginal social cost of using roads was over $40 000 million 1986-87.

Consideration of all such social costs as those above indicate that there is a difference between the price paid by the road user and the marginal cost to society. This gap is the difference between social and private costs and can only be closed by efficient charges.

APPENDIX II GOVERNMENT REVENUE FROM ROAD USE

This Appendix discusses a range of charges and taxes that the three levels of government levy on road-use related activity.

Each revenue item is classified to the three main sources of revenue open to governments. These are economic rents, general taxation and specific charges. Economic rents, as discussed in Chapter 2, arise due to government ownership of a resource. Thus, revenues earned on this basis should not be included in a road cost recovery assessment. Revenue derived from the other two sources may be included, depending in part upon the aim of the assessment. The appropriate allocation of such revenue, in terms of the definitions outlined in Chapter 2, is discussed below. This discussion is used in turn in determining the revenue contributions from various road user groups which are presented in Chapter 5.

EXCISE ON MOTOR SPIRIT AND DIESEL

The Federal Government levies an excise duty on motor spirit and automotive distillate. The excise rate was about 25 cents per litre in June 1987, but only about 25 per cent of the revenue from this duty was hypothecated to road works under the Australian Bicentennial Road Development (ABRD) Program and the Australian Land Transport (ALT) Program. All Federal fuel excise rates are indexed (twice yearly) to increases in the Consumer Price Index (CPI).

The excise is generally considered to be a road-user charge as it applies basically only to road users and it varies directly with road use. A rebate applies in the case of most non-road use. A road user making a decision to use the road system contributes to this revenue.

Narrow definitions of road-user charges might not include either that proportion of fuel excise revenue which is not hypothecated to road works, or that proportion of fuel excise revenue which is intended as a general taxation measure. In the budget speech of August 1986, the Treasurer indicated that a large proportion of the fuel excise charge was intended as a general taxation charge. In this Paper, all of the revenue raised from the Federal fuel excise is treated as road cost recovery revenue.

CRUDE OIL LEVY

This tax is levied on crude oil produced in Australia from oil fields which were discovered before 18 September 1975, termed 'old' oil. At the time the levy was introduced in 1977, the Federal Government relaxed controls over the price at which crude oil could be sold to refineries by introducing a policy of import parity pricing. The concept of import parity pricing is designed to ensure that prices for domestically produced crude oil reflect international prices and hence the opportunity cost of the oil. As a result, oil subject to the production levy (that is 'old' oil) could be sold to refineries at only the same price (approximately) as oil not subject to the levy (that is 'new' oil). Thus, the price to consumers is the same whether the tax is imposed or not. The rate of the levy, however, will vary according to the field involved.

The levy is earned as a resource rent, not as a road-user charge. It is also applied to producers of oil rather than users of roads, and cannot be considered as a consumer charge. A similar argument applies to State petroleum royalties. It is recognised, nonetheless, that these levies, as with other rent levies and taxes, will still have an effect on the level of road use. The issue here, however, is that road use should not be treated differently to other sectors in the application of charges and collection of general taxation.

PETROLEUM FRANCHISE LICENCE FEES

Franchise fees on fuel retailers and wholesalers were introduced in five States between 1979-80 and 1982-83. These fees replaced road maintenance charges which were abolished in June 1979. They take the form of an annual licence charge and a unit charge based, in most States, on the wholesale price, but, in Western Australia it is based on quantity of fuel sold. Queensland and the two Territories do not have fuel franchise fees.

Revenue from these fees is regarded as a road-user charge in this Paper as they are paid largely on fuel used by road vehicles. In addition, the motorist's contribution varies with the use made of the road system. In practice, most of the revenue collected from the franchise fees is allocated to road works, even though very little is legally required to be spent on roadworks. In New South Wales only the revenue raised on diesel fuel is hypothecated to road expenditure.

CUSTOMS DUTIES

The Commonwealth levies a duty on imported motor spirit and diesel, as well as on motor vehicles and parts. Customs duties are generally considered as a measure to protect Australian made goods although they do, of course, raise revenue for the Government as well. They are paid on a wide range of goods, not just those related to road use. Revenue from customs duties, therefore, has nothing to do with road-user charges. An exception may be the duty charged on imported refined petroleum. In this case customs duty is charged at the same rate, and instead of, the excise duty which applies to domestically refined petroleum. The amount of revenue from this source is negligible and so does not affect the analysis.

SALES TAX ON MOTOR VEHICLES, TYRES AND PARTS

Sales taxes apply to a wide range of goods and services as a part of the Federal Government's overall taxation strategy. Sales tax applies on the sale of all plant and equipment unless these are aids to manufacture or are specifically exempted from sales taxes. Trucks and other vehicles are regarded as not producing output and are specifically excluded from the list of exemptions.

The Federal sales tax, therefore, applies to the sale of all motor vehicles (except buses), tyres and parts. It does not vary directly with road use (with the possible exception of sales tax on tyres) and the rate at which it is applied is similar to the rates applied to a range of other goods. Sales taxes form part of the revenue raised as general taxation and so are not a specific charge for road use. This is regardless of any arguments for exemption of vehicles which contribute to the productive process.

VEHICLE REGISTRATION FEES AND TAXES

Vehicle registration fees are levied in all States and Territories. The amount paid varies by vehicle type, with heavy vehicles generally paying more. The Federal Government introduced an interstate registration fee on 1 January 1987. Interstate vehicles paid only a nominal amount in the second half of the 1986-87 financial year.

These charges are specifically directed at road users and most of the revenue is hypothecated to road expenditure.

DRIVERS' LICENCE FEES

Drivers' licence fees are charged in all States and Territories and are specifically directed at drivers of all vehicles. As such, they are a charge for road use.

The revenue raised from these charges is not all hypothecated to road expenditure but some of the revenue is used to meet the costs of traffic administration such as policing, as well as road safety education, various State Department of Motor Transport costs and so on.

ROAD TRANSPORT CHARGES

All States except Tasmania levied a variety of charges on heavy vehicles prior to 1980. Generally, these were applied for the purpose of regulating road and rail competition. These charges have since been almost completely abandoned as part of the deregulation of competition between road and rail. One of the most significant of these charges was the road maintenance charge which was abolished in 1979.

In some areas, some revenue is still raised from heavy vehicles in the form of a road maintenance charge. This occurs on logging trucks using some roads in Tasmania, for example.

Revenue raised from road transport charges in 1986-87 is likely to have been relatively small. The charges are unique to road users and so can be considered as road-user charges.

STAMP DUTY ON VEHICLE REGISTRATION

Stamp duty is charged on each transfer of vehicle ownership in every State and Territory. The duty is generally based on the transfer price of the vehicle and does not vary directly with road use. Stamp duties apply on a wide range of transactions not just those related to road use. Their purpose is to raise general taxation revenue rather than to recover road expenditure.

OTHER CHARGES

A variety of miscellaneous charges are applied to road users. These include parking fees, road and bridge tolls, number plate fees and so on. Most of these can be regarded as specific fees for a specific service provided to road users. As they are applied by a large number of departments and authorities on a wide range of services, the amount of revenue earned overall has not been ascertained nor the amount applied to road works. Some incomplete estimates are included in the Nicholas Clark and Associates study (1984) and in BTE (1987a). As the charges are generally applied to specific services other than provision or maintenance of the road system infrastructure, it can be argued that most of these should not be included in an assessment of infrastructure cost recovery.

APPENDIX III UNITED STATES PAVEMENT CONSTRUCTION COST ALLOCATION MODELS AND DAMAGE RELATIONSHIPS

This Appendix examines in greater detail pavement construction cost allocation models and damage relationships used in the United States' study (US FHA 1982 and 1984). The pavement construction cost allocation models determine the savings in pavement thickness achieved by hypothetically removing vehicles in the manner described in Chapter 4. The damage relationships relate magnitudes of pavement distress to ESALs.

REHABILITATION

Due to the importance of concrete roads in the United States' interstate highway system, rigid and flexible pavements were examined separately. Models were developed for a number of pavement distresses. Each of the models relates a normalised measure of the magnitude of the distress (D) to accumulated traffic (T), the amount of traffic required to cause a defined amount of damage (W) and an exponent to express the shape of the deterioration curve (B). The equations take the form $D = (T/W)^B$. Besides being related to traffic, road damage is also related to environmental factors, soils and pavement strength through the parameters B and W.

Without environmental effects and the effects of soil strengths, the fourth power rule would be followed (sixth power for rigid pavements), but the interaction of weather and traffic leads to the adoption of a lower power in the formulation. Thus, rather than introduce additional variables to account for the environment or soil strength, the fourth power rule is modified. This affected the relative responsibility of different axle loads and thus different truck types. In the case of rigid pavements, factors such as depth of pavement also interact with ESALs. Table 4.4 shows that only 5 per cent of pavement rehabilitation costs could not be attributed, at least partly, to traffic or vehicle characteristics with the models. The balance of costs were thus deemed to be related only to the effects of weathering or were purely joint or common costs.

FLEXIBLE PAVEMENTS

Models relating the magnitude of the distress to ESALs and thus to pavement strength, asphalt thickness, soil strength and climatic conditions, were developed for each of the following flexible pavement distresses:

- loss of serviceability
- alligator cracking
- rutting
- transverse cracking
- loss of skid resistance.

Both the loss of serviceability and rutting relationships were found to be close to the fourth power rule, while other distresses were more highly related to the level of traffic and weather effects. Loss of serviceability included deterioration due to expansion of clay subgrades, which was not related to traffic. Transverse cracking included thermal cracking (also not related to traffic) while loss of skid resistance was found to be related to the number of tyre passes, not ESALs.

RIGID PAVEMENTS

Models were also developed for rigid pavement distresses, relating the magnitude of the pavement distress to ESALs and also varying with pavement strength, subgrade stiffness, climatic conditions and soil strength. These distresses were:

- loss of serviceability
- faulting
- pumping
- loss of skid resistance
- joint deterioration
- cracking
- depression and swell.

All of these distresses except depression and swell were found to be related to traffic. Cracking closely approximated the sixth power rule of ESAL damage, as did loss of serviceability and deterioration of joints to a lesser extent. Other distresses, however, were more closely related to traffic levels and weather effects.

CONSTRUCTION

Use of the general incremental method of assigning costs of new pavement construction to different vehicle classes was found to involve important difficulties because of the economies of scale inherent in pavement design. This issue was discussed in Chapters 2, 3 and 4. Economies of scale are present in road design since, to obtain a given increment to pavement strength, progressively less additional pavement thickness is required. This is indicated in Figure 3.1.

A road is designed for a certain number of ESAL passes during its pavement life. The minimum or basic pavement structure is the design which is needed to withstand only the effects of the environment, and not ESAL passes. Below this design level, pavement construction is impracticable. The cost of the basic pavement structure becomes the residual cost. Costs above this are allocated directly to vehicles. Minimum pavement thickness as a proportion of total thickness was found to vary between 100 per cent on low volume roads, particularly those with rigid pavement, and 39 per cent on urban freeways in the western coastal region. The study does not consider the economic efficiency of pavement designs concerned.

Under the approach adopted in the United States study, vehicles are hypothetically removed in uniform order, as noted above, and pavement designs are revised accordingly. In hypothetically removing vehicles, the method used removes from the design equation that proportion of total ESALs represented by the vehicles removed.

Pavement designs are revised using separate equations for flexible and rigid pavements based on the AASHO Guide. The equation for flexible pavements relates ESALs to pavement thickness, terminal serviceability level, climatic conditions and soil strength. This equation is:

$$W_{t18} = 10^{Z}(SN+1)^{9.36}/R$$

where

$$Z = G_t/B_{18}+.372S_i-1.316$$

W_{t18} = Total number of 18-kip equivalent single-axle loads of 8 tonnes on dual tyre single axle as used in Australia
SN = Structural number of the pavement
G_t = A function of pavement condition at end of design life
B_{18} = A function of pavement strength
S_i = Soil support value
R = A regional factor that accounts for climatic variables.

A similar equation for rigid pavements relates ESALs to pavement thickness, terminal serviceability, soil strength and elasticity of sub grade:

$$W_{t18} = 10^Y(D+1)^{6.98}((D^{.75} - 1.132)/(D^{.75} - .4069k^{.25}))^{1.2014P_t}$$

where

Y = $G_t/B_{18} - 0.2212$

D = Thickness of slab (inches)
k = Modules of subgrade reaction (pounds per cubic inch)
P_t = Terminal pavement serviceability.

Traffic data is converted to anticipated ESALs using AASHO relationships which allow ESALs to vary with pavement strength and axle loads. The relationships used for flexible pavements are:

$$ESAL = 10^W((L_x + L_2)/19)^{4.79}/L_2^{4.33}$$

where

$$W = G_t/B_x - G_t/B_{18}$$

L_x = Axle load (thousands of pounds)
L_2 = Dummy variables: 1 for single axles, 2 for tandems
G_t = Function of pavement serviceability
B_x = Function of axle weight and pavement strength
B_{18} = Function of pavement strength.

For rigid pavements, the equation takes the following form:

$$ESAL = 10^W((L_x + L_2)/19)^{4.62}/L_2^{3.28}$$

It is notable that a power slightly higher than 4 was used for both flexible and rigid pavements.

Pavement thickness is iteratively substituted into the pavement design equations until calculated ESALs equal anticipated ESALs. This is repeated (uniformly removing vehicles) until successive pavement thicknesses are very close together. Thus, the costs of extra thickness assigned to each vehicle class are based on the class' share of total ESALs.

APPENDIX IV ALTERNATIVE ROAD PRICING STRUCTURE

In this Appendix, the current road pricing structure in Australia is examined and suggestions are made for improving it. These improvements are aimed at achieving a balance between the three objectives outlined in Chapter 8:

- economic efficiency
- equity
- administrative simplicity.

As far as economic efficiency goes, the mix of charges used to achieve full cost recovery should not significantly distort road use. Each charge outlined has some efficiency cost. The appropriate structure of charges might best be examined through an explicit road price optimisation model. In the absence of such a model, the discussion below is general and indicative.

The equity objective has been discussed at length in numerous reports on road pricing and cost recovery. In the absence of an objective equity constraint to efficient road pricing, it is assumed that equity objectives are not impaired by such prices.

The last of the objectives is taken to include ease of understanding the basis of the charges, cost of administration, degree of public acceptability and conformity with section 92 of the Constitution. It also includes an objective of achieving a degree of uniformity among the States.

CURRENT SYSTEM

The current road pricing system is characterised by a large range of charges being paid by road users, some of which are directly related to road use and others are not. Some are tied to expenditure on road works and others are not.

It was noted in Chapter 2 that there is little agreement as to which charges can be defined as road-user charges. Before any effective road pricing system can be introduced, agreement must be reached, or governments must decide, on which taxes and charges are to be defined as road-user charges and which taxes are aimed at raising general revenue. The discussion below assumes that can be achieved.

The discussion throughout this Paper has indicated that to meet an expenditure recovery target above short-run marginal cost, while at the same time promoting economic efficiency, at least two mechanisms are required. The first would be related to the marginal cost component of road expenditure, that is principally road damage. Congestion cost charges (and charges for externalities) are ignored due to the difficulty of assessment and implementation. The second mechanism would therefore be related to the balance of expenditure recovery required.

Of all the charges currently available, fuel taxes and vehicle registration charges are the most likely charges to form the basis for an efficient and equitable road pricing system. Vehicle registration charges could be structured to fulfil the function of a road damage charge and fuel taxes used to recover the balance of the road expenditure target. A further refinement suggested in this Paper is for a two-part pricing system to recover this balance. This could be achieved by using both fuel excise and a fixed component of registration charges.

Currently, neither fuel excise rates nor vehicle registration charges are set up to achieve the appropriate objectives outlined. Registration charges are based on a large range of criteria which vary among the States. Table IV.1, which comes from the ISC 1986 Report, indicates the lack of uniformity among the States. If registration charges are to be used to recover road damage, the factors determining the level of charges are vehicle mass, axle configuration and distance travelled. The latter three factors imply a variable charge whereas current vehicle registration charges are fixed annual charges.

Currently, fuel excise rates applied by the Federal and State governments are not set on any basis related to road use. In addition, except for two States, the revenue from Federal and State fuel taxes is not fully tied to road expenditure. While this latter point is not important from an economic efficiency viewpoint, it needs to be made clear how the rates are related to road costs.

SUGGESTED IMPROVEMENTS

The major improvement required of the current system of road charges is to relate vehicle registration charges to road damage. This

TABLE IV.1 FACTORS RELEVANT TO DETERMINATION OF STATE AND TERRITORY REGISTRATION CHARGES FOR HEAVY VEHICLES

Factors	*NSW*	*Vic*	*Qld*	*WA*	*SA*	*Tas*	*NT*	*ACT*
Tare of unit	Yes	Yes	..	..	Yes	..	..	..
Tare of prime mover	..	..	..	Yes	..	..	Yes	Yes
Tare of trailer	..	..	..	Yes	..	Yes	Yes	Yes
Gross vehicle mass	..	Yes	Yes	..	..	Yes	..	..
Engine capacity	..	..	..	..	..	..	Yes	..
Number of cylinders	..	Yes	..	Yes	..	..	Yes	..
Cylinder diameter	..	Yes	..	Yes	..	..	..	..
Number of seats (bus)	..	..	..	..	..	..	Yes	..
Fixed fee	Yes	Yes	Yes	Yes	Yes	Yes	..	..

.. Not applicable.

Source ISC (1986).

requires that the charges be related to the three factors affecting road damage. Thus, a schedule of charges is required that takes account of vehicle mass and axle configuration and is set as a charge per kilometre. This is discussed further in Chapter 8, and some problems are noted. However, assuming these issues can be sorted out over time, the basic level of charge required should be based on the road damage costs caused by individual vehicle types and an appropriate schedule of charges should be established for each vehicle type.

It should be stressed that it is not envisaged that the dramatic changes suggested could or should be introduced over-night. In all of the examples outlined below, a lengthy phasing in period would be required. Again, the reasons for this are outlined in the report.

In Table IV.2 a uniform charge is calculated which broadly relates to the road damage cost of each vehicle type assuming the average loads and average distances travelled for each vehicle type from Chapter 5. The annual charges for a particular vehicle would depend on distance travelled, assuming hubodometers were fitted to vehicles, either voluntarily or by legal requirement. Ideally, vehicle operators would nominate a maximum load they will carry and pay a charge based on this. Otherwise charges could be based on the maximum legal load for each vehicle, with the charge scaled down so as to reflect average loads for each vehicle type and thus raise only actual avoidable cost each year. The charges could be based on an average of 2 cents per

TABLE IV.2 CALCULATION OF AN ALTERNATIVE ROAD PRICING STRUCTURE

Vehicle type	Annual average distance travelled ('000 kms)	Annual average avoidable cost ($ per vehicle)	Annual average total cost ($ per vehicle)	Number of vehicles ('000)	Average ESALs per vehicle	Average fuel consumption (litres/ 100 km)	Annual charge per vehicle from: Possible damage charge (14.8c per ESAL km)	Annual charge per vehicle from: Fuel tax (9c/l MS) (20c/l AD)	Total annual charge per vehicle ($)	Cost recovery ratio
Cars	15.8	nil	157	8 695.6	..	12.12	..	172	172	1.10
Rigid trucks										
2 axles	16	473	1 178	381.7	0.20	22.15	474	319	793	0.67
3 axles	24	3 898	4 697	45.1	1.22	38.02	4 333	1 825	6 158	1.31
> 3 axles	31	8 245	9 648	21.5	1.93	44.26	8 855	2 744	11 599	1.20
Articulated trucks										
< 5 axles	36	8 243	10 376	14.6	1.56	42.68	8 312	3 073	11 385	1.10
5 axles	56	19 482	24 788	11.6	2.37	51.19	19 643	5 733	25 376	1.02
6 axles	100	35 237	48 279	26.0	2.34	54.95	34 632	10 990	45 622	0.94
> 6 axles	110	75 416	110 146	2.4	4.26	74.19	69 353	16 322	85 675	0.78
Long-distance buses	250	48 896	83 109	0.3	1.22	51.00	45 140	25 500	70 640	0.85

.. Not applicable.

Sources Tables 5.1 and 7.4. ABS (1987). BTCE estimates.

tonne-kilometre as a simple guide, or preferably calculated on the basis of 14.5 cents per ESAL kilometre. On the latter basis, the annual charge for a six-axle articulated truck with a nominated mass of 35 tonnes travelling 100 000 kilometres per year would be of the order of $30 000. A similar vehicle with a nominated mass of 41 tonnes travelling 250 000 kilometres per year would be charged around $130 000 per annum. These charges could also be used as a basis for setting fines for overloading.

Table IV.2 shows how a differentiated fuel tax, with different rates for motor spirit and automotive distillate, might be used to recover the balance of road expenditure. It is assumed in the calculations that all two-axle rigid trucks use motor spirit and all other trucks use automotive distillate. The calculations indicate that a tax rate of 9 cents per litre on motor spirit and 20 cents per litre on automotive distillate, along with the vehicle registration charges, produce overall total cost recovery ratios near unity.

Table IV.3 shows that a better result can be achieved by introducing a fixed registration charge for some vehicles as well. However, the basis of this charge does not correspond with the ideal of a fixed element of a Ramsey two-part pricing system. It is not closely related to elasticities of demand, and should be levied on all vehicles. However, it does produce a better cost recovery result and so a compromise may need to be made. If elasticities for all vehicle types are fairly low then the charges are unlikely to involve a large loss of economic efficiency. The test is whether they cause a significant exit of operators from the market place.

Table IV.4 shows possible charging levels based on two broad assumptions concerning fuel excise. If only hypothecated fuel tax is considered to be a road-user charge, yet little change is to be made to current fuel tax levels, Structure A could be adopted. If all fuel excise is to be considered as a road user charge, Structure B could be adopted. In addition, the road damage charge set in Structure B is similar to the level of avoidable cost found in Chapter 6 where the Nicholas Clark and Associates (1984) estimates of vehicle travel on arterial and local roads are taken into account. Obviously, combinations could be constructed matching different fuel tax rates and road damage charges. These two structures are simply examples.

Under both structures, trucks and buses would, overall, meet their full costs. However, Structure B would lead to a $3200 million excess in revenue above the 1986-87 level of road expenditure. This simply reflects the current over-recovery of costs or expenditure from private motorists.

TABLE IV.3 ALTERNATIVE ROAD PRICING SCHEME

Vehicle type	*Road damage charge*		*Fuel tax*		*Under-recovery gap to be filled by a fixed annual vehicle registration charge*
	Charge per ESAL km (cents)	*Average annual payment per vehicle ($)*	*Rate per litre (cents)*	*Average annual payment per vehicle ($)*	
Cars	0	0	5	96	61
Rigid trucks					
2 axles	14	448	5	177	550
3 axles	14	4 100	6	547	0
> 3 axles	14	840	6	823	400
Articulated trucks					
< 5 axles	14	785	6	922	1 500
5 axles	14	1 835	6	1 720	4 500
6 axles	14	3 275	6	3 927	12 000
> 6 axles	14	6 560	6	4 897	40 000
Long-distance buses	14	42 700	6	7 650	33 000

Source BTCE estimates.

TABLE IV.4 ALTERNATIVE ROAD PRICING STRUCTURES

Vehicle type	Road damage charge: Charge per ESAL km (cents)	Road damage charge: Average annual payment per vehicle ($)	Fuel tax: Rate per litre (cents)	Fuel tax: Average annual payment per vehicle ($)	Fixed annual regis-tration fee ($)	Total average annual payment per vehicle ($)	Total cost recovery ratio
Structure A							
Cars	0	0	9	172	0	172	1.10
Rigid trucks							
2 axles	14.8	470	9	320	500	1 290	1.10
3 axles	14.8	4 300	9	820	500	5 620	1.20
> 3 axles	14.8	8 800	9	1 200	500	10 500	1.10
Articulated trucks							
< 5 axles	14.8	8 300	9	1 400	2 000	11 700	1.13
5 axles	14.8	20 000	9	2 600	2 000	24 600	0.98
6 axles	14.8	34 500	9	5 000	5 000	44 500	0.92
> 6 axles	14.8	69 000	9	7 400	10 000	86 400	0.79
Long-distance buses	14.8	45 000	9	11 500	10 000	66 500	0.80
Structure B							
Cars	0	0	27	520	0	520	3.29
Rigid trucks							
2 axles	12.5	400	27	960	0	1 360	1.15
3 axles	12.5	3 600	27	2 450	0	6 050	1.30
> 3 axles	12.5	7 500	27	3 600	0	11 100	1.16
Articulated trucks							
< 5 axles	12.5	7 000	27	4 200	1 000	12 600	1.08
5 axles	12.5	17 000	27	7 800	1 000	25 800	0.98
6 axles	12.5	29 000	27	15 000	1 000	45 000	0.91
> 6 axles	12.5	58 000	27	22 000	1 000	81 000	0.73
Long-distance buses	12.5	38 000	27	34 500	5 000	77 500	0.87

Source BTCE estimates.

Both structures could be slightly improved if the road damage charge on two-axle rigid trucks was replaced by a low fixed registration fee (increased from $500 to $860 under Structure A, and set at $220 rather than nil, under Structure B). This would be simpler administratively, although it would not be as efficient. In fact, the fixed registration charges could all be restructured to achieve better cost recovery ratios as in Table IV.3, although the level of total revenue raised might then be increased. The cost recovery ratios shown are based on total (fully distributed) annual road expenditure using the efficiency based approach in Chapter 7. They do not take account of travel by road category, although this was shown to have little effect on the cost allocation results. Using the Nicholas Clark and Associates travel estimates does not alter the cost recovery ratios significantly. In fact, adjusting for these estimates brings most ratios closer to unity.

In the absence of an explicit road price optimisation model, both structures would appear to meet the objectives of economic efficiency and equity fairly well.

Structure A is closer to the optimum efficiency charge since the road damage charge is set to exactly recover road damage by all vehicle types. It also produces slightly more consistent cost recovery ratios. However, the choice is constrained by the decision as to what level of fuel taxation is deemed to be a road-user charge.

The system of charges in either case should generally fit within the constraints of section 92 of the Constitution. Certainly, the road damage charge falls within the provisions of section 92, since it is clearly related to maintaining the road system. section 92 also does not restrict the levying of uniform fuel excises. However, the fixed registration charge has yet to be tested in the High Court. Under both structures this charge represents only a small component of total charges. The main criteria for conformity with section 92, would appear to be that the basis of charges does discriminate between intrastate and interstate road users.

The system proposed appears fairly simple to understand and should not be difficult or costly to administer. The major problem would seem to be that of obtaining acceptance from operators of heavy vehicles. This will be true for any pricing system aimed at achieving full cost recovery at the same time as encouraging economic efficiency. Any such scheme will require that operators of heavy vehicles pay considerably more for the use of roads than they do at present.

REFERENCES

Abbreviations

ABS	Australian Bureau of Statistics
AGPS	Australian Government Publishing Service
ISC	Inter-State Commission
NAASRA	National Association of Australian State Road Authorities
NRFII	National Road Freight Industry Inquiry

Abelson, Peter (1986), *The Economic Evaluation of Roads in Australia*, Australian Professional Publications, Sydney.

ABS (1978), *Survey of Motor Vehicle Usage, Twelve Months Ended 30 September 1976*, Cat. No. 9215.0 (microfiche), ABS, Canberra.

__ (1984), *Survey of Motor Vehicle Usage, Twelve Months Ended 30 September 1982*, Cat. No. 9215.0 (microfiche), ABS, Canberra.

__ (1986), *Taxation Revenue, Australia 1984-85*, Cat. No. 5506.0, ABS, Canberra.

__ (1987), *Survey of Motor Vehicle Use Twelve Months Ended 30 September 1985, Microfiche Tabulations*, Cat. No. 9215.0, ABS, Canberra.

Australian Institute of Petroleum Ltd (1986), *Oil and Australia*, Petroleum Gazette, June 1986.

Baumol, W. J. & Bradford, D. F. (1970), 'Optimal Departures from Marginal Cost Pricing', *The American Economic Review*, Volume 60.

Biggs, A. J. G. & Anderson, R. (1987), 'Australian Road Transport Charges and Taxes', *12th ATRF Forum Papers*, Vol. 2. Department of Transport Queensland, Brisbane.

Both, G. J. & Bayley, C. (1976), *Evaluation Procedures for Rural Road and Structure Projects*, Australian Road Research Board, Proceedings, Vol. 8, pp6-25.

Bureau of Transport Economics (BTE) (1979), *An Assessment of the Australian Road System: 1979,* Part 1, AGPS, Canberra.

__ (1982a), *Road Pricing and Cost Recovery - A Review of Approaches to Allocating Road System Costs*, Reference Paper No. 38, unpublished.

__ (1982b), *Road Financing in Selected Countries,* Occasional Paper 49, AGPS, Canberra.

__ (1982c), *An Assessment of Vehicle Operating Cost Models*, Reference Paper 29, unpublished.

__ (1983), *BTE Road Construction Price Indexes: 1971-72 to 1981-82,* Information Paper 7, AGPS, Canberra.

__ (1984a), *Assessment of the Australian Road System: Operational Characteristics,* Information Paper 10, AGPS, Canberra.

__ (1984b), *Assessment of the Australian Road System: 1984,* Report 56, AGPS, Canberra.

__ (1985a) Review of Australian Road Cost Recovery Studies and Alternative Estimates for 1981-82, Reference Paper 105, Unpublished.

__ (1985b), *Review of Road Pricing in Australia and Overseas,* Occasional Paper 73, AGPS, Canberra.

__ (1985c), *Australian Long Distance Coach Industry Review*, Occasional Paper 74, AGPS, Canberra.

__ (1987a) *Australian Road Financing Statistics 1975-76 to 1984-85*, Information Paper 21, AGPS, Canberra.

__ (1987b) *Assessment of the Australian Road System: 1987,* Report 61, AGPS, Canberra.

__ (1987c), *An Assessment of the Review of Road Vehicle Limits (RoRVL) Study*, Reference Paper 132, Unpublished.

Bureau of Transport and Communications Economics (BTCE) (1988), *Cost of Road Accidents in Australia,* Occasional Paper 91, AGPS, Canberra.

Commission of Enquiry into the NSW Road Freight Industry, (Second Report, McDonnell G, Chairman) (1980), Vol. iv January 1980, Sydney.

Commonwealth of Australia (1986-87), *Budget Statements 1986-87,* Budget Paper no. 1, AGPS, Canberra.

Diamond, P. A. and Mirlees, J. A. (1971), 'Optimal Taxation and Public Production II: Tax Rules,' *American Economic Review,* June 1971, 261-278.

Department of Main Roads (DMR) NSW (1976), *The Roadmakers*, DMR, Sydney.

Fowkes, A. S. et al (1984), *Road Track Cost Allocation in Great Britain*, Institute for Transport Studies, University of Leeds, Leeds, U.K.

Fwa, T. F. and Sinha, K. C. (1986), 'A Unified Approach for Allocation of Highway Pavement Costs', *Transportation Research,* Vol. 20A, No.3.

Gruen F. H. (1986), 'How Bad is Australia's Economic Performance and Why?,' *The Economic Record,* Vol. 62 No. 177, June 1986.

Henderson, S. & Pierson, G. (1980), *Issues in Financial Accounting*, Longman Cheshire, Melbourne.

ISC (1986), *An Investigation of Cost Recovery Arrangements for Interstate Land Transport,* AGPS, Canberra.

Kolsen, H. M. (1968), *The Economics and Control of Road-Rail Competition*, Sydney University Press, Sydney.

Kolsen, H. M. & Docwra, G. E. (1979), 'Background to a Dispute: The Road Haulage Industry in Australia, *Truckin Life,* Vol. 3, No. 1.

Kolsen, H. M. & Docwra, G. E. (1987), 'Cost Recovery Policy in Theory and Practice', *12th ATRF Forum Papers,* Vol. 1, Department of Transport Queensland, Brisbane.

Lay, M. G. (1986), *Handbook of Road Technology, Volume 8, Planning and Pavements,* Gordon and Breach Science, New York.

Luck, D. P. & Martin, I. J. (1987), *Road Pricing and Cost Recovery*, 12th ATRF Forum Papers, Vol. 2, Department of Transport Queensland, Brisbane.

McDonnell Enquiry. *See* Commission of Enquiry into the NSW Road Freight Industry.

National Association of Australian State Road Authorities (NAASRA) (1976), *Economics of Road Vehicle Limits Study, Technical Report T4, Pavements,* NAASRA, Sydney.

__ (1983), *The NAASRA Roads Study, Funding and Expenditure, Technical Report T-1*, NAASRA, Sydney.

__ (1984a), *The NAASRA Roads Study, 1984, Report on the Australian Road Network, Study Report R4,* NAASRA, Sydney.

__ (1984b), *Use of NIMPAC, Technical Report T-7,* NAASRA, Sydney.

__ (1985) *Review of Road Vehicle Limits for Vehicles using Australian Roads,* NAASRA, Sydney (and computer tape of Vehicle Mass and Dimension Survey held in BTCE).

__ (1987), *The Australian Roads Outlook Report* (TAROR), NAASRA, Sydney.

NRFII (1984), *National Road Freight Industry Inquiry Report*, AGPS, Canberra.

Nicholas Clark & Associates (NCA) (1984), *Assessment of Cost Recovery Levels: Road and Rail* (Report prepared for the NRFII), unpublished.

Oum, T. H. (1982), 'Efficiency Losses from the Unbalanced Recovery of the Costs of Transport Infrastructure in Canada', *The Logistics and Transportation Review,* Vol. 18, No. 1, March 1982.

Pittard, J. H., Webber, J. R. & Both, G. J. (1977), *Report on Separable Road Costs for ATAC Road Pricing Study*, Country Roads Board, Victoria.

Ramsey, F. P. (1927), 'A Contribution to the Theory of Taxation', *The Economic Journal,* March 1927, Vol. 37.

Rattray, A. L. & Robinson, J. F. (1986), The Recovery of Public Costs due to Road Freight Transport, 11th Australian Transport Research Forum Proceedings, Darwin.

Small, K. A. and Winston, C. (1986), 'Efficient Pricing and Investmnet Solutions to Highway Infrastructure Needs', *American Economic Association Papers and Procedings,* Vol. 76 No.2, May 1986.

Standingford, J. (1985), *Road Maintenance Cost Savings Accruing from Construction of the Alice Springs-Darwin Rail Link,* John Standingford and Associates Pty Ltd, Adelaide.

Taplin, J. H. E. (1980), 'Second Best Pricing for Competing Modes of Transport', *6th Australian Transport Research Forum Proceedings,* Brisbane.

Transport Economics Centre (TEC) (1981), *Pricing Tasmania's Roads*, University of Tasmania, Hobart.

Travers Morgan Pty Ltd (1985), *South Australian Road Cost Recovery Study*, Vol. 1, Main Report, South Australia.

Turvey, R. (1971), *Economic Analysis and Public Enterprises*, Allen and Unwin Ltd, London, UK.

United States Department of Transportation, Federal Highway Administration (US FHA) (1982), *Final Report on the Federal Highway Cost Allocation Study*, Washington, D.C.

__ (1984), *Allocation of Life-Cycle Highway Pavement Costs*, United States Department of Transportation, Federal Highway Administration, McLean, Virginia, USA.

Vickrey, W. (1985), 'The Fallacy of Using Long-Run Cost for Peak Load Pricing', *Quarterly Journal of Economics*, Vol. C No. 4, November 1985.

Webber, J. R., Both, G. J. & Ker, I. R. (1978), 'Commercial Vehicle Costs and Charges: A Study of Separable Pavement Costs', *Proceedings of the 1978 Annual Conference of the Australian Road Research Board*, Vol. 9.

Wilson, G. W. (1978), 'Notes on the Elasticity of Demand for Freight Transportation', *Transportation Journal*, Spring 1978.

World Bank (1985), *The Highway Design and Maintenance Standards Study*, Volume III, 'Prediction of Road Deterioration and Maintenance Effects: Theory and Quantification', by William D. O. Paterson, Transportation Department, The World Bank, Washington, D.C.

ABBREVIATIONS

AASHO	American Association of State Highway Officials
ABRD	Australian Bicentennial Road Development
ABS	Australian Bureau of Statistics
ALTP	Australian Land Transport Program
ARRB	Australian Road Research Board
ARTF	Australian Road Transport Federation
ATAC	Australian Transport Advisory Council
BTE	Bureau of Transport Economics
BTCE	Bureau of Transport and Communications Economics
CPI	Consumer Price Index
DMR	Department of Main Roads
E	Elasticity
EEC	European Economic Community
ERVL	Economics of Road Vehicle Limits
ESAL	Equivalent standard axle load
GVM	Gross vehicle mass
LPG	Liquefied petroleum gas
LRAC	Long-run average cost
LRMC	Long-run marginal cost
NAASRA	National Association of Australian State Road Authorities
NCA	Nicholas Clark and Associates
NIMPAC	NAASRA Improved Model for Project Assessment and Costing
NZ	New Zealand
NRFII	National Road Freight Industry Inquiry
PCU	Passenger car equivalent units (also PCE)
SMVU	Survey of Motor Vehicle Usage
SRAC	Short-run average cost
SRAPC	Short-run avoidable pavement cost
SRMC	Short-run marginal cost
RoRVL	Review of Road Vehicle Limits
TEC	Transport Economics Centre
Tkm	Tonne-kilometres
TWU	Transport Workers' Union
US DoT	United States Department of Transportation

US FHA	United States Federal Highway Administration
Vkt	Vehicle-kilometres travelled
Vmt	Vehicle-miles travelled
VOC(s)	Vehicle operating cost(s)