PRODUCTIVITY COMMISSION INQUIRY INTO ROAD AND RAIL FREIGHT INFRASTRUCTURE PRICING

Supplementary Submission - The Impact of Alternatives to PAYGO

September 2006

National Transport Commission

Prepared by

NTC with Maunsell Australia Pty Ltd

National Transport Commission

Supplementary Submission - The Impact Alternatives to PAYGO

Report Prepared by: **NTC With Maunsell Australia Pty Ltd**

ISBN: 1 921168 46 3

REPORT OUTLINE

Date:	September 2006
ISBN:	**1 921168 46 3**
Title:	**The Impact of Alternatives to PAYGO**
Address:	National Transport Commission Level 15/628 Bourke Street MELBOURNE VIC 3000 E-mail: ntc@ntc.gov.au Website: www.ntc.gov.au
Type of report:	Supplementary Submission
Objectives:	To assess possible alternative road cost allocation methodologies in Australia.
NTC Programs:	Efficiency- pricing
Key Milestones:	Submit to the Productivity Commission Inquiry of Road and Rail Freight Infrastructure Pricing
Abstract:	This report explores two main alternatives to the existing PAYGO approach namely an enhanced PAYGO model and a whole of lifecycle cost method. The analysis is largely qualitative but some analysis using a pavement life cycle cost model has been done. The work is intended as a preliminary assessment to identify future research requirements and assist in identifying viable reform options.
Purpose:	For information
Key words:	Costs, costing, PAYGO, depreciation, life cycle, whole-of-life costing, capital expenditure, maintenance expenditure, optimisation, replacement cost

FOREWORD

The National Transport Commission (NTC) is an independent body established under an Inter-Governmental Agreement, and funded jointly by the Australian Government, States and Territories. The NTC has an on-going responsibility to develop, monitor and maintain uniform or nationally consistent regulatory and operational reforms relating to road transport, rail transport and intermodal transport.

The NTC's heavy vehicle road pricing work contributes to strategies pursuing transport as a more sustainable activity, and in devising smarter approaches to regulation, provides both increased flexibility and greater certainty about results achieved.

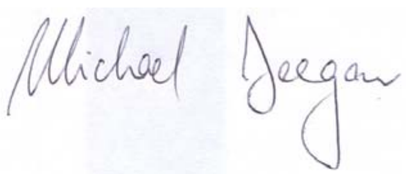
This paper has been prepared as a supplementary submission to the Productivity Commission's Issues Paper on its Inquiry into Road and Rail Freight Infrastructure Pricing. The Issues paper raised questions in relation to the costs of providing and maintaining road freight infrastructure. One of the key technical considerations in pricing infrastructure is how the costs of infrastructure use are established. This is one of the major areas of difference between current approaches to road and rail infrastructure pricing. In its main submission, the NTC discussed the current approach to costing for heavy vehicle charging purposes, known as PAYGO. Although the submission noted that PAYGO was effective in ensuring heavy vehicle expenditure recovery in aggregate, it also noted there were a number of shortcomings of the approach which meant that efficient economic costs may not be recovered.

The NTC believes this is an important technical issue which will have a considerable impact on the amount any new pricing regime will be required to recover. It therefore commissioned Maunsell Australia to further consider what may be appropriate alternatives to the PAYGO approach. In doing so Maunsell was asked to identify feasible alternatives, consider how they may address some of the shortcomings of PAYGO and identify what may be some of the implementation challenges. Furthermore, Maunsell was asked to undertake some initial analysis to assess whether the alternatives did indeed provide a better indication of costs. Whilst the discussion in this report does not provide definitive answers, it is hoped that it furthers the debate on the appropriateness of PAYGO and offers potential ways forward to improving cost estimation.

This project is critically linked to:

- the capability to implement future road pricing systems including incremental pricing and potentially a national direct pricing system; and
- effective extension of Performance Based Standards to support additional productivity improvements in movement of road freight, which will require an ability to determine charges for additional mass increases based on accurate assessments of the resulting road costs.

The NTC acknowledges the work of Maunsell Australia Pty Ltd as the major contributor to this report, as well as the contributions of the following members of the NTC Transport Pricing Team, Chris Egger, Meena Naidu and Fiona Calvert.



Michael Deegan
Chairman

SUMMARY

The Productivity Commission has been asked to conduct an inquiry into rail and road freight infrastructure pricing. As part of the Inquiry, the Productivity Commission has been asked to:

> *"assess the full economic and social costs of providing and maintaining road and rail freight infrastructure, if it judges this to be feasible. Such costs would include environmental and safety impacts of different transport modes. The review would assess existing studies of these economic and social costs and comment on the strengths and weaknesses of methodologies used. The review should also assess what information or future research could improve the quality of the estimates"*[1]

NTC's main submission discussed in some detail the current approach to estimating costs of road use. The methodology is known as PAYGO (or Pay-As-You-GO), which uses past road expenditure as a proxy for costs. This paper seeks to discuss in more detail alternative approaches to costing methodologies which may better reflect economic and social costs. In preparing this paper, the NTC engaged the services of Maunsell Australia and ARRB to look at the impacts of various alternatives and identify some of the implications of adopting any of these approaches.

The Shortcomings of PAYGO

PAYGO has been successful in ensuring that heavy vehicles pay the financial cost of operating on the road network. It does so by estimating historic expenditure. In response to criticisms of the data used by PAYGO, the NTC has engaged in data improvement projects over time to improve the quality of the data fed into the PAYGO model.

Despite these continuing improvements, the NTC acknowledges that there are other shortcomings associated with PAYGO. Some are inherent in the model, others are related to the application of PAYGO and associated frameworks which weaken the validity of the PAYGO assumptions.

Inherent shortcomings include estimation errors (resulting from lack of consistency and quality of data across over 700 road agencies which provide road services in Australia) and lumpiness in road expenditure (meaning that historical expenditure may not reflect future expenditure requirements).

The main shortcoming of PAYGO failing to optimise expenditure is due less to PAYGO and more to the institutional framework supporting heavy vehicle charges. The optimising of expenditure would mean that expenditure would take place at the right time on the right roads, depending on actual usage. This would mean the road expenditure is more effective in delivering efficient transport outcomes.

Alternative Approaches to PAYGO

The NTC has identified two main alternative approaches to PAYGO which may address some of the shortcomings described above.

The first is an enhanced version of PAYGO. The enhanced PAYGO model would still be based on historical expenditure. However, it would average expenditure over a longer time period to address the medium term lumpiness in expenditure.

---

[1] Terms of Reference for Productivity Commission Inquiry into Road and Rail Freight Infrastructure Pricing

The enhanced PAYGO would also incorporate an efficiency review. This would require the price setting agency to undertake an *ex-post* adjustment to expenditure to disallow expenditure which was not efficiently undertaken. Whilst this does, to some extent, introduce efficiency into the pricing process, it does create an element of uncertainty in the recovery of expenditure for road agencies as the adjustment does not take place until after the investment has been made. However, the presence of "rules" setting out how an efficiency review would be undertaken helps to mitigate this.

One of the major benefits of this approach is that it is not excessively cumbersome, and does not require a new (and potentially costly) costing mechanism to be developed.

The major drawback of this approach is that it does not optimise expenditure going forward, and therefore is not able to take account of expected future growth patterns, where these differ from those of the past.

The second alternative to PAYGO is Whole of Lifecycle Costing. Unlike PAYGO's backwards looking approach to expenditure, the Whole of Life Cycle Costing approach estimates forward expenditure requirements based on optimal and efficient expenditure on the whole life of the asset. However, this approach requires considerable understanding of the condition and use of the network, and the relationships between the two. The partial nature of heavy vehicle pricing also adds a complicating dimension to the costing approach as light vehicles are also drivers of expenditure and need to be taken into account in the optimisation process.

In order to estimate future costs, it is important to accurately depreciate the network. Instead of recovering full capital costs in the year incurred, a whole of lifecycle approach spreads out the recovery of this expenditure to match the benefit derived from the expenditure. Furthermore, the rate of deterioration influences how much maintenance expenditure will be incurred in each year going forward.

However, depreciation requires a valuation of the existing network. There are various approaches to valuation, although it is almost certain that any approach that is taken is likely to have a degree of error and the extent of the error will be unknown. Furthermore, depreciation of the network is difficult due to the various deterioration rates of the various asset types, much of which can only be roughly estimated when it comes to roads. It is not clear that a straight line approach to depreciation (i.e. depreciating the asset by the same amount each year) will be an appropriate proxy over the whole asset base. It is likely that multiple asset bases will be required with different depreciation rates.

Despite the complexities behind this approach, the considerable data requirements and the lack of fundamental knowledge of the links between road condition and use, this approach would provide the most sound theoretical approach to estimating full infrastructure costs if it was possible to apply. It also places greater pressure for institutional reform and allowing charges revenue to flow back to road agencies. Furthermore, it is likely to provide the most sound cost base for direct pricing as it provides the most disaggregated road cost data. However, ultimately the cost and complexity of this approach (which reduces transparency) may mean that it is not appropriate – at least in the medium term.

Impact of Alternatives to PAYGO

Modelling was undertaken to assess the impacts of the two alternative approaches to PAYGO. However, due to the data requirements of both enhanced PAYGO and Whole of

Lifecycle Costing the analysis has been limited and therefore probably underestimates the value (in terms of reducing the under and over recovery of expenditure) of the alternative approaches. It is also important to remember that under and over recovery of expenditure is a feature of the current pricing structure itself which has not been factored into this analysis.

The limited modelling analysis undertaken at this stage indicates that there is no clear cut conclusions that can be drawn in terms of whether the current PAYGO or enhanced PAYGO approach either under recover or over recover compared to a whole lifecycle cost. It can be said that the over or under recovery associated with PAYGO is unsystematic, whilst the under or over recovery associated with the enhanced PAYGO approach is simply due to a timing lag. .

The difficulty in undertaking modelling demonstrates that further analysis will need to be undertaken to better understand:

- the optimisation of expenditure over both capital and maintenance costs;
- how optimisation can be done in a partial market;
- the impact of an efficiency review on costs; and
- how to establish the initial asset value.

Recommendations for Further Research

The discussion in this report suggests that either an enhanced PAYGO or Whole of Lifecycle Costing approach would be a better estimator of costs than PAYGO, although with the limited data available it is difficult to quantify this improvement. It would also suggest that should Whole of Lifecycle Costing be demonstrated to be cost effective (i.e. deliver a greater benefit than the cost of implementing) and a practical alternative, then it is likely to be more of a longer term solution. This is because the data requirements to support the methodology are extensive and will take some time to collect. The enhanced PAYGO approach offers an attractive short to medium term approach.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. OVERVIEW

1.1 Purpose

The Productivity Commission has commenced an Inquiry into Road and Rail Freight Infrastructure Pricing. As part of the Inquiry, the Productivity Commission has been asked to

> *"assess the full economic and social costs of providing and maintaining road and rail freight infrastructure, if it judges this to be feasible. Such costs would include environmental and safety impacts of different transport modes. The review would assess existing studies of these economic and social costs and comment on the strengths and weaknesses of methodologies used. The review should also assess what information or future research could improve the quality of the estimates"*[2]

The Productivity Commission initially published an Issues Paper which the NTC responded to in May 2006. In its response, the NTC described PAYGO – the current methodology for estimating costs of road use for pricing purposes. The NTC acknowledged that despite PAYGO being successful in helping to ensure that heavy vehicles in aggregate paid their way, it did have a number of shortcomings which meant that perhaps full economic and social costs were not captured.

At the time of preparing its initial submission, the NTC had not fully explored alternative approaches to costing. In order to more completely address this particular issue in the Productivity Commission's Terms of Reference, the NTC engaged the services of Maunsell Australia to identify alternative approaches and discuss how they might be applied in the road sector. This paper discusses its findings although it should be noted that the information relating to issues with the current approach and options for alternative mechanisms is purely exploratory at this stage. A more detailed analysis will be able to be undertaken once guidance has been provided by the Productivity Commission on the preferred way forward.

The current system of road cost recovery in Australia is based on the aggregate recovery of heavy vehicles' share of the costs of providing and maintaining roads. Total costs are calculated on the basis of the PAYGO model, which recovers expenditure in the year it is incurred, and are then shared between different classes of road users on an occasioned basis. The PAYGO assumption is that the costs of providing and maintaining roads for current users are equivalent to the average of the total amount spent in the current year and the two previous years, including both capital and maintenance costs.

Once the current PAYGO system has established the costs to be considered, they are allocated across vehicle types using road usage and impact data. This second step is necessary to work out how much of the total costs of the road system are the responsibility of heavy vehicles, with light and heavy vehicles sharing the road network. A number of criticisms of the current system have been raised, including the potential undercharging of large vehicles, not matching the timing of expenditure requirements with revenues (cost recovery) and the potential economic inefficiencies from incorrect pricing signals.

[2] Terms of Reference for Productivity Commission Inquiry into Road and Rail Freight Infrastructure Pricing

The primary purpose of this paper is to identify alternative road costing methodologies to PAYGO and then provide an assessment as to the probable impact that each of these alternatives will have on road cost recovery. The current work will highlight the differences in approaches including the relative advantages and disadvantages of each as well as providing an overview of possible implementation issues for each alternative.

1.2 Study Context

This paper focuses on the costing methodology of roads for the purpose of setting charges for heavy vehicles. In doing so, it is important to understand the context of road service provision to assess the need to change the current approach.

Road service provision is multi-jurisdictional in nature and is primarily provided by government[3]. Roads are provided by both State and Territory governments as well as local governments. The federal government provides funding support for roads of national and strategic importance, but does not directly operate any part of the road network.

There are a number of drivers for investment in roads. Whilst they are primarily provided when there is an economic argument for doing so (i.e. when the costs[4] of road provision are outweighed by the economic benefits[5] generated as a result of their use), a mixture of political, social, safety or environmental considerations may be given a greater weight in the final investment decision. As will be discussed later in this paper, this can have considerable implications in assessing the optimal provision of road services.

A key defining characteristic of the road network is its multi-product nature. Roads provide access for both passenger and freight trips, with the former being the main generator of demand in Australia. Indeed, it is generally passenger demand which drives investment decisions concerning new capacity and to a degree maintenance assessments. Freight traffic comprises a much smaller component of total demand and has different impacts on the network. Whilst heavy vehicles form a relatively minor part of total transport demand, they do contribute a disproportionate amount to pavement damage and hence drive asset maintenance decisions. The accurate determination of heavy vehicle charges is fundamental to ensuring road cost recovery is achieved.

NTC is guided in recommending these charges by principles established by the Australian Transport Council. In relation to costing, NTC is required to ensure that in aggregate heavy vehicle charges recover the cost of heavy vehicle usage on the network for each vehicle class.

The PAYGO model is a key tool in achieving this. Over time there have been increasing criticism of the model, particularly in relation to data quality. Although the NTC has made considerable improvements in the quality of data used, it has become increasingly evident that the shortcoming of the current model may mean that full economic costs are not being recovered.

In December 2005 the NTC released its third heavy vehicle pricing determination which recommended a number of improvements in both the determination of expenditure and the allocation across the various vehicle classes. The recommendations were subsequently

[3] Although some roads are privately provided as toll roads or for public use, they are not relevant for this discussion as their costs are excluded from the cost base.
[4] These include capital, maintenance and operational costs over the life of the asset
[5] These include travel time, reduction in vehicle operating costs and wider economic impacts

rejected by the Australian Transport Council in March 2006. This outcome further supported the view that the objectives the current regime supported were insufficient to meet the requirements of both service providers and users.

The PC Inquiry has provided an opportunity for the pricing principles which guide the NTC to be revisited as well as the mechanisms used in the pricing process to be challenged to assess their effectiveness and efficiency.

As part of its research program, the NTC convened a workshop in April 2006 to discuss the issue of national road costing and allocation. The workshop covered topics including the impact of heavy vehicles on road, bridge and earthwork costs, alternatives to PAYGO and the establishment of a new national pavement management database. Outcomes from the workshop were to provide a basis to inform the Productivity Commission Inquiry and guide future research efforts in costing and cost allocation by the NTC and other government agencies.

This paper is primarily concerned with establishing alternatives to the current PAYGO system of estimating the total cost of providing, maintaining and operating the road network and how the amount recovered might differ under alternative approaches. The analysis also extends to include an assessment of the practicalities of implementing alternative methodologies.

1.3 Structure of the Report

The report structure is:

- Chapter 2 includes a discussion of the economic principles underpinning efficient road user charging.
- Chapter 3 includes a description of the current PAYGO approach including a discussion of the relative advantages and disadvantages of this approach.
- Chapter 4 includes a discussion of the first alternative approach to PAYGO and is concerned with developing and enhancing the current PAYGO approach to maintain its advantages whilst reducing the inherent disadvantages.
- Chapter 5 includes a discussion of adopting an alternative whole lifecycle cost approach to road cost recovery including identifying the advantages and disadvantages of this alternative.
- Chapter 6 includes an analysis of applying these alternative approaches to cost recovery to a simplified road network to compare the impact of the different methodologies.
- Chapter 7 includes the conclusions and recommendations for further study.

2. BACKGROUND TO ROAD EXPENDITURE AND COSTING

2.1 Introduction

The purpose of this chapter is to describe the specific characteristics of road infrastructure asset management. It is important to understand these specific characteristics of the road network in order to assess the appropriateness of cost determination methodologies.

2.2 Factors Influencing Deterioration of Different Road Asset Categories

Understanding asset deterioration is important in costing for two primary reasons. The first is that under some costing methodologies deterioration is explicitly taken into account through depreciation costs. The second is that deterioration determines timing for optimal expenditure.

Deterioration can be defined as the worsening in the condition of an asset. In the case of the road network, this relates to wear and tear on pavements and fatigue in structures. The deterioration profile of an asset refers to the worsening of the condition of the asset over time. Deterioration profiles of the assets forming the road network are predominantly influenced by four factors:

i) the road asset category;

ii) load repetition;

iii) climate influences; and

iv) construction quality.

Firstly, the type of road asset category strongly influences the deterioration profile. The road asset base comprises three main categories of assets:

- roads;
- bridges; and
- street furniture (such as road lighting, signing, road safety features, etc).

Each of these categories has distinct engineering characteristics and subsequently deterioration profiles differ among categories and road use cost allocation methodologies need to address these differences. In order to understand the factors influencing the deterioration profiles of different types of roads, a further disaggregation of different types of road and bridge assets is undertaken in section 2.2.1.

Load Repetition

The strain from load repetition places stresses on pavements and structures. Over time the stresses accumulate leading to fatigue and eventually resulting in the visible signs of asset degradation, such as cracks, potholes and rutting (in the case of pavements) and fatigue (in the case of structures). The level of load repetition is determined by the demand for road use, with the drivers of demand discussed further in section 2.2.2. The level of understanding of the exact relationships between load repetitions and asset deterioration is limited, both in Australia and elsewhere in the world. This makes modelling of these relationships a challenging task.

Climatic Influences

The climatic conditions of the area can strongly influence deterioration patterns. A road will generally deteriorate more quickly in a wet climate relative to a dry climate. The impact of water is greater where water is able to get into the pavement structure (often through surface cracks or where drainage is not sufficient). Once this occurs, the impacts of load repetitions are magnified. Surface condition is strongly influenced by temperature and exposure to sunlight. In addition, deterioration will tend to be greater in climates subject to large variation in temperature where freeze thaw conditions exist.

Construction Quality

The fourth factor that affects the rate of deterioration is construction quality. If construction is undertaken poorly, then this will lead to a faster rate of deterioration than if construction had been undertaken to a high quality. Poor construction occurs when design requirements are not fully adhered to or were not applied. For example, air bubbles in cement can weaken structures. The quality of available materials is also a significant factor. The geology of the surrounding area is also significant, with strong, well drained material leading to better road performance than otherwise.

The four influences can not be completely isolated. Environmental influences can make the road more or less vulnerable to damage, resulting from load repetition. Similarly, different types of assets can be more or less susceptible to load repetition.

Partly due to these interactions, technical knowledge of the performance of road infrastructure in sufficient detail and accuracy to allow accurate modelling roads is limited. There is little data, for instance, on the impact on future deterioration of maintenance works. Similarly, there is little information on the impact of a change in loading repetitions on future deterioration of a road pavement or structure.

2.2.1 Categories of Assets

Roads

In order to describe the specific characteristics of road infrastructure asset management, it is important to point out the heterogenous nature of roads. For example, roads are generally classified according to their function, such as:

- National Highway;
- arterial (urban/rural); and
- local road (urban/rural).

These classifications imply a certain level of usage which influences the rate of deterioration and subsequent maintenance works.

Roads are made up of multiple layers, each layer is made of a different material and each pavement may have a different combination of these factors. Generally, the more layers the stronger the pavement, but strength is also a function of the materials used in each layer. A freeway typically includes a sub grade, sub base (compacted soil), base (crushed rock), asphalt base and a wearing coarse (chip seal, etc). On the other hand, an unpaved road may simply comprise a sub grade with a compacted dirt wearing coarse.

As such, roads are designed for the expected type and volume of traffic. Typically, roads are designed to cater for a certain equivalent standard axle load given the composition of traffic that is expected to use the road.

Heavy vehicle road use causes the most wear and tear damage to roads. It has been estimated that there is an exponential relationship between vehicle load and the imposed stress on the pavement. Vehicles that are overloaded (i.e. above the equivalent standard axle design level) cause exponentially more stress on the pavement. Generally, stresses accumulate over time and lead to the visible damage of roads.

Another important element of pavement design is drainage. Poor drainage will lead to the pavement being more susceptible to damage from loads and repetitive use.

At any one time, the road network comprises individual routes with different designs, usage patterns, levels of maintenance and weather conditions.

Bridges

There are primarily three types of bridge constructions: pre-stressed concrete, steel (or iron) and timber. The type of construction technique typically reflects the era in which the bridge was built. Bridges constructed recently (within Australia) predominantly use pre-stressed concrete techniques, though there remains a significant stock of steel/iron and timber bridges.

In bridge design there are stringent standards that need to be met. These standards result in bridges being designed to accommodate much larger loadings than expected, whilst also including a safety margin. This is undertaken to reduce the likelihood of failure. The design life of a bridge is typically 100 years.

Designing bridges to higher standards means that their deterioration is less dependent on load and more dependent on environmental influences relative to pavements. Nevertheless, the existing stock of timber steel/iron bridges is susceptible to damage from traffic flows. As the construction materials fatigue, their susceptibility to loadings increases.

Steel/iron and timber bridges are typically much older than concrete bridges and were not designed for the current vehicle usage. As a result load limits are frequently imposed on such structures.

2.2.2 Road Network Demand Drivers

Road use has a significant influence on deterioration of roads. In general, three main drivers for road use can be identified as follows:

- access (customer service obligations);
- passenger demand (capacity impacts); and
- freight demand (pavement strength impacts).

The demand for the road network is driven by two broad categories of vehicle – light vehicles (typically private vehicles) and heavy vehicles (typically commercial vehicles). It is often argued that demand for access and passenger demand can mainly be attributed to light vehicles and freight demand relates to heavy vehicles only. However, it is important to point out that demand drivers are not independent as for example, demand for access can be driven by heavy vehicles. Moreover, light vehicles often have multiple purposes and can overlap each of the demand drivers.

In general, expansion of road capacity is mainly provided to satisfy the demand of light vehicles, whilst strength and maintenance requirements are driven by the road use of heavy vehicles. Increases in capacity are generally not provided to satisfy the growing demand of heavy vehicles, even though they do benefit from it. Nevertheless, the expenditure associated with provision of capacity is incorporated into heavy vehicle charges, although they do not drive the need for expansion (i.e. an additional lane).

Conversely, pavement strength and maintenance are provided as a result of heavy vehicle demand, though benefits accrue to all road users. Expenditure associated with strength and maintenance benefits all users, but only heavy vehicles are directly charged for it. Light vehicles are charged registration and fuel levies, however these are general taxes and not cost recovery charges. Therefore, cost recovery is only applied to part of the market (heavy vehicles), and those charges include an element which accounts for network expansions that are undertaken in response to demand driven by other market segments.

Added to this problem is the complexity associated with:

- lower levels of past heavy vehicle traffic that results in current repair requirements;
- expansions to capacity are determined by expected future growth in light vehicle traffic; and
- the need to minimise traffic disruptions associated with road works.

These all contribute to the complexity of optimising investment in the road network (refer to Section 2.7.2).

2.3 Road Expenditure

The profile of expenditure on roads is an important element in cost recovery and is complicated primarily as a result of the inherent uneven nature of expenditure (also referred to as ‘lumpiness’). This lumpiness in expenditure is a result of a number of factors, including:

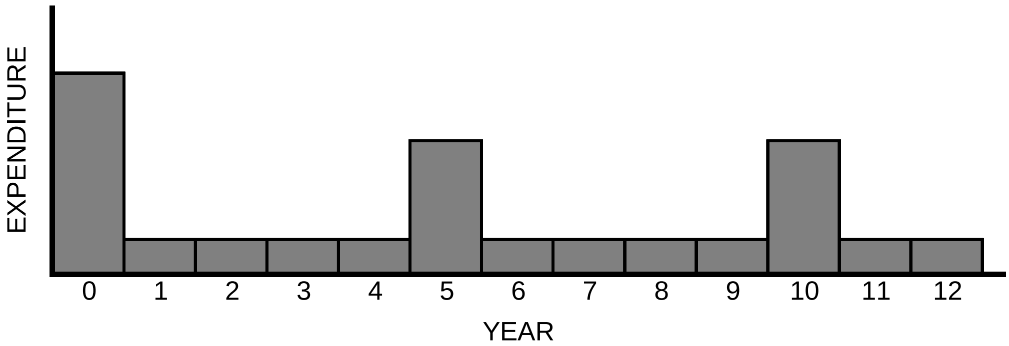
- different rates of asset deterioration;
- different age profile of assets; and
- political influences on expenditure decisions.

As the first factor has already been dealt with in section 2.2, the age profile and political influences are discussed in sections 2.3.1 and 2.3.2.

2.3.1 Age Profile of Assets

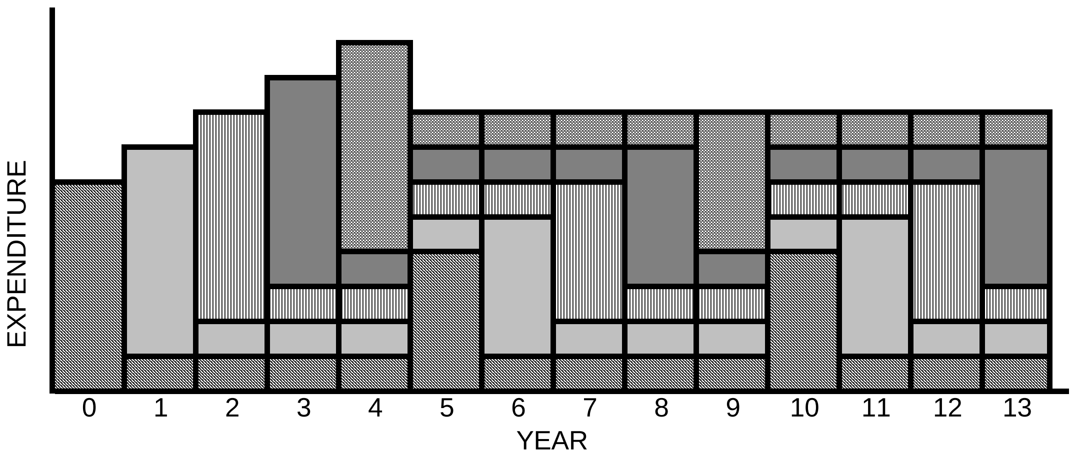
The age profile of assets will influence the timing of asset maintenance requirements on the road network. Consider a single road that has a deterioration profile which leads to different amounts of expenditure to be distributed over time as shown in Figure 1. In the first year initial capital costs are incurred, with subsequent rehabilitation expenditure incurred every five years. In all other years relatively small ongoing maintenance expenditure is required.

Figure 1. Example of an expenditure profile of a single road



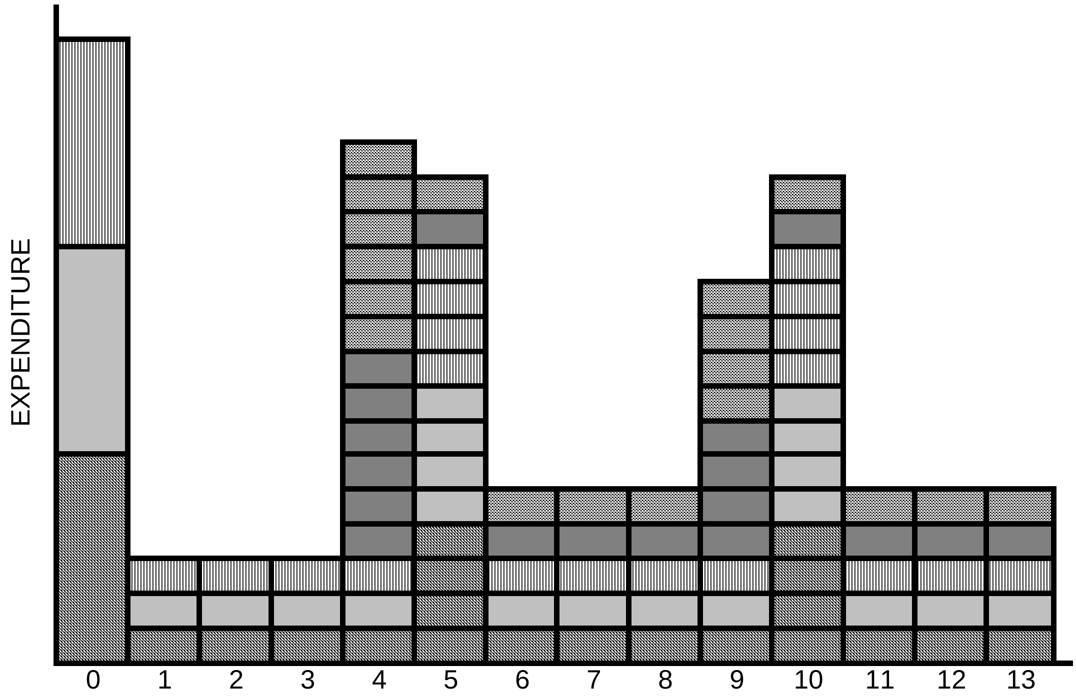
Now consider a small network which is made up of five roads (see Figure 2). It is implicitly assumed that all roads are not only made of the same material, using the same methods but also that other factors influencing deterioration lead to identical deterioration profiles. Assuming that the first road is built in year 1, the second in year 2, and so on, the resulting expenditure profile of the road network is shown below. Expenditure initially increases (as the capital stock is established) and from year 5 onwards expenditure is constant. The age profile of this simple network is even, and results in a constant profile of future expenditure (once the capital stock is established).

Figure 2. Example of an expenditure profile–even age profile



Now consider a small network that is also made of five of the simple roads and assume that three roads are built in the first year, and two in the fifth year (see Figure 3). This implies that the age profile is uneven. The resulting expenditure profile is shown below, and illustrates that with an uneven age profile, expenditure can vary significantly.

Figure 3. Example of an expenditure profile–uneven age profile



'Clustering' of investment in new roads is likely to lead to clustering in rehabilitation expenditure, and hence a volatile expenditure profile.

It should be stressed that it was assumed that the deterioration profile of all individual roads has been assumed to be constant. Relaxing this assumption will mean that the resulting expenditure profile may be random, through the combination of different age profiles of the network and individual deterioration profiles of each road. However, it is unlikely that a constant expenditure level is achieved.

2.3.2 Political Influences

Volatility in road expenditure is also driven by political influences. Ultimately, political decisions determine road agency budgets and funding, and hence expenditure. Road agency budgets and funding levels are usually influenced by the following factors:

i) general economic conditions; and

ii) voter groups and their preferences.

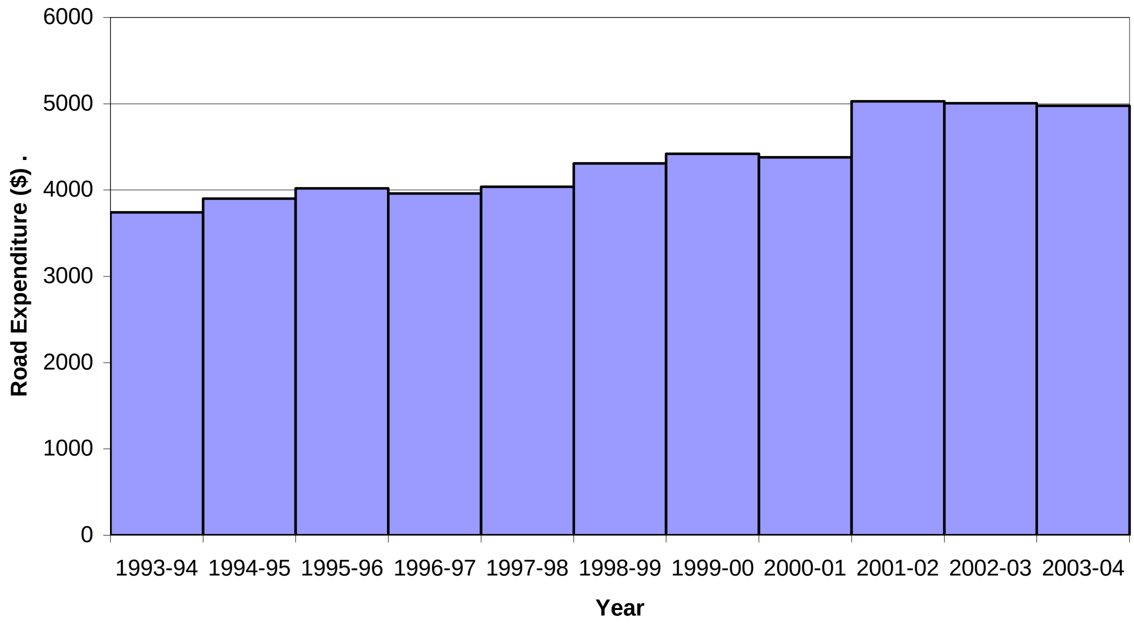
During periods of economic expansion, government revenues will be increasing, which usually flows through to higher expenditure budgets. Conversely, during economic recessions, government revenues fall, which often results in a reduction in departmental budgets. Therefore, the general business cycle will influence the volatility of road expenditure through the levels of government expenditure.

Voter groups influence the decisions of politicians through lobbying. These activities can result in expenditure to be undertaken at politically decisive points in time. It also tends to be the case that different sectors of the economy are of more importance to the general public at different points in time. Therefore, if the quality of roads is a priority issue to voters, the expenditure on roads may increase. Likewise, road funding could be reduced in order to satisfy demands for increased expenditure in other areas of the economy.

2.3.3 Historical Road Expenditure

A plot of historical arterial road expenditure is shown in Figure 4. The figure shows a fairly level arterial road expenditure in 2001-02 real prices (inflated/deflated using the Bureau of Transport and Regional Economics, Road Construction and Maintenance Price Index). It is evident that there has been a general upward trend in expenditure, with a significant increase around 2001-02. Even though the figure shows expenditure levels that are steadily increasing, further disaggregation of the network would show that investment (e.g. by state) and within different expenditure classifications (i.e. rehabilitation, expansion, operating and servicing), has in fact been 'lumpy'.

Figure 4. Historical Arterial Road Expenditure (2001-02 Real Prices, millions)



Source: NTC Road Expenditure Data

2.4 Components of Expenditure

There are essentially three broad areas of expenditure associated with the road network:

- capital expenditure;
- maintenance expenditure; and
- operating expenditure.

The distinction of different types of expenditure is important as it can have implications for the periodic pricing determinations. The current NTC Road Expenditure Reporting Categories are shown in Table 1. Capital expenditures are captured within the template through Item F – Asset Extensions/Improvements, and Item E – Low Cost Safety/Traffic improvements, is also essentially a capital cost.

Expenditure associated with maintenance activities (including rehabilitation) are disaggregated into a number of different categories. Broadly, they could be grouped as those maintenance activities that occur at a frequency of more than once a year, and those that occur at a frequency of less than once year. The latter group tends to provide benefits over multiple years. Accounting principles suggest that maintenance expenditure should be amortised over the number of years in which benefits are expected to accrue. Therefore, it can be argued that some items that may be considered as maintenance (such as rehabilitation) are better treated similarly to capital. The classification of expenditure is important as it implies how expenditure should be recovered over time. Expenditure that provides long-term benefits should be recovered in the long-term whereas expenditure that provides short-term benefits should be fully recovered at an earlier point in time.

Items B2, C and D are those maintenance activities that occur at an interval of more than once a year, and are perhaps considered more like capital. Item B1 is maintenance activities that occur at a frequency of more than once a year.

Operating expenses are those expenditures incurred from administering the road network, and include Items A and G. Item H relates purely to Local Roads and are an aggregate measure of local road expenditure. The expenditure on local roads can also be classified into Items A through G, which provides a more useful breakdown when considering alternative cost recovery methodologies and distinguishing between different assets and expenditure items (e.g. capital, maintenance or operating).

Table 1. Current NTC Road Construction and Maintenance Expenditure Reporting Template

ACTUAL EXPENDITURE ($ million)					
	Expenditure Category	**National Highways**	**Urban Arterial**	**Rural Arterial**	**Total**
A	**Servicing and operating**				
B	**Road Pavement and Shoulder Construction**				
B1	Routine maintenance				
B2	Periodic surface maintenance				
C	**Bridge maintenance/rehab**				
D	**Road Rehabilitation**				
E	**Low-cost safety/traffic**				
F	**Asset Extension/Improvements**				
F1	Pavement improvements				
F2	Bridge improvements				
F3	Land acquisition, earthworks, other extensions /Improvement expenditure				
G	**Other Miscellaneous Activities**				
G1	Corporate services				
G2	Enforcement of HV regs				
G3	Vehicle registration				
G4	Driver licensing				
G5	Loan servicing				
Totals					
H	**Other Road Related Payments**				
H1	Payments of grants and assistance to councils for work on arterial roads managed by councils				
H2	Payments to councils for contract work carried out on State managed roads				
H3	Spending on local access roads in unincorporated Areas				
H4	Direct State/Territory spending on council managed local access roads				
H5	Any other direct State spending on local access Roads				

Source: NTC

2.5 Expenditure versus Cost

It is important that a distinction between cost and expenditure be made at this early stage. Cost can be defined as the amount by which the value of an asset is reduced, or consumed, as a result of usage of that asset. Therefore, as a vehicle drives along a road, it will continually be accruing a cost associated with its use.

Expenditure is the amount spent, or the cash flows, associated with providing, maintaining and operating the road network. At a theoretical level, as a vehicle drives across a road it causes (some degree) of damage to the materials of the road, although it may not be visible through cracking, rutting or a pothole. No expenditure occurs as the damage occurs, instead, the damage from repeated use accumulates over time until such time that the cumulated damaged is repaired. It is at this point, when the damage is repaired, that expenditure is incurred. Therefore, large differences in the timing of damage (cost) and the expenditure associated with repairing the damage can arise.

2.6 Components of Costs

Costs incurred by heavy vehicle road use can be distinguished as to whether they are economic or financial costs and according to whether they are short-run or long-run marginal costs. Determining which costs should be recovered can result in considerable differences in charges.

2.6.1 Economic versus Financial Costs

In order to assess cost determination methodologies, the type of costs that should be included in the total costs to be recovered has to be determined. Two different types of costs can be considered. Firstly, financial costs are costs with a monetary value and entail a financial outlay. Secondly, economic costs include all costs to society, and typically include externality costs in addition to financial costs.

Externalities are the impacts caused by one economic agent's actions on another economic agent, such that one agent's decisions make another better or worse off. In the context of a road network financial costs would include cash flows associated with construction, maintenance and operations (including raw materials, labour and equipment, etc).

Economic costs of a road network include:

- those financial costs above; and
- externality costs for which no cash flow occurs (including pollution, congestion, amenity, etc)

Currently, the heavy vehicle pricing regime only recovers financial costs. However, the Australian Transport Council pricing principles do provide the possibility of charging for noise and air emissions if:

- there are clear net economic gains;
- the extent of effort is recognised; and
- transparency and more accurate pricing within the road mode are ensured.

It is debatable whether externality costs should be included in the cost determination. It is arguable that many externalities are not associated with the provision of road infrastructure but with the operation of vehicles on that infrastructure. Therefore it may be more appropriate that these externality costs are reflected in final freight rates rather than in heavy vehicle access charges. If it were deemed that these externalities should be associated with infrastructure provision, in the short term it is unlikely these costs could be accurately included. This is because there are often difficulties in measuring externality costs and their quantification can involve the application of a series of assumptions which are subject to uncertainty.

2.6.2 Short Run Marginal Cost

The economic marginal cost of road use in the short-run includes the wear and tear caused by road use (predominately heavy vehicle road use) as well as externality costs (a financial marginal cost would exclude the externality costs). The short run marginal cost is the additional cost associated with an additional vehicle using a road. The effect of this additional vehicle on future capacity extensions is not taken into account.

Costs associated with future capacity extensions (i.e. capital costs) are excluded from a short run marginal cost because the capacity in the short term is fixed, as current capacity can not be easily adjusted (traffic engineering solutions can make small adjustments to capacity through improved signal co-ordination, signage, etc). As a result, the short run marginal cost in infrastructure–based industries is typically close to zero.

Those cost items in the NTC expenditure template that relate to short run marginal cost would include Items A, B1 and G. Items B2, C and D are also related as they are the result of the accumulation of short run marginal costs associated with road usage, but because of their frequency, are more likely to be considered long run costs. More specifically, the short run element would be localised wear, such as pot holes, that are repaired as part of routine maintenance.

2.6.3 Long Run Marginal Cost

In the long run, capacity is variable as new roads can be built, old roads can be closed off or pavement strength can be varied. Therefore, long-run marginal costs (both economic and financial) include the costs of expanding capacity in order to accommodate additional vehicles.

Long-run marginal costs are the costs of adjusting the level of capacity in order to accommodate one additional vehicle. In the long-run the road network can be optimally adjusted to match demand.

Items F and E are long run marginal costs. As noted above, Items B2, C and D are the result of accumulation of wear and tear, which is essentially a short run cost. However, the decision to spend money to repair wear and tear is linked to decisions about capacity expansions. Therefore, there is a long run element to these items. More specifically, resealing, cracking and rutting are items related to long run costs, and are addressed through rehabilitation or reconstruction.

2.7 Efficiency and Optimisation

2.7.1 Efficiency

Efficiency is a concept which recognises that resources are scarce and therefore should be utilised in a manner which maximises their benefits. There are several types of efficiency which should be considered in the provision of road services. The most prominent is allocative efficiency. This is where resources are directed or allocated to the area that derives most benefit. There are two ways this could be interpreted in road provision. The first is the extent to which resources are allocated appropriately within the road network (i.e. is right investment being made on the right roads that derive the maximum benefit). The second is the extent to which resources are appropriately spent on roads rather than other sectors. This form of allocative efficiency is at the heart of the competitive neutrality debate.

The other key form of efficiency is productive efficiency. This addresses whether resources are being used at their optimal level, thereby reducing overall costs. In the roads context this essentially means whether investment being undertaken in the least cost manner, for example, without wasteful practices.

In summary these two forms of efficiency determine whether the right investment or expenditure is being undertaken and whether it has been undertaken in the least cost manner[6].

As discussed earlier, there are multiple demand drivers for the use of roads, including the movement of freight, and people, access and connectivity. Efficient investments in the road network will result in achieving the optimal level of service towards these outcomes (output) from minimal investments. Inefficient investments will either lead to overinvestment or underinvestment in parts of the network and therefore will not contribute to achieving these outcomes.

The relevance of the concept of efficiency to cost recovery (and hence pricing) is that only efficient investments should be recovered. Any inefficient investment should not be recovered, as it does not contribute to the achievement of the outcomes in a more productive manner.

Inclusion of inefficient investment in cost recovery may lead to road charges being higher than if only efficient investment was undertaken. Therefore, road users would be paying a premium for which they do not necessarily receive a better service. In cases in which resources spent on project implementation such as contract management can lead to overinvestment, the higher costs do not lead to an increase in services. In some cases however, overinvestment might lead to a level of service that is higher than the optimal level.

Overall, this suggests that inefficient investments need to be excluded from the determination of the total cost to be recovered. Equally, underinvestment which will result in greater costs at a later date or to road users, should not drive prices lower.

2.7.2 Optimisation

Optimisation in a road network sense refers to the maximisation of the network to satisfy the economically optimal level of demand. In this report it refers more to usage of the network as well as the timing of efficient expenditure. Through optimising the network, capital, maintenance and operating expenditure associated with the road network across its whole life are minimised as expenditure occurs at a rate determined by the best level of usage of the network. The optimisation process aims to minimise these ‘network’ expenditures as well as the vehicle operating costs that road users incur – though the vehicle operating costs to road users are not included in the cost base. Thus the network and its usage are optimised when the total cost of providing, maintaining **and using** the network are minimised across its whole life.

The optimisation of a road network is a complex problem, given the number and variety of roads, the varying climatic and geographic conditions, road construction types and traffic volume and composition. Furthermore, the need to optimise across both capacity (capital

[6] It is important to note that dynamic efficiency (the development of new technologies to improve productivity) is also an important concept in road service provision but is a secondary issue in costing.

investment) and condition (maintenance and rehabilitation) means that inter-temporal issues need to be taken into account.

Capital investment and maintenance expenditure are inherently linked. An expansion of the road network (increase in the capital stock) will result in a higher maintenance requirement. Furthermore, delaying network expansion may increase maintenance requirements, so a trade off between capacity and maintenance exists. Alternatively, a delay in maintenance may mean that at some point in the future, more expensive capital investment is required in order to continue to provide the road.

2.8 The Disconnect between Revenues and Expenditure

The current regime of expenditure and revenue relating to the road network is a taxation based system. Expenditure is determined through the allocation of government resources to different sectors of the economy. Revenues from each sector are collected by means of taxation and are (primarily) pooled in consolidated government revenues. The degree of earmarking (or hypothecating) funds collected in the road sector for subsequent expenditure in the road sector is limited.

A preferred regime for total road cost recovery is one in which there is a link between revenues and expenditure. This would lead to correct price signals to economic agents about the cost of providing, operating and maintaining the road network, and providing them with a network that satisfies their demand. Better pricing signals will not only lead to road users using the network in an optimal manner, but it also results in the correct pricing signals for land use development. Therefore, there is more efficient allocation of resources across the whole economy, as well as within the transport sector.

A link between revenues and expenditure could also improve transparency in road network funding. Users could follow the link between the revenues collected, and how much was spent on the road network.

3. PAYGO

3.1 Existing Approach

In assessing alternatives to PAYGO it is first necessary to understand the existing approach including its underlying assumptions and its relative strengths and weaknesses.

Currently applied by the NTC, this method assumes the costs of road use are equal to a 3 year rolling average of actual and budgeted road expenditure (the last two years of actual expenditure, and the current budget year at the time of determination). Road expenditure is disaggregated into its sub components including construction, maintenance and miscellaneous costs (refer to Table 1). Expenditure is then allocated to different road users based on the road use giving rise to that expenditure. Road use variables used to allocate costs include:

- vehicle kilometres (VKT);
- passenger car equivalent kilometres (PCU-km);
- gross vehicle mass kilometres (GVM-km); and
- equivalent standard axle load kilometres (equivalent standard axleL-km).

Once the share of costs attributable to each class of road user has been determined, a two part charging system is applied. This includes:

i) an access component which is collected as a fixed annual charge by the States and Territories at vehicle registration on the basis of vehicle size; and

ii) a road use component which is collected by allocating a proportion of the diesel fuel excise collected by the Federal government as a payment for road use.

In the past, heavy vehicle road pricing determinations have been undertaken on three occasions in 1991, 1998 and 2005. Given the gap between these determinations, the average allocation assumptions calculated at each were applied over a number of years. Given changes to the vehicle fleet and usage over time, these assumptions gradually became increasingly inaccurate and did not account for changes in conditions in the intervening period. In addition, the quantum of vehicle charges was gradually eroded over time through inflation. This issue was partially addressed in 2001 when an annual adjustment procedure was introduced in order to account for changes in expenditure and expected traffic and fleet growth (only the annual registration charging mechanism is adjusted annually). Since the introduction of the annual adjustment vehicle charges have largely been updated to reflect changes in the Consumer Price Index. However, its cap of the Consumer Price Index may lead to the gradual erosion of the real value of heavy vehicle charges if road construction industry prices are increasing at a greater rate.

Despite these changes, PAYGO is based on the assumption that average annual expenditure is equal to annual cost. The validity of this assertion requires the following assumptions:

- Expenditure decisions concerning the road network are assumed to be based on economic criteria. Thus expenditure that is not economically justified does not occur and expenditure that is worthwhile is not deferred.
- The road network is in a steady state condition which means that it is neither expanding nor contracting.
- Across the network there is no overall deterioration in the asset base over time and that no backlog maintenance liability exists.
- There are no administrative or budgetary constraints to maintaining the steady state condition of the road network and that the money raised from road user charges is spent entirely on the road network.
- Expenditure on the road network is broadly unchanged over time and any ‘lumpiness’ in expenditure through increased periodic investment costs is limited so that across the network the amount spent on each type of road work does not fluctuate markedly year-on-year.
- Traffic growth is relatively small and steady both across the road network and across different vehicle types implying the vehicle fleet characteristics do not change.

The relative advantages and disadvantages of the PAYGO approach are discussed in the following sections.

3.2 PAYGO Advantages

There are two main advantages with the current PAYGO system which are:

- simplicity and transparency; and
- other assumptions aside, PAYGO ensures that costs (proxied by expenditure) allocated to heavy vehicle classes are recovered in aggregate.

Under the current PAYGO system, the road cost allocation process is well established and relies on data that is currently available on road expenditure and usage. Data on arterial road expenditure is provided by the State and Territory road agencies whilst details of local government expenditure on local roads are available from the Australian Bureau of Statistics. Road use estimates are provided from the Australian Bureau of Statistics Survey of Motor Vehicle Use for each State and Territory.

More importantly the cost allocation process is transparent and well understood by the freight industry. This ease of understanding by industry as to how cost allocation and subsequent road user charges have been determined, means that there is a degree of industry buy-in and acceptability of the current system.

The second advantage of the PAYGO approach is that, on average, vehicles are charged on the basis of their share of the cost of road construction and maintenance expenditure as it occurs in any year. Thus all expenditure is recovered.

3.3 PAYGO Disadvantages

Section 3.1 highlighted a number of assumptions which are required to hold if the PAYGO approach is to be seen as a valid method for determining cost allocation. The following discussion highlights a number of weaknesses in the PAYGO approach.

3.3.1 Economic Efficiency

The PAYGO approach implicitly assumes that all expenditure decisions concerning the road network are assumed to be based on economic criteria and that the expenditure budget is optimised. Thus expenditure that is not economically justified does not occur and expenditure that is worthwhile is not deferred. There are a number of potential difficulties with this assumption.

Firstly, a significant proportion of road agency budgets in Australia are allocated to roads where there is no economic justification for that expenditure. Community Service Obligations play a major role in the decision making process in constructing and maintaining certain roads. In Australia a significant proportion of the road network is provided solely for the purposes of amenity rather than being economically justified. This is particularly the case for local roads in rural areas where the level of road design provided is often in excess of what is economically justifiable given current and future expected usage. In this instance the level of this road expenditure is usually determined taking into account political or social considerations to meet the needs of particular interest groups. Furthermore, windfall gains in taxation revenue can also lead to the investment in roads that are uneconomical.

Secondly, some economically efficient road expenditure may not occur due to budgetary or resource constraints. State/Territory and local governments do not have unlimited funds at their disposal and largely rely on Federal Government grants or locally generated taxation to support expenditure decisions. It is usually the case that the funds available for government expenditure are insufficient to meet all of the demands on those funds and some degree of rationing occurs. This is not just true of road sector expenditure. Government spending decisions usually require the application of political priorities to determine the level of expenditure across a range of sectors including transport, health, education, defence and policing. Similarly, some road sector expenditure, for which a sound economic case exists, might not be implemented simply because resource constraints make it impossible to undertake at a point in time. For example, economically justifiable road maintenance activities might not occur due to a shortage of labour or equipment.

Thirdly, inefficient expenditure might also occur when a certain level of government funding has to be spent on roads in a given year. In this case, some projects might be undertaken earlier than the economically optimal point in time. If funds are allocated according to political reasoning, in some situations governments might be obliged to spend resources on inefficient projects.

3.3.2 Steady State Network

PAYGO assumes that the road network is in a steady state condition which means that it is neither expanding nor contracting. This assumption is not unreasonable in inter-urban situations where the basic road network is well established with linkages between population, employment and other centres of economic activity largely in place. However, the assumption is more questionable in urban and semi urban areas. For example, in the past decade, the rapid growth of a number of Australian cities (particularly in Sydney, Melbourne, Brisbane and Perth) has resulted in increasing urbanisation in previously rural areas. In these instances there has been a growth in the road network coverage as transport infrastructure is provided to service these new communities.

3.3.3 Constant Asset Condition

Under the PAYGO approach it is assumed that across the road network there is no overall deterioration in the asset base over time and that no backlog maintenance liability exists. Given the historical limitation of road funding it is quite likely that expenditure to rectify pavement and bridge deterioration will not have been available. When governments are looking to make savings in road budgets, it is often tempting to reduce road maintenance expenditures as the immediate impact of this deferral is not readily apparent. It is only over the medium to long term that effects of sub optimal maintenance activities become apparent with asset deterioration occurring at a higher rate than would occur under an optimal maintenance regime.

3.3.4 Administrative and Budgetary Constraints

The PAYGO approach also assumes that there are no administrative or budgetary constraints to maintaining the steady state condition of the road network and that the money raised from road user charges is spent entirely on the road network. The validity of the latter part of this assumption is clearly questionable. There is currently little or no connection between the amount of money raised from road user charges and taxes and the amount of expenditure in the road sector. This situation raises the issue of hypothecation.

As discussed above, hypothecation occurs when taxes collected from one group in society are then subsequently re-spent on that same group. In the road sector this currently does not occur. Instead, road user charges revenue flows back into consolidated government revenues (fuel levy revenues go into Federal Government consolidated funds and annual registration charges generally form part of the States and Territories consolidated funds). State and Territory treatment of registration charges do differ. Currently only one State hypothecates registration revenues back to the road agency (however there is no distinction between light vehicle and heavy vehicle (or PAYGO) expenditure). Some States divert registration revenues to a dedicated road fund. However, Treasury approval is required before these funds can be spent. The remaining States flow registration funds directly to consolidated funds and allocate funding for road infrastructure through the government budgeting process. It is also important to note that registration revenues provide only a portion of the funding required for road expenditure – all other funding comes from consolidated funds.

Treasuries often resist demands for hypothecation as it limits their discretionary powers to direct government expenditure to particular areas. Thus the monies collected from heavy vehicle taxation is not directly spend on road maintenance activities and, as discussed above, road sector expenditure is usually determined by a range of political, economic and social criteria. However, moving towards a situation where there is a greater degree of hypothecation in the transport sector would be advantageous as it would establish clearer price signals for transport users and facilitate a more efficient use of resources across transport modes.

3.3.5 Constant Expenditure Profile

PAYGO assumes that expenditure on the road network is broadly unchanged over time and that any 'lumpiness' in expenditure through increased periodic expenditure is limited so that across the network the amount spent on each type of road work does not fluctuate markedly year-on-year.

This assumption is questionable since electoral and economic cycles have the potential to create distortions in long run expenditure patterns. This effect is to some degree mitigated by the three year rolling average assumed in PAYGO. However, road networks are disaggregated into a number of different jurisdictions (National, State/Territory and Local Authorities) which means these pressures are more likely to have an impact since it is unlikely that all levels of government will be at the same point in these cycles at a point in time. For example, if one state might have embarked on a major network expansion program for a short period then this could alter the proportion of expenditure on different types of road works which could in turn impact on the share of costs allocated to heavy vehicles.

3.3.6 Traffic Growth

PAYGO assumes that traffic growth is relatively small and steady both across the road network and across different vehicle types implying the vehicle fleet characteristics do not change. There is some statistical evidence from Survey of Motor Vehicle Use data to support this assumption. However, at a more local level this is less likely and it seems probable that local influences of economic activity, stage in the business cycle, availability of alternative modes such as rail will influence traffic growth levels.

3.3.7 Inter-Temporal Distortions

The current road network is the result of construction activity which occurred previously when traffic levels were lower. The amount spent in the current year is based on expected future traffic levels, which assuming a degree of traffic growth will be higher than currently. Consequently, construction costs in the current year might be higher than the level directly attributable to the current level of traffic. Conversely, the amount currently spent on road maintenance is the result of the historical accumulations in pavement and bridge wear caused by past traffic which was less than at present. Consequently, maintenance costs in the current year might be expected to be smaller than the true share of maintenance costs (which are yet to be incurred) resulting from current traffic.

These two effects are assumed to balance out under the PAYGO approach, so that the amount spent in the current year approximates the true share of costs associated with the current traffic. This assumption will not hold if there are variations in traffic growth over time.

3.3.8 Difficulties in Data Estimation

Expenditure data under PAYGO is collected from State authorities (for arterial roads) and the Australian Bureau of Statistics (for local roads). Local road expenditure which is adjusted to allow for additional State agency spending on this road type and to avoid double counting. State level expenditure is broken down into a number of different expenditure categories known as the NTC Road Expenditure Reporting Categories. Currently, for cost allocation purposes it is assumed that local road expenditure (which is only disaggregated between capital and maintenance expenditure) is distributed in the same proportions across each of the expenditure categories as arterial roads.

Each of the different cost items is allocated according to a different measure of usage. Therefore, the accuracy of the expenditure estimate on each of the different NTC Expenditure Categories will have a bearing on the user charges ultimately developed. The allocation of total costs also relies upon estimates of usage, including vehicle kilometres travelled, proportions of different vehicle types, equivalent standards axles.

Therefore, estimation errors are likely to occur in both the determination of total expenditure as well as in the allocation of total expenditure. The allocation process relies on averages across states for fuel consumption, vehicle mix and expenditure, which in itself can see some states subsidising other states.

The difficulties in data estimation are more concerned with the cost allocation process and are, as such, not a direct criticism of the PAYGO approach. If data collection and estimation accuracy could be improved this would lead to improved cost recovery through PAYGO as well as any alternative approach.

4. ALTERNATIVE APPROACH – ENHANCED PAYGO

An enhanced PAYGO approach has the ability to address some of the weaknesses of the current PAYGO approach, but not all. An enhanced PAYGO approach is outlined in the following sections.

4.1 Potential Framework

Two weaknesses of the PAYGO approach are addressed in this proposed enhanced PAYGO methodology. They are:

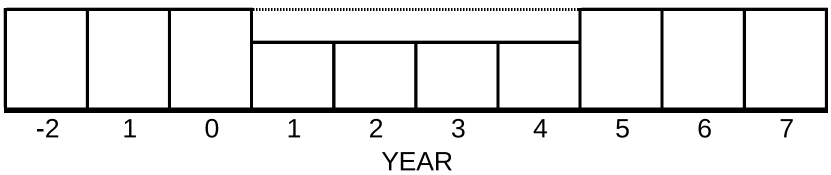
- the averaging in expenditure only capturing part of the expenditure information; and
- the assumption of expenditure being efficient.

These are discussed below.

4.1.1 Averaging of Expenditure

Each of the three pricing determinations that have been undertaken to date have been at intervals of about seven years[7] . In the determinations, a three year average of expenditure data is used to determine the total average expenditure to be recovered. This means that there are four years of information between determinations that is not taken into consideration. It is noted that there is an annual adjustment process applied to registration charges each year, but has limited scope to correct for over/under recovery, due to the adjustment being capped at CPI and the price floor which means road user charges can not be reduced by the annual adjustment process.

Use of a subset of the expenditure information will mean that the lumpiness of road expenditure will not be fully captured. Consider the case where the expenditure in years -2 to 0 and 5 to 7 are equal, but expenditure is lower during the intervening years. This is illustrated below. The dotted line represents the level of recovery based upon road user charges set based upon the average of the first three years. This results in over recovery of total cost.



The alternative case is if expenditure in the intervening years is higher. Such a case would result in under recovery of total cost. (It is noted that it is also possible that expenditure could be equal across the whole horizon, in which case total cost is recovered exactly).

One way to overcome this problem is to adopt a longer period over which the average expenditure is calculated. Taking all expenditure information between determinations, rather than just three years information, will capture the 'lumpiness' in expenditure, and will remove the potential for under and over recovery. The period over which the average is taken should be linked to the time between determinations, such that all expenditure information is included in at least one pricing determination.

---

[7] This seven year period between determinations is not a *rule* but is a guideline which NTC attempts to target.

Although extending the period of which average expenditure is calculated addresses under and over recovery it does not resolve the issue of a lag between cost and expenditure. There will still be a build up in cost that results in expenditure in the future. This lag means that future users will be subsidising current road users use of the network (though the affect of this at an inter-generational level is unclear – past users are subsidised by current users, who are in turn subsidised by future users, and so on).

There is also an issue associated with lags in recovery. Historical information is used to set future charges, therefore, expenditure from one period is essentially recovered in the following period. Though this is complicated by traffic growth, as charges determined from the first period of expenditure are based upon traffic usage in that period. Traffic growth will mean that there is higher traffic in the second period relative to the first. This will result in revenues collected during the second period being higher than the expenditure in the first period.

4.1.2 Ex-post Review of Expenditure

Charging of users for inefficient (and sub-optimal) investments does not send pricing signals that enable economic agents to make efficient allocation of resources, they create distortions in the market. Adjusting historical expenditure data used for determining future charges for inefficient (and sub-optimal) expenditure will help to minimise the distortions under an enhanced PAYGO framework.

Undertaking an *ex-post* review of expenditure to determine whether expenditure has been efficient will enable any inefficient expenditure to either be excluded, or adjusted for, in the process of setting road charges. Excluding inefficient expenditure from the determination of total cost is quite simple (once the level of expenditure to be excluded has been estimated). However, this will simply mean that there is a reduction in the average charge applied to the road network. Perhaps adjusting for inefficient expenditure within the charges applied to different roads is more prudent. It is then transparent as to which roads are being provided for customer service obligations.

Ideally, any ex-post review incorporated into an enhanced PAYGO approach would also address the issues of optimality. However, as optimality is related to the timing of works, and enhanced PAYGO is still a backward looking approach, the questions of how to identify sub-optimal expenditure, and how to adjust for it, arise.

To identify sub-optimal expenditure, you need to know what the optimum is. This would essentially require a whole of lifecycle cost (whole lifecycle cost) modelling exercise, which defeats the point of an enhanced PAYGO approach. Therefore, identification of sub-optimal expenditure is difficult to determine as part of a review.

Even if sub-optimal investments could be identified as part of an ex-post review, adjusting for them is difficult. It would essentially require knowing how undertaking the sub-optimal investment changes the present value of the whole lifecycle cost, and then making an adjustment to charges.

A review of total revenues collected versus total expenditure will help to establish whether there has been over or under recovery. An adjustment for any over and under recovery would seem to be appropriate. However, the nature of this adjustment needs to be established. Adjusting for any under or over recovery during one pricing determination period in the next might not affect those users who were over/under charged. Instead, users in the second period will be subsidised by users in the first period (if there was over recovery), and vice versa (if there was under recovery).

Therefore, it only seems feasible to determine, ex-post, inefficient investments, and adjust for these.

Undertaking an ex-post efficiency review, to validate actual expenditure, should include both a bottom up and a top down analysis. Bottom up analysis would include a sampling of projects to examine each one on a case by case basis to determine whether they achieved economic efficiency in terms of generating an economic return on the cost of investment, whether works were completed in an efficient manner (avoidance of poor project management and supervision) and whether the works achieved the desired outcome in terms of restoring the road network to the desired and planned condition.

In terms of the top down assessment this could include an analysis of total network wide road sector expenditure and revenues received. In the case of expenditure data, analysis of the actual amount spent compared to budget might indicate whether efficiency was being achieved. An under-spend compared to budget might indicate some economically justified projects were not being implemented, which would lead to a loss in efficiency, or that there had been an improvement in productivity. Similarly, if there was over-spend compared to budget then this might indicate that either planned projects were running over budget or some additional unjustifiable projects were being undertaken (it may also indicate that additional projects were identified that were economically justifiable, but had not been identified within the budget.

Undertaking an efficiency review in the roads sector is likely to be complicated. In addition to reviewing expenditure undertaken by over 700 road agencies, it will be difficult to estimate the appropriate efficiency levels. Typically this is done by some form of benchmarking exercise. However, a lack of information in this area might initially require efficiency assessments to be conservative.

4.2 Advantages

Three main advantages of an enhanced PAYGO approach to cost determination have been identified. The enhanced PAYGO approach:

- maintains much of the simplicity of PAYGO, but addresses some of its problems;
- retains much of the transparency of the current PAYGO approach; and
- contributes to reducing the disconnection between revenues and funding.

Firstly, the enhanced PAYGO approach maintains much of the simplicity of the PAYGO approach to cost determination. It addresses some of the problems associated with PAYGO whilst improving the overall approach to cost determination.

Secondly, an enhanced PAYGO would retain much of the transparency associated with PAYGO. The transparency of determining total expenditure is retained as it is simply proposed to capture more of the information. The introduction of an ex-post review on efficiency does create transparency in expenditure relating to Community Service Obligations as these are identified and adjusted for (either through the cost base or some other means). However, there is a reduction in transparency associated with the ex-post review process in that the process may be complex, and not immediately obvious to outsiders.

Thirdly, an enhanced PAYGO approach could reduce the disconnection between revenues and funding as it will provide a better estimate of average total expenditure. The resulting road user charges would reflect to a greater degree the actual expenditure across a period of time, hence revenues would be more aligned with actually expenditure.

4.3 Disadvantages

An enhanced PAYGO approach has three disadvantages:

- full optimisation of asset expenditure is not achieved;
- the invalidity of the steady state assumptions remains a drawback; and
- lumpiness of expenditure and revenues is not fully removed.

Firstly, under enhanced PAYGO optimisation of the expenditure on assets is not improved when compared to the current PAYGO approach. Although ex-post efficiency reviews can be part of an enhanced PAYGO approach, the question of whether the timing of expenditure is optimal is only addressed from a backward looking point of view. Therefore, an enhanced PAYGO approach does not improve the timing of future works to be undertaken.

Secondly, for an enhanced PAYGO system to be applied the assumption of the network being in a steady state still has to be made. However, this assumption is no more likely to hold under enhanced PAYGO than it is under PAYGO. Consequently, this drawback of the PAYGO approach is not addressed.

Thirdly, lumpiness in expenditures and revenues will not be fully removed. Increasing the time span over which to average expenditure smoothes out some of the expenditure. In addition, the enhanced PAYGO system ensures that expenditure of all years between two determinations is included and thus the average does not exclude any years. Nevertheless, the backward looking nature of the enhanced PAYGO approach implies that cost recovery of the current period is based on past expenditure. In addition, enhanced PAYGO cannot fully remove the risk of basing charges on lumps in expenditure.

4.4 Implementation

The implementation of an enhanced PAYGO system has two components. On the one hand, implementation is likely to be relatively easy as the basic structure of the PAYGO approach is maintained. For example, instead of using expenditure data over threw years, seven years of data are required. As the availability of expenditure data is not an issue, the implementation of this component of the enhanced PAYGO system is likely to be straightforward. It should also be pointed out that time span of seven years is chosen rather arbitrarily. It is based on the fact that in the past cost determinations have been undertaken approximately every seven years. The underlying principle implies that cost determinations should include expenditure data on all years between two cost determinations.

On the other hand, the implementation of the ex-post review component of an enhanced PAYGO system requires significant resources and is likely to be problematic. In order to implement a successful system of efficiency reviews, a number of conditions have to be fulfilled.

Generally, agreement on the methodologies adopted for reviews is essential. As road projects are funded and approved by all three levels of government (local, state and federal), broad support for the implementation of ex-post efficiency reviews would be required. This includes agreement on the institution that should undertake the reviews and the institutional mechanisms for deciding in which cases expenditure should be adjusted. It is very likely that agreement on these issues could easily be achieved. However, as various levels of government already conduct ex-post project evaluation and the issue is also addressed by the ATC guidelines on Transport System Management (ATC, 2004), it might be possible to make use of some of the existing evaluation frameworks instead of developing new procedures. This approach could be a cost-effective and efficient way to approach the topic.

The level of resources required to undertake ex-post reviews of a representative sample of road projects should also be taken into account when considering the implementation of an enhanced PAYGO system.

Overall, it can be concluded that the implementation of basic cost determination of an enhanced PAYGO approach is likely to be relatively simple. In contrast, a number of difficulties arise when considering the implementation of ex-post reviews.

5. ALTERNATIVE APPROACHES – WHOLE OF LIFECYCLE COSTS

5.1 Introduction

A whole of lifecycle cost approach is able to address most of the weakness associated with PAYGO. Such an approach is based upon the asset management principles of minimising the whole of life costs of assets, through determining the optimal timing for asset maintenance, rehabilitation and replacement. This section outlines some of the issues involved in applying a whole lifecycle cost approach to the road sector and, in particular, in informing road cost allocation decisions. The section also includes a discussion of the relative advantages and disadvantages of applying a whole lifecycle cost approach.

5.2 Potential Framework

The concept of applying a whole lifecycle cost approach involves an ex ante determination of the future cost associated with providing, maintaining and operating the road network. This cost establishes the revenue required in order to recover costs (including the opportunity cost of capital) from which road use charges are then established. However, there are a number of important considerations including:

- the determination of a regulatory asset base;
- depreciation charges;
- rate of return; and
- the treatment of disposal and residual values.

Each of these is considered below.

5.2.1 Regulatory Asset Base

A whole lifecycle cost approach requires the determination of an opening regulatory asset base (original asset value). The original asset value is the capital value of the existing assets. It is used as the basis for determining the return *of* capital (depreciation) and the return *on* capital invested.

There are a number of approaches that have been developed for the purpose of estimating a original asset value, including:

- depreciated optimised replacement cost;
- current cost valuation;
- gross optimised replacement cost; and
- economic based valuation.

Depreciated Optimised Replacement Cost

The depreciated optimised replacement cost is the current cost of replacement of an asset less deductions for physical deterioration taking account of all obsolescences and optimisation. In depreciated optimised replacement cost valuations, optimisation often reduces valuations by factoring in any over-engineering, technical obsolescence (e.g. new construction techniques, materials and/or standards) or surplus capacity.

Current Cost Valuation

Current cost valuation is calculated by taking the historic purchase price and rolling it forward by adjusting for inflation and depreciation over the intervening period. The main problem with such an approach is that the rolled forward value can quickly diverge from what the actual condition is.

Gross Optimised Replacement Cost

Gross optimised replacement cost approach (also known as the reference utility methodology) is based on constructing the asset from scratch assuming a new entrant to a market. This approach is similar to the depreciated optimised replacement cost methodology.

Economic Valuation

Economic or market based approaches which value an asset based on the net present value of the future income generated by the asset. This approach is attractive because it does not require historical information (which may not exist) to calculate a value. However, it is likely that future income may need to be supplemented to reflect economic benefit derived from use of the asset (depending on the approach taken to pricing).

General Issues in Determining Original Asset Value

In establishing the opening original asset value it is necessary to consider the treatment of historical cost. Since the first heavy vehicle charges determination, PAYGO has recovered capital costs effectively in the year they have been incurred. It could therefore be argued that all capital expenditure since that determination has been recovered and therefore should not have a value in the original asset value.

However, the value of capital prior to the first determination is less clear. It could be argued that because road operators still paid registration and fuel charges prior to the first determination that road costs were also fully paid for which would imply that the historical cost is zero. Alternatively, it could also be argued that historical charges were less closely aligned with expenditure and should therefore be treated solely as a tax. That being the case, road operators' contribution to costs is probably best treated as the difference between the average tax contribution of other industries and the rate road operators were charged. The present value of this difference would then need to be deducted to form the opening original asset value. However, the lack of historical data makes this a difficult exercise.

The treatment of historical cost may impact on the method of establishing a value of the opening original asset value. Instead of applying a depreciated optimised replacement cost valuation, an economic value based on future returns may instead be used. An economic valuation is likely to discount the value of the original asset value (i.e. less than the depreciated optimised replacement cost valuation), however, over time as new capital is added to the asset base, the economic value would converge with the depreciated optimised replacement cost valuation.

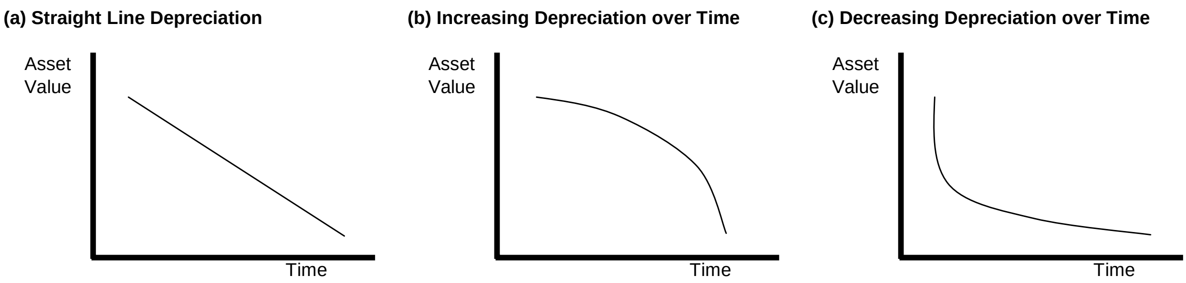
Whichever approach is undertaken to developing a original asset value, one of the key problems in applying a whole lifecycle cost approach in the road sector is that there are a large number of different asset types which would each potentially require an individual original asset value to be established. The magnitude of such a task would be significant and some degree of aggregation would be required in reality. This represents a weakness in the whole lifecycle cost approach as the greater the degree of aggregation the reduced accuracy of the initial valuation.

5.2.2 Depreciation Charges

Capital invested in the network is returned through the depreciation associated with each particular asset. Depreciation is defined as the consumption of an asset and should reflect the physical deterioration of the asset over time. This results in the cost of capital being spread across the expected useful life of an asset.

Figure 5.1 shows possible depreciation profiles which could be applied to road assets. The most straightforward is shown in Figure 1(a) which is the straight line depreciation. Figures 5.1(b) and 1(c) show alternative profiles with increasing and decreasing deterioration rates over time.

Figure 5. Potential Asset Deterioration Profiles



The failure rate of different assets will vary and thus will have different shaped depreciation curves. Some assets will depreciate more quickly simply with age whilst others will depreciate more quickly with usage.

Ideally different depreciation profiles would be available for each asset type but this would require a significant amount of asset condition data to be collected. In the absence of such information, a simplifying assumption of straight line depreciation might be applied.

As has been discussed previously, different road assets deteriorate (and hence depreciate) at different rates. Pavement condition is heavily reliant upon the level of usage (and in particular heavy vehicle usage), and it has been estimated that there is an exponential relationship between load and the damage caused over time. The adoption of an exponential deterioration rate may make the determination of an average asset life difficult for similar asset classes, especially over time.

Across a determination period, an asset may well deteriorate in a manner that is different than what was forecast, which essentially changes the life of the asset. Therefore, it may be necessary to continually update the asset life to reflect the actual point on a deterioration curve where the asset is, and its expected remaining life.

In contrast, bridges are designed to withstand significantly higher loadings than pavements, and the rate of deterioration is more related to environmental factors and age rather than usage. Thus a straight line depreciation curve might be a reasonable approximation. The average asset life of structures is rather long (typically 60 to100 years).

Deterioration of road furnishings (street lights, road signs, traffic signals, etc) are likely to be relatively independent of usage (though some replacement may be required due to vehicles, i.e. vehicles colliding into traffic signals) and a straight line depreciation approach may be applicable. This illustrates the difference between short and long lived assets. Road furnishing assets may not have long enough lives for an increasing or decreasing rate of deterioration to give a result that is significantly different to that of a straight line.

An investigation by the Organisation of Economic Cooperation and Development (OECD) into asset management in the roads sector concluded that use of condition based depreciation was acceptable for pavements and bridges, and that a straight line approach is reasonable for road furnishings[8].

If a whole lifecycle cost approach is to be developed further then it will be important to get a better understanding of what the deterioration profile across all assets would look like.

5.2.3 Rate of Return

The opportunity rate of return of capital should represent the risk associated with a level of expenditure. At a theoretical level, there are likely to be different discount rates for different assets and routes which comprise the road network.

Calculating a rate of return for publicly owned assets is complicated due to the lack of information related to the risk associated with the initial expenditure. The existence of private roads may provide some sort of basis for estimating these parameters as privately funded toll road projects usually derive a weighted average cost of capital which is applied to new investments as the opportunity cost of capital. However, this may not provide sufficient information to differentiate risk across the entire network.

5.2.4 Residual Values

At the end of an asset's life it may have either a residual value and/or a disposal cost which needs to be reflected in a whole lifecycle cost analysis.

At the end of a road asset's life, there may be some value in the asset. The most obvious example is the value of earthworks, that can be used for the development of a new road along the existing alignment. In accounting standards the appropriate treatment of a residual value is to deduct the residual value from the asset value prior to calculating the annual depreciation charge. However, such an approach may not be appropriate given the uncertainty around the life of a road asset and the value of any residual value.

Alternatively, at the end of an asset's life there may be a cost associated with its disposal. These disposal costs could arise through costs of demolition and/or decontamination. Such costs should be taken into consideration in determining the whole of life costs. In practice it may be simplest to assume that these are offsetting, or simply make an adjustment once such costs/values arise, rather than building them in at the outset.

Generally, disposal costs and residual values are assumed to form part of the cost of the new asset replacing the old asset.

5.3 Advantages

The main advantage of the whole lifecycle cost approach is that it provides the best alternative to determine the optimum cost of maintaining the road network over a period of time. The application of a whole lifecycle cost model should incorporate all routine and

[8] OECD, 2001, *Asset Management for the Roads Sector*

periodic maintenance costs to achieve a desired state of repair for the road network. In addition, the whole lifecycle cost approach allows for the optimisation of road network expenditure to achieve the required asset condition. It also establishes a direct relationship between road network expenditure and road user charges revenue as the present value of the lifecycle maintenance cost can be used as the basis for establishing road user charges.

A whole lifecycle cost approach opens up the ability to develop road user charges for different states, road types and even road sections (theoretically). Such charging would require technological advances that would essentially enable the tracking of different vehicles and the roads they utilise.

Furthermore, the whole lifecycle cost approach addresses most of the weaknesses of the PAYGO approach in that takes into account the lumpiness inherent in road expenditure over time and allows this to be incorporated into the cost allocation process.

5.4 Disadvantages

The main disadvantages of the whole lifecycle cost approach to road cost allocation are as follows.

The application of a whole lifecycle cost approach would require detailed road asset information on condition and likely depreciation/deterioration profiles. In addition current and future traffic data on each road section would be required as this would be used to predict the future deterioration of the asset which would trigger when remedial maintenance work is required. At one extreme this information would be required for the entire network but this would be prohibitively expensive. More likely some degree of sampling would be undertaken but even in this case the data collection task and financial cost would be significant.

The second main disadvantage of applying a whole lifecycle cost approach is that it would necessitate the use of complex software such as the models developed by the Australian Road Research Bureau or the World Bank's HDM model. These models require significant input data relating to the road network but also contain complex algorithms in predicting asset depreciation. These models rely on a number of simplifying assumptions and relationships between the various factors that influence deterioration which may lead to inaccurate results in predicting lifecycle asset costs and there may be the need for further subsequent ex-post adjustments.

The use of complex models makes the cost allocation process far less transparent than is currently the case with the PAYGO approach. This lack of transparency might create difficulties in justifying subsequent road user charges to the general public and, in particular, the freight transport industry.

The third main disadvantage of applying a whole lifecycle cost approach is that the treatment of Customer Service Obligations is not straightforward. The provision of roads which are provided on the basis of non economic criteria would not easily fit into a whole lifecycle cost approach and would skew the maintenance budget optimisation process. Some method of excluding these roads would need to be established but this would require knowledge of the location of these roads which might not be readily available – this is the subject of a separate supplementary submission to the Productivity Commission.

A fourth disadvantage is that whilst the whole lifecycle cost approach does facilitate optimisation over the road network, this represents only a partial approach as it solely focuses on asset deterioration. The whole lifecycle cost approach excludes the issue of expenditure relating to increasing capacity of the network which would result in response to congestion issues. The lifecycle cost models such as Australian Road Research Bureau and HDM are not able to currently accommodate this effect as one of the simplifying assumptions is that of a fixed road network. However, the impact of this focus on pavement deterioration in the whole lifecycle cost approach is consistent with cost allocation to heavy vehicles given this is the vehicle category which imposes the largest damage to the network. Capacity issues are more likely to be concerned with light vehicles which are by far most numerous vehicle type in the fleet.

The requirement to derive a required rate of return is another disadvantage of the whole lifecycle cost approach. As discussed above the lack of a risk profile for publicly procured projects means that this information is not readily available and would require a degree of subjectivity in its determination. Moreover, the value attributed to this variable will have an impact on the lifecycle costing analysis.

5.5 Implementation

It is likely to be difficult to implement a whole lifecycle cost approach to road sector cost allocation in Australia in the short term. To undertake a meaningful analysis would require a significant amount of data relating to the condition of the current asset base. It would be necessary to determine over what set of measures asset condition would be defined. This may include roughness, cracking, disintegration, potholes, rutting, etc. Not only do the measures need to be determined, but there also needs to be a process that ensures that the variation in asset condition assessments is minimised (i.e. minimising the subjectiveness of the process). Related to the condition assessments is the establishment of an ongoing monitoring process and data management system.

This is currently not available and thus would require the establishment of detailed asset management systems which would record the existing road asset base and its current condition. This asset management system would need to be updated on an ongoing basis and would entail a significant financial cost on the part of State road agencies.

The implementation of the whole lifecycle cost approach would also require the same degree of validation in terms of top down and bottom up efficiency reviews as described in Section 4.

It would also be necessary to establish an appropriate institutional framework that supports the use of a whole lifecycle cost approach. Elements of this would include a defined determination period, such that there is certainty for both road agencies and road users, agreement from relevant stakeholders as to the selection of model, adjustment procedures and ultimately the charging policy.

6. ANALYSIS

This section outlines the model and assumptions used to undertaken a preliminary analysis of the differences in the total amounts recovered under PAYGO and the two alternatives that have been identified. The results of the analysis are then discussed.

6.1 Model Description

The Australian Road Research Bureau pavement life cycle cost (PLCC) model has been used to undertake an expenditure optimisation analysis. The model estimates the optimum expenditure profile for maintenance and rehabilitation expenditure, and therefore only addresses part of the overall network optimisation problem (i.e. it does not address capacity). This is an important point to keep in mind when interpreting the results.

The PLCC model estimates the minimum possible (or optimum) total whole of lifecycle costs for unconstrained annual agency budgets, which is determined by minimising the sum of the present values of road agency and road user costs.

Agency and road user costs are based upon roughness predictions during each road categories life cycle. Road roughness predictions are based upon both a pavement deterioration model and a pavement rehabilitation model.

The pavement deterioration model predicts the deterioration of the road network. This is achieved through predicting the change in road roughness given the volume of traffic and proportion of heavy vehicles, and the pavement strength since the previous rehabilitation.

The pavement rehabilitation model predicts the required thickness for the intervention. It also estimates the pavement roughness and strength after rehabilitation, which is then used as the starting point for the pavement deterioration modelling.

6.1.1 Network

A network considered representative of the Australian network was developed. This representative network consists of:

- national highway road sections;
- arterial road sections; and
- local road sections.

Each of these road categories includes both urban and rural road sections, and is in proportion to the actual proportions observed in the network. The network also reflects the proportions in the eight States and Territories. The specific characteristics of the road sections, including traffic volume and growth, traffic composition, age of the road, length, initial roughness and strength, rehabilitation unit cost amongst others, are used to describe the initial condition. This information was part of an Australian Road Research Bureau database and is based upon information collected in 2001.

6.1.2 Parameters

Two parameters required to undertaken the optimisation are the evaluation horizon and the discount rate. An evaluation horizon of 60 years and a real discount rate of 7% pa were considered appropriate.

6.1.3 Intervention Points

There are two ways in which intervention points are determined by the PLCC model, scheduled or condition triggered. Scheduled triggered intervention points are based upon fixed time intervals between interventions. The condition triggered approach enables roughness interventions to be based upon road roughness levels at either the network level, category level (i.e. National Highway, Arterial or Local road), or individual road level. Under condition trigger interventions, strength rehabilitation is triggered when the ratio of current strength to initial strength falls below 0.58, regardless of the level of roughness. For the purposes of this optimisation task, the condition triggered approach is adopted.

6.1.4 Limitations

Use of the PLCC model is to provide an indication as to what the optimal expenditure profile may look like, and is not meant to be definitive. As such, there are a number of limitations associated with its use. These include the partial optimisation (across maintenance only) and the inability to capture the resource constraints faced in the real world (i.e. the volume of works that can be undertaken in any individual year is constrained through labour constraints and time constraints).

Undertaking a partial optimisation on pavement maintenance and rehabilitation excludes the capacity side of the equation. The provision of additional capacity inherently means that maintenance requirements increase. Within the optimisation problem itself the presence of capital expansion introduces a dynamic between maintenance and capacity. To illustrate this dynamic, a simple example is developed.

Consider a single road. Assume that the optimal timing for the road to be rehabilitated, when capacity is excluded from the optimisation process, is after nine years. Now consider that this same road is scheduled to have an upgrade in its strength after ten years. It is clearly sub-optimal to undertake the rehabilitation after nine years, and then in the following year undertake the road strengthening, which would require reconstructing the whole road anyway.

Assuming traffic growth in the model adds further to the implications of partial optimisation, as it simply leads to a faster rate of deterioration within the model, but which may actually be accommodated through changes in capacity (either strength or the number of lanes).

A further limitation is that the model estimates the theoretical (partial) optimal expenditure profile. The model is unable to take into account the construction industries finite resources, limiting the amount of works that can physically be undertaken in any individual year.

6.2 Purpose of Modelling

The aim of the modelling was two fold:

- to assess whether alternative approaches results in an outcome different to PAYGO; and
- to determine the circumstances under which differences are pronounced.

In order to address these two objectives, a number of different scenarios were run through the model. A central case was developed, and then a number of sensitivities were applied. The sensitivity scenarios that were modelled include:

- application of a budget constraint;
- differing traffic growth rates; and
- alternative of minimum road standards.

6.2.1 Scenario Inputs

The table below outlines the values adopted in the modelling for each of the different scenarios. All other inputs and data (initial traffic volume, initial roughness, etc) are held constant across the various scenarios.

Table 2. Scenario Inputs

Scenario	Budget Constraint	Traffic Growth(1)			Average IRI for Local Roads(4)	Average IRI for Arterial Roads(4)	Average IRI for National Highways(4)
		Local Roads	Arterial Roads	National Highways			
Central Case	n/a	3.10%	3.80%	3.80%	6.65	5.33	4.2
Constrained Budget	$5.6 billion pa	3.10%	3.80%	3.80%	n/a	n/a	n/a
Higher Quality Network	n/a	3.10%	3.80%	3.80%	5.65	4.33	3.2
Lower Quality Network	n/a	3.10%	3.80%	3.80%	7.60	6.60	5.3
Higher Traffic Growth(2)	n/a	4.10%	4.80%	4.80%	6.65	5.33	4.2
Lower Traffic Growth(3)	n/a	3.10%	3.80%	3.80%	6.65	5.33	4.2
		2.10%	2.80%	2.80%			

(1) Central case freight traffic growth is based upon Bureau of Regional and Transport Economics Freight Measurement and Modelling in Australia report 112

(2) Growth rates based upon a 1 percentage point increase over the central case

(3) Central case growth applied for first 15 years and 1 percentage point lower for remainder of period

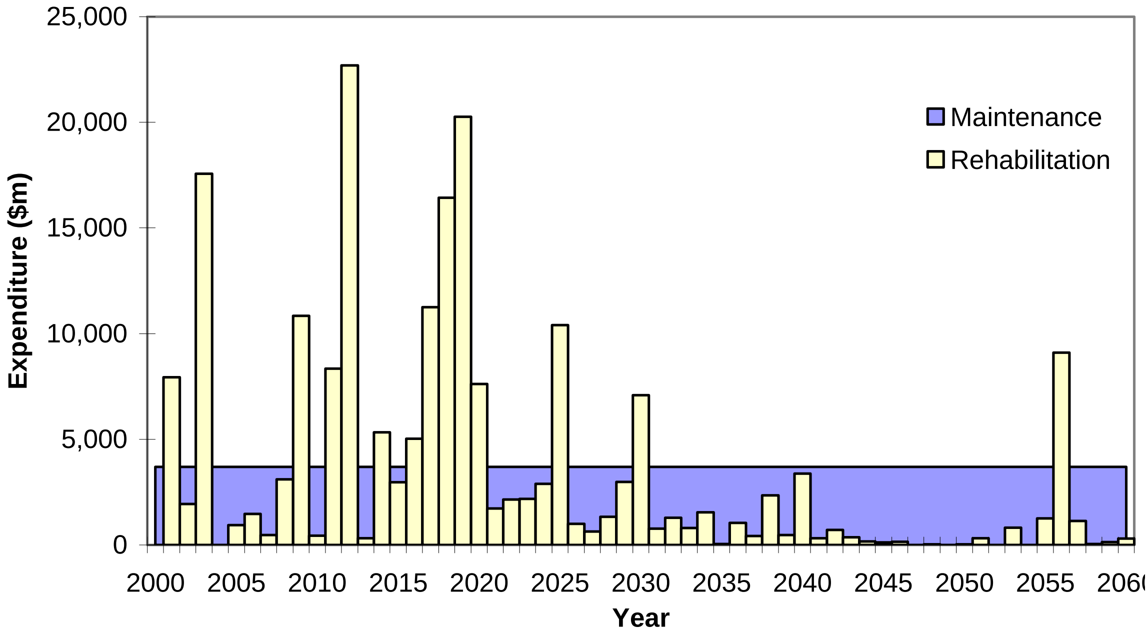
(4) IRI – International Roughness Index, a measure of the road roughness

6.3 Results of Modelling

6.3.1 Model Outputs

The output from the model is an optimised expenditure profile for maintenance and rehabilitation. Figure 6 illustrates this expenditure profile for the central case. As is evident there is significant variation in annual expenditure – which may not be representative of the real world as it does not take into account physical limitations on the amount of construction work that can undertaken in an individual year.

Figure 6. Optimal Expenditure Profile - Central Case



A graph of the expenditure profiles for each of the different scenarios is contained in Appendix A. Summary statistics for each of the scenarios are shown in Table 3 to provide an overview of the differences in the optimised expenditure profiles.

The summary statistics for the whole 60 year period show that:

- Higher traffic growth leads to a higher degree of expenditure, and larger variation in expenditure from one year to the next.
- Maintaining the network to a higher quality condition also leads to more expenditure overall, and greater variation in expenditure.
- Lower growth and a lower quality of network condition lead to less overall expenditure and lower degree of variation in expenditure.
- Application of a budget constraint also leads to a lower degree of variation and lower overall expenditure.

Table 3. Summary Statistics of Optimised Expenditure Profiles ($million)

Time period	Summary statistic	Central Case	Budget Constraint	High Quality	Low Quality	High Growth	Low Growth
60 years	Mean	7,040	5,523	8,014	7,017	7,562	6,767
	Standard Deviation	5,220	5,121	6,783	5,165	6,292	5,402
	Minimum	3,688	2,304	3,759	3,696	4,367	3,365
	Maximum	26,389	24,286	39,769	25,927	36,330	31,393
First 20 years (2000-2020)	Mean	10,555	9,006	11,810	10,476	11,688	8,905
	Standard Deviation	7,317	7,159	9,409	7,244	9,414	6,203
	Minimum	3,688	2,304	3,759	3,696	4,367	3,365
	Maximum	26,389	24,286	39,769	25,927	36,330	25,197
Second 20 years (2020-2040)	Mean	6,126	4,732	6,271	6,180	6,173	7,179
	Standard Deviation	2,740	2,698	2,880	2,759	2,363	6,225
	Minimum	3,735	2,362	3,759	3,742	4,403	3,365
	Maximum	14,095	12,607	15,650	14,159	14,013	31,393
Third 20 years (2040-2060)	Mean	4,593	2,993	6,150	4,562	4,985	4,383
	Standard Deviation	2,080	1,886	5,069	1,972	1,829	1,837
	Minimum	3,688	2,304	3,759	3,696	4,367	3,372
	Maximum	12,784	10,398	25,935	12,238	12,588	11,451

Furthermore, the breakdown of the total time period into 20 year periods shows that the mean and standard deviation are constantly decreasing. This implies that the average optimal expenditure decreases for later time periods. Also, the volatility of optimal investment decreases from the first 20 year period to the second and third ones. An exception is the high quality scenario for which the standard deviation actually increases from the second to the third 20 year time period.

In contrast to the mean and standard deviation, the minimum optimal expenditure is rather similar in all three time periods. The maximum optimal expenditure decreases from the first to the second and second to third 20 year period. An exception is again the high quality scenario which not only requires higher average expenditure but also entails maximum expenditure increasing from the second to the third time period. Overall, it can be concluded that the mean and the volatility of optimal expenditure decrease over time. This is mainly due to decreasing maximum optimal expenditure and constant minimum optimal expenditure.

6.3.2 Modelling the Alternatives

In order to assess the impacts of the alternative approaches to PAYGO, the optimal expenditure profiles are used as the basis for determining the amount of expenditure that would be recovered. Given that PAYGO and enhanced PAYGO are actually ex-post methods for determining cost recovery, and whole lifecycle cost is an ex-ante, it has been necessary to assume that the forecast expenditure profile is what actually occurs, so the amount recovered under each approach can be determined.

The first year of output of the model is 2000. It is necessary to base year 2006 as year zero, such that there is historical information to enable PAYGO and enhanced PAYGO to be calculated.

PAYGO

To determine the amount of expenditure that would be recovered under PAYGO a three year average is calculated (based upon previous two years and current year expenditure). This three year average is calculated every seven years (the time between historical determinations, though seven years is not a set rule).

For intervening years, the amount recovered is assumed to grow in proportion to traffic growth. This reflects the fact that charges are established based upon a given level of traffic and applied to future years. If charges are fixed, and traffic grows, then there will be growth in the amount recovered. Furthermore, given PAYGO's annual adjustment process has a floor such that charges can not decrease and a cap that restricts increases to CPI, the amount recovered in the intervening years is also adjusted to reflect in change in the level of expenditure from one year to the next. It is assumed that inflation across the evaluation horizon is 2.5%.

Enhanced PAYGO

Enhanced PAYGO is modelled in much the same way as PAYGO, however it is based upon a seven year average rather than a three year average. This means that every year's expenditure is captured in the averaging process. It is noted that the enhanced PAYGO process described earlier in this report incorporates an ex-post efficiency review, but the modelling of enhanced PAYGO has been unable to incorporate such a review.

Whole lifecycle cost

By design, the whole lifecycle cost approach recovers the expenditure in full.

6.3.3 Impact of Alternatives

The total amount recovered under each of the alternatives across the 60 year evaluation period is shown in Table 4. This is presented in both undiscounted terms, and discounted terms. It is worth noting that the analysis is based upon a single data point, due to the representative network being modelled at a single point in time (but across a number of years). On the basis of the single data point there appears to be significant variation due to lumpiness, but further data points are required in order to compare the alternatives more fully.

Table 4. Expenditure Recovered by Alternatives

SCENARIO		PAYGO	Enhanced PAYGO	whole lifecycle cost
Central	Undiscounted	$480,426	$375,978	$378,957
	Discounted	$151,135	$129,316	$132,065
Low Growth	Undiscounted	$482,563	$353,480	$364,970
	Discounted	$112,499	$90,792	$95,224
High Growth	Undiscounted	$446,414	$410,297	$405,381
	Discounted	$112,918	$118,018	$120,814
Low Quality	Undiscounted	$498,260	$376,841	$377,557
	Discounted	$115,266	$98,332	$100,308
High Quality	Undiscounted	$533,179	$432,905	$435,788
	Discounted	$132,444	$108,409	$113,115
Constrained Budget	Undiscounted	$404,681	$292,211	$295,046
	Discounted	$96,789	$81,598	$83,690

Given that the whole lifecycle cost approach is by design the amount of expenditure required to be recovered, comparison of the two PAYGO approaches to whole lifecycle cost will provide an indication as to whether they under or over recover.

The enhanced PAYGO approach under recovers in all situations except the high growth scenario. The amount by which enhanced PAYGO under/over recovers is fairly small (generally within around 5% or less). Closer analysis of the enhanced PAYGO approach revealed that the over or under recovery was simply a result of the lag created through its backward looking approach. The final seven years of expenditure information is not captured in the analysis, but this is offset by incorporating seven years of historical information. Therefore, any over or under recovery is due to the difference between these two seven year averages.

PAYGO over recovers in all cases except the high growth scenario. The amount by which PAYGO under/over recovers varies significantly, from a low of around 10% to over 30%. The under/over recovery in PAYGO is a result of it only using a portion of the available expenditure information. Whether PAYGO under or over recovers depends on how the expenditure information captured in the three year averages compares to the overall average expenditure.

To explain this further, consider a one period scenario with seven years of expenditure information. Take an average of the first three years (or any three years). If the average of the three years is above the average across all seven years, there is over recovery. Likewise the three year average is less than the average across all seven then there is under recovery, and if the three year average equals the seven year average than there is exact recovery. This is the principle underlying the over/under recovery of PAYGO, and shows that whether PAYGO under or over recovers is unsystematic.

Interestingly, the high growth scenario sees both PAYGO and enhanced PAYGO over recover in undiscounted terms, but under recover in discounted terms. There are two reasons why this appears to be the case. Firstly, there are a number of large expenditures early in the evaluation horizon. Given that these expenditures are smoothed under PAYGO and enhanced PAYGO but are not smoothed under whole lifecycle cost, the discounted amount under whole lifecycle cost is greater than under the PAYGO and enhanced PAYGO approaches.

Secondly, the undiscounted amount is influenced by a large expenditure in the ‘historical’ information period (i.e. between 2000 and 2006), which is not captured under the whole lifecycle cost approach (as whole lifecycle cost is completely forward looking).

7. CONCLUDING COMMENTS

An initial assessment of costing methodologies suggests that both enhanced PAYGO and whole lifecycle cost approaches are worthwhile alternatives to the current PAYGO approach. Furthermore, adopting an enhanced PAYGO approach in the short term will assist in the development of a whole of lifecycle approach as both will require an efficiency review.

An enhanced PAYGO approach is able to address some of the shortcoming of the existing approach including short term lumpiness and inefficient/non-optimal expenditure. It also has the benefit of being built off the existing PAYGO approach and does not require considerable new data to be collected. However, a methodology for an efficiency review will need to be carefully considered. Regardless, this approach would appear to be an effective short to medium term alternative.

In terms of the enhanced PAYGO approach, it is recommended that further research focus on:

- investigating the *ex-post* efficiency review process, specifically looking at the overall framework, performance criteria, and the development of institutional requirements in order to support such a process. It is also necessary to investigate the exact adjustment process that would be applied for those expenditures that are identified as inefficient; and
- assessment of whether there are opportunities to implement the alternative across jurisdictional boundaries.

The whole lifecycle cost approach is perhaps more in the infancy stage. Whilst it would arguably provide the most accurate cost estimates, there is some concern over the efficiency of the approach itself. There are a number of complexities in undertaking this approach and the data requirements are considerable, particularly given the limited understanding of the technical relationships underpinning road infrastructure costs. As such, recommendations for further work include:

- development of the *ex-post* review framework, and the adjustment process (this is likely to be able to built off the *ex-post* review required for the enhanced PAYGO approach);
- identification of an appropriate model that has the ability to undertake the optimal expenditure analysis for both capital and maintenance, capacity and condition;
- development of an asset management database and the criteria against which asset condition will be assessed;
- further investigation into the issues surrounding the establishment of a regulatory asset base and the associated issues of deterioration profiles and discount rates; and
- establishment of the institutional framework that would be required in order to support such an approach.

In any case, development of either or both approaches is likely to assist in a long term objective of a more efficient heavy vehicle pricing regime.

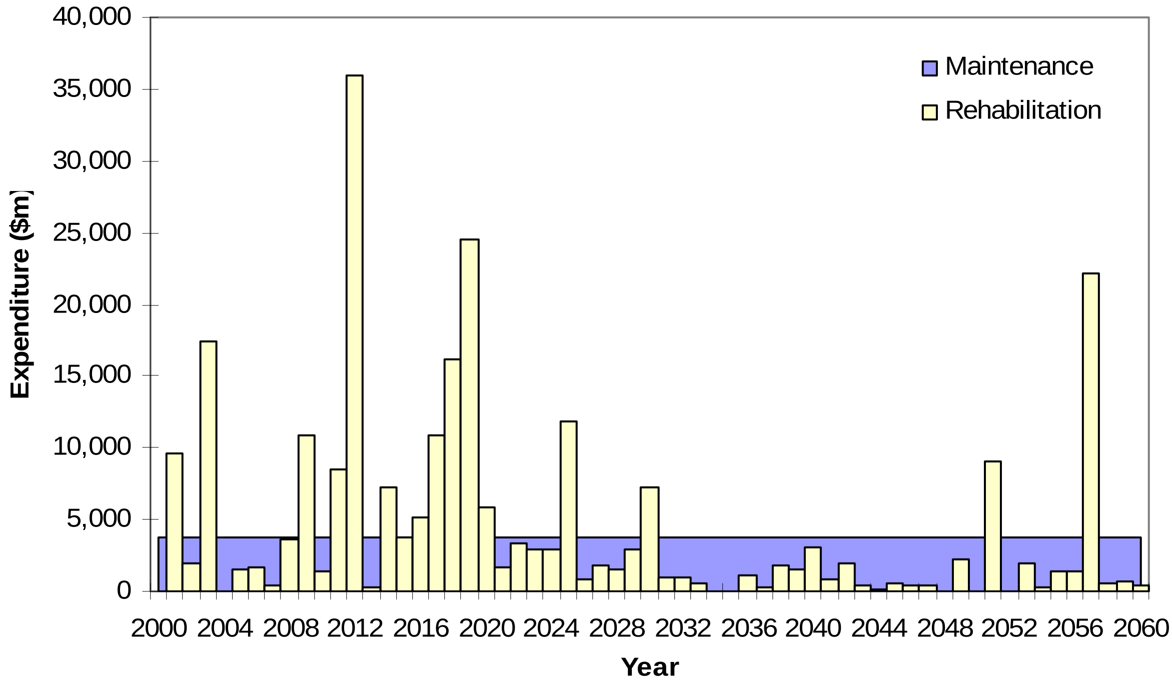
8. REFERENCES

National Transport Commission, 2006, *Productivity Commission Inquiry into Freight Infrastructure Pricing - Submission*

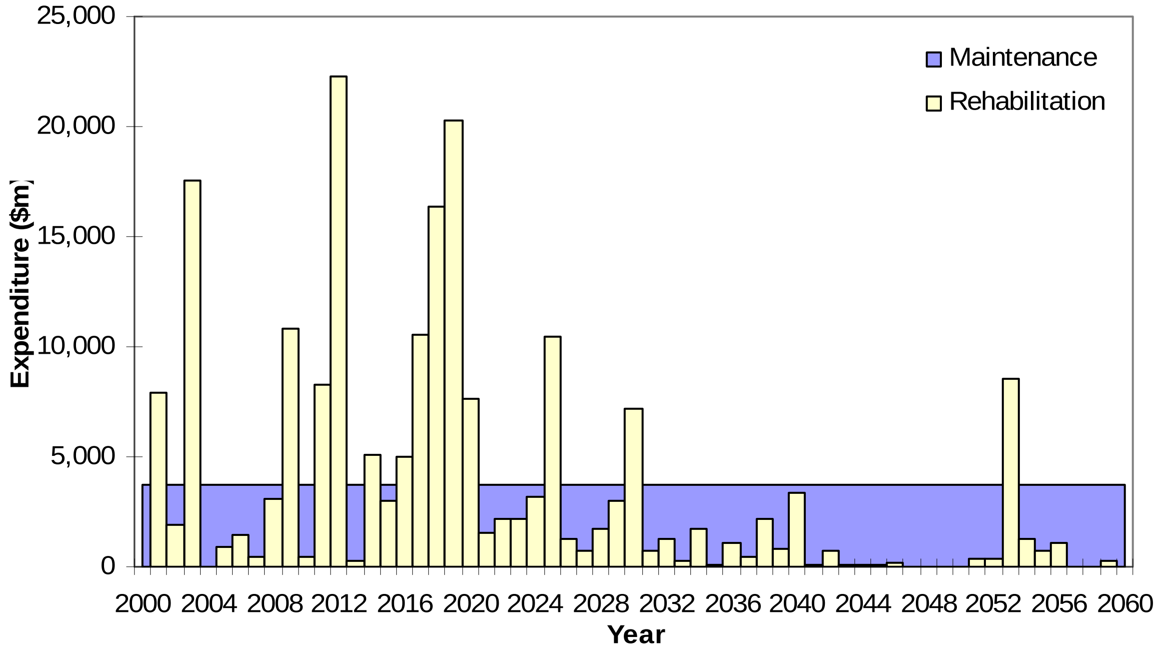
Organisation for Economic Co-Operation and Development (OECD), 2001, *Asset Management for the Roads Sector*

APPENDIX A – OPTIMISED EXPENDITURE PROFILES

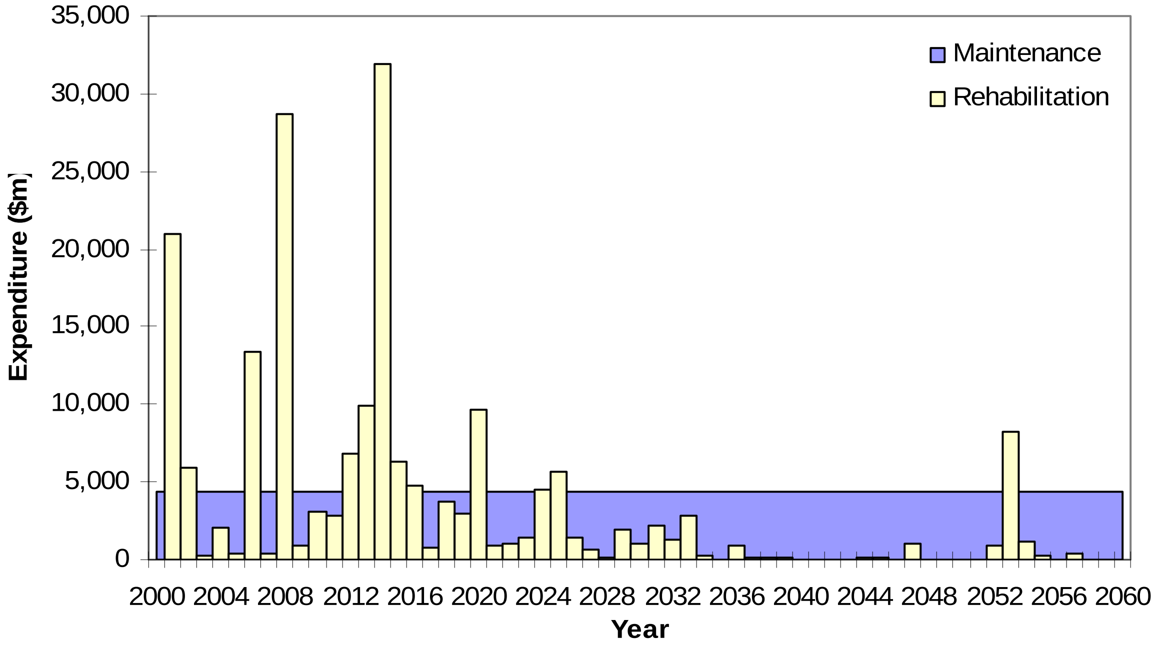
High Quality Network Scenario



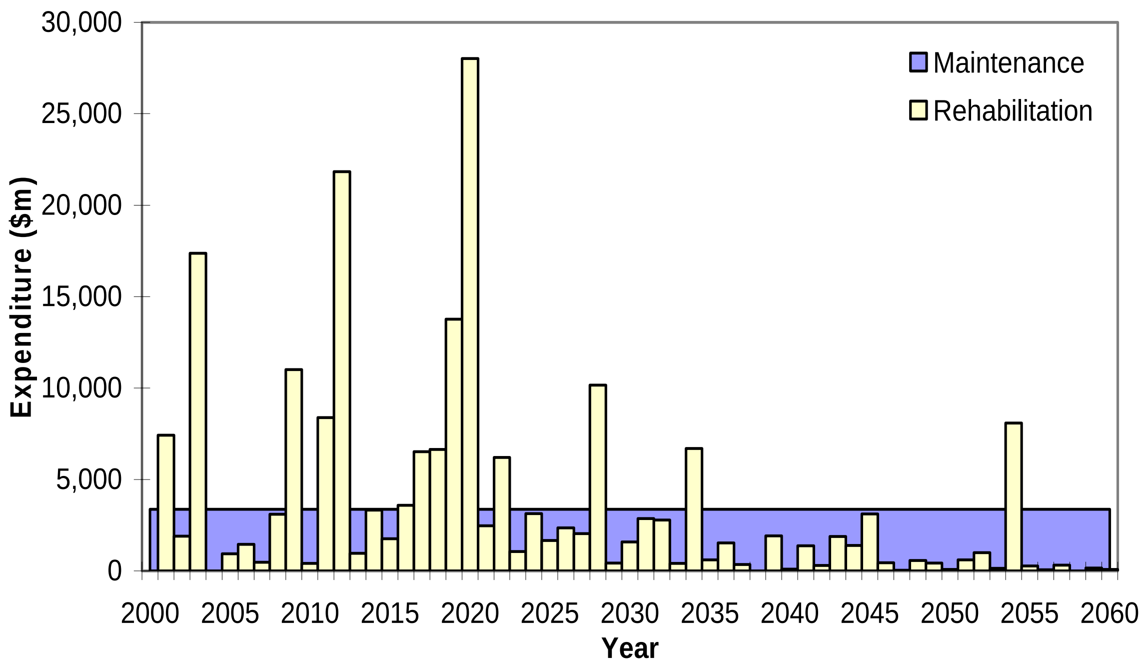
Low Quality Network Scenario



High Growth Scenario



Low Growth Scenario



Budget Constraint Scenario