HOUSTONKEMP

Economists

Review of the parameters used to allocate road infrastructure costs to heavy vehicles

A report for the National Transport Commission

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Executive Summary

The National Transport Commission uses cost allocators to estimate the heavy vehicle cost base

The National Transport Commission (NTC) is responsible for recommending heavy vehicle road charges to the Transport and Infrastructure Council (the Council). To this end, the NTC applies a pay-as-you-go (PAYGO) framework to determine the share of total road infrastructure costs to be recovered from heavy vehicles.

This is an inherently difficult task, given the shared nature of the road network, ie, a number of different vehicle classes use the road network. It follows that a substantial proportion of road expenditure cannot be directly traced to the provision of road services to a particular vehicle class.

The PAYGO framework applied by the NTC involves separating the total cost of providing road infrastructure services into expenditure categories, and then allocating to heavy vehicles a proportion of the costs comprising each expenditure category. In particular, the PAYGO framework involves determining, for each expenditure category:

- the proportion of costs that vary with road use (attributable costs) and the remainder (common costs) that do not vary with road use;

- allocating to heavy vehicles a proportion of attributable costs on the basis of heavy vehicles' contribution to the underlying cost driver, or drivers, for that expenditure category; and

- allocating to heavy vehicles a proportion of common costs on the basis of heavy vehicle kilometres travelled, as compared to other vehicle kilometres travelled.

What we have been ask to do?

The NTC has asked us to undertake two discrete tasks, ie:

- to review the current parameters used to allocate road infrastructure costs to heavy vehicles under the PAYGO methodology; and

- to propose a categorisation of road expenditure to facilitate the implementation of a forward-looking cost base (FLCB).

This draft report presents the output of these tasks.

The economic principles of cost allocation

The economic principles of cost allocation do not, in themselves, lead to a uniquely correct allocation of costs incurred in the provision of more than one service, ie, shared costs. In other words, cost allocations are not a precise science for which there is a unique and single answer.

By consequence of the quantum of shared costs involved in the provision of road services, determining the share of total road costs that should be borne by heavy vehicles is not a straight forward task, and one characterised by the exercise of discretion and judgment, to be guided by the relevant economic principles.

Indeed, the exercise of judgement in the allocation of infrastructure costs arises in a broad range of sectors, including in the provision of electricity, water and telecommunications network services.

We explain in section 2 that a number of principles are relevant to a consideration of cost allocation and heavy vehicle charging, namely that:

- road charges to all road users should be set so as to recover the total costs of providing and operating the road network, less any contributions resulting from charges to other beneficiaries of road infrastructure;

- heavy vehicle road users should pay at least the costs caused by having access to the road network, including costs related to wear and tear as well as any additional road infrastructure costs that would otherwise be avoided;

- the total revenue expected to be recovered from a particular road user should lie between:

  > an upper bound represented by the standalone cost of providing road infrastructure to that road user; and

  > a lower bound represented by the avoidable cost of providing road infrastructure to that road user;

Application of these principles will have the effect of promoting the efficient use and provision of road infrastructure services. However, application of some of these principles, at least in their theoretical form, may be complicated by a lack of the requisite data, as is the case in a number of other sectors.

> **In our opinion the current PAYGO framework is consistent with the economic principles of avoidable and stand alone cost. Based on current cost allocators, the approximately $3 billion of revenue collected from heavy vehicles in 2015-16 through the application of the PAYGO methodology lies between our estimates of the avoidable and standalone cost of providing heavy vehicle road services of $2.3 billion and $7.4 billion in 2015-16, respectively.**

We did not find any robust evidence to depart from existing allocators

In undertaking our review of the PAYGO allocators, the NTC asked us to rely on primary, independent empirical research on the relationship between heavy vehicle road use and road costs.

Our review identified that road cost and use data generally suffers from a number of shortcomings, which pose a considerable challenge for statisticians, engineers and econometricians endeavouring to evaluate the causal relationship between heavy vehicle road use and road costs. Indeed, these data limitations contribute:

- to often-conflicting evidence on the relationship between heavy vehicle road use and road costs; and

- to a general lack of industry consensus on fundamental elements of the relationships between heavy vehicle road use and road costs.

It is therefore unsurprising that the empirical evidence in support of both the existing and alternative allocation parameters in the PAYGO matrix all have relative merits and shortcomings. This is perhaps most evident in respect of the 'periodic surface maintenance' expenditure category.

Given the often-conflicting views presented in the empirical evidence, each with relative merits and shortcomings, selection of the appropriate allocators necessarily requires some degree of judgement, taking into account the surrounding circumstances.[1] Indeed, the exercise of judgement in the allocation of infrastructure costs arises in a broad range of sectors, including in the provision of electricity, water and telecommunications network services.

In our opinion, the exercise of such discretion in this context should be guided by generally accepted considerations as applied in other sectors. In the context of conflicting evidence, it is important that a balance is struck between:

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[1] Productivity Commission, p.112

- the potential benefit of any changes over the period in which they are expected to be in effect; and

- the potential for changes to the heavy vehicle allocation methodology to cause winners and losers and, in so doing, contribute to uncertainty in heavy vehicle road pricing.

> **We found that new research on the relationship between heavy vehicle road use and road costs since the last NTC review was insufficient, in and of itself, to support a departure from the current PAYGO allocators.**

We summarise our findings in relation to the current PAYGO expenditure categories in more detail in Table 1 below.

Table 1 Summary of findings on PAYGO allocators

Expenditure category	Current allocation	Basis for current allocation	HoustonKemp findings
A: Servicing and operating expenses	100% attributable to VKT	Evidence to suggest costs are related to traffic volumes but not vehicle types	No new evidence to support a change to the current allocation at this time
B1: Routine maintenance	38% attributable to PCU, 38% attributable to AGM and 24% non-attributable	Based on analysis conducted by the Urban Logistics Group (ULG) and inference that some costs are non-attributable	No new evidence to support a change to the current allocation at this time
B2: Periodic maintenance	10% attributable to PCU, 60% attributable to AGM and 30% non-attributable	Based on analysis conducted by ULG and inference that some costs are non-attributable	New analysis undertaken by Austroads is an improvement on earlier studies, but still suffers from data limitations which likely affect the reliability of results. Austroads makes an in-principle case for the use of weight-based allocation parameters. In our opinion, it is open to the NTC to either: • not change the current allocation; or • use one or more weight-based allocation parameters. In arriving at its preferred choice, the NTC should take into account the likely benefits from a change (which may be limited), compared against the implications for heavy vehicle charges. In our opinion, there is merit in not changing the current allocation towards weight based measures at this time so as to avoid bill impacts to heavy vehicle users. We therefore conclude that, notwithstanding the reasonableness of adopting one or other of the abovementioned options, in our opinion **there exists no strong evidence for departing from the existing approach to allocating 'road pavement and shoulder maintenance' costs at this time.** However, consideration should be given to transitioning to weight-based allocation parameters as part of a transition to a FLCB.
C: Bridge maintenance and rehabilitation	33% attributable to AGM and 67% non-attributable	Based on historical spending on costs that are load/impact related and other expenditure unrelated to load/impact	Austroads has suggested a new methodology for allocating bridge costs, using bridge fatigue analysis. Absent that work having been undertaken there is no new evidence to support a change to the current allocation at this time.
D: Road rehabilitation	45% attributable to ESA and 55% non-attributable	Based on analysis conducted by ARRB	No new evidence to support a change to the current allocation at this time
E: Low cost safety/traffic improvement	80% attributable to VKT and 20% PCU	Based on analysis conducted by VicRoads	No new evidence to support a change to the current allocation at this time
F1: Pavement components	45% attributable to ESA and 55% non-attributable	Based on analysis conducted by ARRB	No new evidence to support a change to the current allocation at this time
F2: Bridges	15% attributable to PCU and 85% non-attributable	Based on analysis conducted by ARRB	Austroads has suggested a new methodology for allocating bridge costs, using bridge fatigue analysis, which would not use PCU as a basis for allocating attributable costs. Absent that work having been undertaken there is no new evidence to support a change to the current allocation at this time.
F3: Land acquisition, earthworks, other extension improvement expenditure	10% attributable to PCU and 90% non-attributable	Based on analysis conducted by VicRoads	No new evidence to support a change to the current allocation at this time
G1: Corporate services	100% non-attributable	Based on analysis conducted by VicRoads	No new evidence to support a change to the current allocation at this time

A general observation arising from our review was that further empirical studies are unlikely to provide meaningful guidance on the appropriate allocation of road costs to road users, owing to:

- the complex relationships driving road costs, which significantly complicate the identification of explanatory variables that reflect all the factors driving variability in road costs; and

- the present limitations of road use and cost data.

With this in mind, it is important to emphasise the context in which we have undertaken this assessment, namely the potential move to a FLCB approach in the future, and the corresponding trade-off between the likelihood of realising any potential benefit of change and the potential to cause winners and losers and create uncertainty. Any future change in the methodology used to set heavy vehicle charges, eg, to a FLCB approach, would present an ideal opportunity to revisit the appropriateness of these allocation parameters and the merits of relying on empirical evidence.

New expenditure categories are needed to implement a forward-looking cost base

The PAYGO expenditure categories are not compatible with a FLCB approach because a PAYGO approach recovers all costs in the year in which they occur, whereas a FLCB approach recovers some costs over a period of more than one year, thereby necessitating:

- a distinction between costs to be recovered in the year in which they are incurred (ie, operating costs) and those to be recovered over the useful life of the corresponding asset (generally more than one year, ie capital costs);[2] and

- the separation of the costs to be recovered over the useful life of the corresponding asset into categories relating to assets with similar useful lives.

Although we have not been asked to consider potential allocators to apply to this potential categorisation of road costs, we have sought to group sub-categories on the basis of possible cost drivers to simplify the reporting requirements needed.

Bearing in mind that the development of these expenditure categories is being undertaken in the very early stages of considering the application of a FLCB, it is important that these expenditure categories constitute a starting-point, for exploration and consideration by stakeholders. In our opinion, in these early stages of development it is appropriate to place an emphasis on presenting first-best expenditure categories as a starting point. Consequently, we place an emphasis on expenditure categories that reflect first-best principles, but note that there are likely to remain a number of practical, data collection, considerations to be worked through by stakeholders.

We identified that, as a starting point, a categorisation of road expenditure to facilitate the implementation of a FLCB would involve the following high-level groupings of expenditure, ie:

- operating;

- maintenance;

- renewal; and

- development.

The operating and maintenance categories comprises costs to be recovered in the year in which they are incurred.[3] The separation of these costs into two categories reflects the different underlying cost drivers.

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[2] Sometimes referred to in other industries as operating expenditure and capital expenditure, respectively.

[3] We note that costs in the periodic maintenance category (B2) under the current PAYGO approach would be categorised as renewal, rather than maintenance, under the proposed approach.

On the other hand, the renewal and development categories comprise costs to be recovered over the corresponding asset's useful life. The separation of these costs reflects the different underlying planning and funding drivers, as well as the different service outcomes, and will assist in facilitating industry discussion on the different types of costs caused by heavy vehicle road use.

As noted above, a FLCB approach necessitates a further separation of certain costs into categories comprising assets with similar asset lives. At one extreme, this could be undertaken by applying assumptions to separate each of the abovementioned groups into the applicable sub-categories, although this may significantly compromise the accuracy of the allocation process. On the other hand, road agencies could be required to separate expenditure for every single asset, but this would likely impose a significant administrative burden on road agencies.

With this trade-off in mind, we propose, as a starting point, a further disaggregation of these cost groups consistent with that presented in Table 2 below.

Table 2   Initial number of expenditure categories for reporting purposes

Expenditure Group	Sub-categories for reporting purposes
Operating	5
Maintenance	3
Renewal	15
Development (upgrade and expansion)	17
Total	**40**

Importantly, there exists the potential for the number of initially proposed categories to be significantly reduced by either, consolidating expenditure groups, eg, renewal and development, or by consolidating some of the sub-categories that comprise each group. As explained above, assumptions could be used to disaggregate expenditure categories that are consolidated for reporting purposes, although this may comprise the accuracy of the resulting allocation. Nevertheless, we consider a more granular categorisation is appropriate as a basis for engaging stakeholders.

A full list of expenditure categories for reporting purposes is presented in section 4.3. Further, we present a potential further disaggregation for the NTC's consideration in Appendix A.2. Opus has provided to the NTC a separate technical report that explains technical aspects of the methodology applied and the proposed categorisation, eg, the engineering definitions of each proposed category.

> **New expenditure categories are needed to implement a FLCB. Our proposed categories have been developed using first best principles and represent a starting point for discussion amongst stakeholders. The implementation of a FLCB would also represent an ideal opportunity to re-examine the cost allocators to be applied for the purpose of setting heavy vehicle charges.**

1. Introduction

The shared use of road infrastructure by light and heavy vehicles means that there is a need to allocate costs between each road user for the purpose of estimating the cost base to be recovered through heavy vehicle charges. Currently the National Transport Commission (NTC) allocates costs to heavy vehicles based on identified allocation parameters across a number of road expenditure categories. We understand that the parameter choices were made based on earlier research on the relationship between each parameter and historic road expenditure within the associated expenditure category.

A number of the current cost allocation parameters were determined on the basis of decisions formed as far back as 1989.[4] The NTC last reviewed the cost allocation parameters in 2013 and at that time decided not to make any changes to the parameters that were being used.[5]

Given that the level of heavy vehicle charges is closely linked to the choice of cost allocation parameter, the choice of parameter is an important decision to be made by the NTC in the context of a heavy vehicle charging determination. Within this context, the Transport and Infrastructure Council (the Council) has directed the NTC to review the current cost allocation parameters against the available evidence.

At the same time, the Council in conjunction with the NTC is investigating changes to the methodology used to determine the cost base to be recovered through heavy vehicle charges. One such alternative involves moving to a methodology that is based on forward-looking road expenditure (a forward-looking cost base (FLCB)), as compared with the current pay-as-you-go (PAYGO) methodology, which is based on past road expenditure. How road expenditure is to be allocated as part of a FLCB is therefore also a relevant consideration for the NTC, and the Council has directed the NTC to develop a prototype FLCB.

Within this context, HoustonKemp has been asked by the NTC:

1. to review the current parameters used to allocate road investment and maintenance costs to heavy vehicles under the PAYGO methodology; and

2. to propose a categorisation of road expenditure to facilitate the implementation of a FLCB.

The purpose of the first task is to ensure that the cost allocation parameters to be used under PAYGO reflect the current best available evidence.

The second task is directed at providing some guidance to the NTC on how road expenditure should be categorised so as to facilitate a FLCB. New expenditure categories are required under a FLCB because development costs are recovered during the life time of the asset, requiring the grouping of assets with similar asset lives. Our starting point for the project was to develop a set of cost allocation principles, consistent with economic theory to promote efficient use of, investment in and operation of the road network. In so doing, we drew heavily on the historic experience in both road infrastructure and other regulated infrastructure sectors. These principles:

- provide a lens through which to evaluate the existing cost allocation parameters, along with the underlying empirical evidence; and

- serve as a reference point for policy makers considering potential reform to the cost allocation methodology, particularly in the context of a potential FLCB;

We also undertook a thorough literature review of the available research evidence on cost allocation parameters, both from within Australia and overseas. This review allowed us to make findings about the current cost allocation parameters.

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[4] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989.

[5] NTC, *Heavy vehicle charges review Discussion paper*, March 2013.

Finally, we drew upon the road asset management experience of Opus International Consultants Limited (Opus), combined with our own experience in designing and implementing forward looking cost bases in other infrastructure sectors (ie, electricity networks and water), to identify cost categories that would be appropriate to facilitate implementation of a FLCB.

The remainder of this report sets out the detail of our analysis and findings, and is structured as follows:

- Section 2 sets out cost allocation principles consistent with economic theory and best practices;

- Section 3 presents the detailed results of our review of the current cost allocation parameters and presents the findings of the review; and

- Section 4 proposes a categorisation of road expenditure to facilitate the implementation of a FLCB.

In Appendix A1 we summarise the information sources and databases we searched and present a bibliography of documents we reviewed. In Appendix A2 we present for the NTC's consideration a potential further disaggregation of the proposed categorisation to facilitate a FLCB.

2. Principles for road infrastructure cost allocation and heavy vehicle pricing

The economic principles of cost allocation do not, in themselves, lead to a uniquely correct allocation of costs incurred in the provision of more than one service. In other words, cost allocations are not a precise science for which there is a unique and single answer. Rather, they necessitate a degree of judgement to be guided by the relevant economic principles.

A number of principles are relevant to a consideration of cost allocation and heavy vehicle charging, namely that:

- road charges to all road users should be set so as to recover the total costs of providing and operating the road network, less any contributions resulting from charges to other beneficiaries of road infrastructure;

- heavy vehicle road users should pay at least the costs caused by having access to the road network, including costs related to wear and tear as well as the new road infrastructure costs that would otherwise be avoided;

- the total revenue expected to be recovered from a particular road user should lie between:

  > an upper bound represented by the standalone cost of providing road infrastructure to that road user; and

  > a lower bound represented by the avoidable cost of providing road infrastructure to that road user;

Application of these principles will have the effect of promoting the efficient use and provision of road infrastructure services. However, application of some of these principles, at least in their theoretical form, may be complicated by a lack of the requisite data, as is the case in a number of other sectors.

The PAYGO framework is consistent with the cost allocation principles above. Approximately $3 billion of revenue was collected from heavy vehicles under the PAYGO framework in 2015-16, which falls between our estimates of the avoidable and standalone cost of providing heavy vehicle road services of $2.3 billion and $7.4 billion in 2015-16, respectively.

In this section we develop and explain a set of cost allocation principles, consistent with economic theory to promote efficient use of, investment in and operation of the road network. These principles:

- provide a lens through which to evaluate the existing cost allocation parameters, along with the underlying empirical evidence; and

- serve as a reference point for policy makers considering potential reform to the cost allocation methodology, particularly in the context of a potential FLCB approach;

It is well understood in economics that economic efficiency will be promoted by setting the price for goods or services equal to the marginal cost of production. However, in practice this concept is difficult to apply and so necessitates a consideration of cost averaging, and a consideration of the extent to which users and producers of a good or service are likely to respond to such price signals through changes to their usage and productive behaviour, respectively. It is through the process of changed behaviour that cost savings can be achieved over time.

How the economic pricing principles can be translated to inform the allocation of costs and determination of heavy vehicle price structures is the subject of this section. These principles will be an important consideration when developing a road infrastructure cost basis and charging arrangements under a forward-looking cost base.

2.1   Costs should be allocated on the basis of causal responsibility

The essential criterion for determining what belongs in marginal costs, and which costs should then be included in prices for a particular road user is _causal responsibility_. As Alfred Khan explains:[6]

> All the purchasers of any commodity or service should be made to bear such additional costs –
> _only_ such, but also _all_ such – as are imposed on the economy by the provision of one additional
> unit.

Similarly, over the last fifty years the Federal Highway Authority in the United States, and its predecessor agencies, have applied a 'cost occasioned' approach to allocate highway cost responsibility amongst different vehicle classes, ie, where the underlying philosophy is:[7]

> …that each user should pay the highway costs that it creates or 'occasions'.

The concept of causal responsibility by necessity requires a consideration of the time dimension of the incurrence of costs. It is conceivable that all costs incurred to establish productive capacity to supply a good or service, if a sufficiently long time horizon is used, could be considered marginal. However, such an interpretation would not promote efficient outcomes because it includes costs that are sunk and so cannot be avoided through changes in behaviour. Efficiency is promoted through charges that signal to users only the current and future costs that will be incurred as a consequence of further usage, thereby allowing users to assess whether those costs are warranted given the benefits they expect to derive.

Owing to the shared nature of the road network, a substantial proportion of resources deployed in the provision of road services cannot be directly traced to the provision of road services to a particular vehicle class. As Kahn notes in the context of shared infrastructure services:[8]

> In general, some costs can be directly assigned exclusively to one service or other… But most
> costs must be allocated at least in part because they are incurred in serving more than one class
> of customers.

By consequence of the quantum of shared costs involved in the provision of road services, determining the share of total road costs that should be borne by heavy vehicles is not a straight forward task, and one characterised by the exercise of discretion and judgment. Consistent with this observation, Phillips highlights that:[9]

> …all methods of allocation rest ultimately on judgement, and the final decision is open to dispute.

To put this more plainly, cost allocations are not a precise science for which there is a unique and single answer. Rather, an understanding of causal relationships between the use of a service and the incurrence of costs combined with considerations about the likely response of users to changes in prices and equity considerations are all relevant.

It follows that economic principles of cost allocation do not, in themselves, lead to a uniquely correct allocation of costs that are common to the provision of more than one service. Notwithstanding, economic principles do establish clear boundaries within which the cost allocation to each service must fall for the resultant allocation to be regarded as presumptively efficient.

Those boundaries are established by, at one end of a spectrum, the standalone cost of each relevant service and, at the other, the avoidable (or incremental) cost of each service (given the others). We explain these economic concepts below.

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[6] Kahn, A. E., _The Economics of Regulation – Principles and Institutions_, 1988, p.71.

[7] Federal Highway Administration, _Cost Allocation Study Final Report_, 2000, Chapter 5, p.1.

[8] Kahn, A. E., _The Economics of Regulation – Principles and Institutions_, 1988, p.151.

[9] Phillips, C. F. _The Regulation of Public Utilities_, Third Edition, 1993, p.654.

2.2 Standalone and avoidable cost

Economic principles establish that, in the presence of shared costs, the quantum of costs to be allocated to a particular service should be:

- no more than the standalone cost of each relevant service; and

- no less than the avoidable cost of each relevant service.

An allocation of costs within these bounds will ensure that the costs allocated to each service are more than the level at which it may be beneficial for users to bypass the service, and no less than the level at which users of one service are subsidising the provision of any others. It follows that an allocation of costs within these bounds will ensure there exists no cross-subsidy between services, consistent with the NTC's pricing principles.

2.2.1 Standalone cost

The upper bound on the allocation of shared costs to one or other service (in our case heavy vehicle road users) is the standalone cost of providing that service.

In economics, the standalone cost of a particular service which has costs in common with another service is the total cost of providing that service alone. This principle forms the upper bound because, once the price for any service exceeds its standalone cost, the user is being asked to pay more than the cost of delivering the service by another means. Prices set above this threshold are presumptive inefficient because, in principle, the user can procure the service by some other means, for a lower price.

The concept of standalone cost is illustrated in Figure 1 below.

Figure 1   Illustrative standalone cost of providing heavy vehicle road services

2.2.2 Avoidable cost

The lower bound on the allocation of shared costs to one or other service is the avoidable, or incremental, cost of that particular service.

In economics, the avoidable cost of a particular service is the cost that could be avoided if that service was not provided, given all other circumstances (including the provision of other services). In practice, the avoidable cost of a particular service that is provided with costs in common with other services can be calculated in two equivalent ways, ie, it is equal to both:

- the total cost of providing all services less the standalone cost of all other services; and

- the cost that could be avoided if that particular service was no longer provided, given the existence of all other services.

The concept of avoidable cost is illustrated in Figure 2 below.

Figure 2   Illustrative avoidable cost of providing heavy vehicle road services
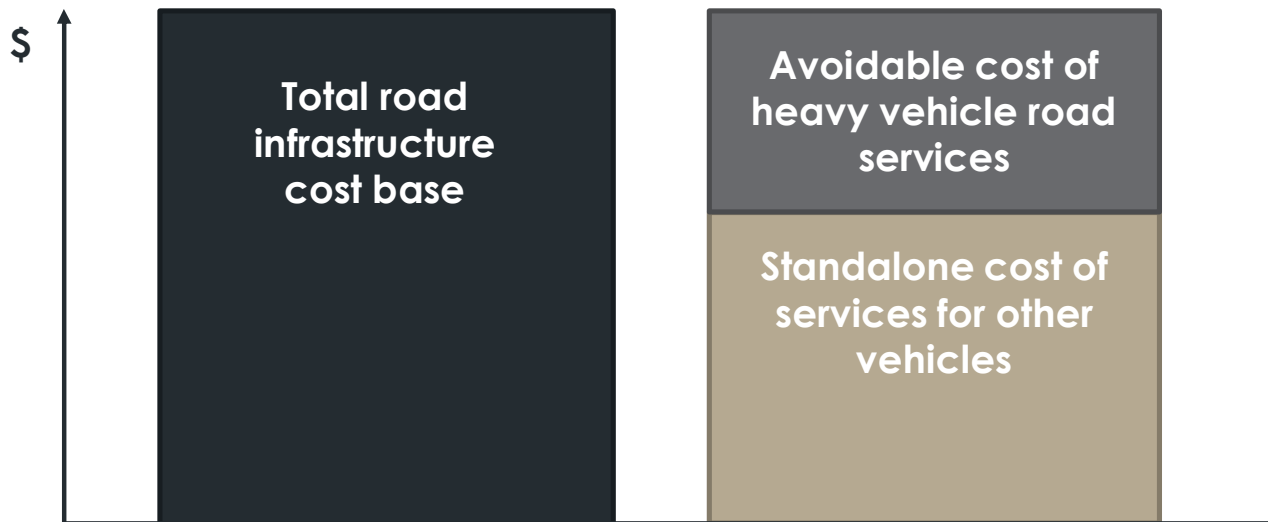
2.2.3   Summary

In summary, economic principles show that in the presence of shared costs, the quantum of costs to be allocated to a particular service should be:

- no more than the standalone cost of each relevant service; and
- no less than the avoidable cost of each relevant service.

An allocation of shared costs within these bounds will ensure that each service is priced at no more than the level at which it may be profitable for users to bypass the service, and no less than the level at which one service is subsidising the provision of any others. We illustrate these concepts in Figure 3 below.

Figure 3   Illustrative range of potential heavy vehicle road infrastructure cost allocations
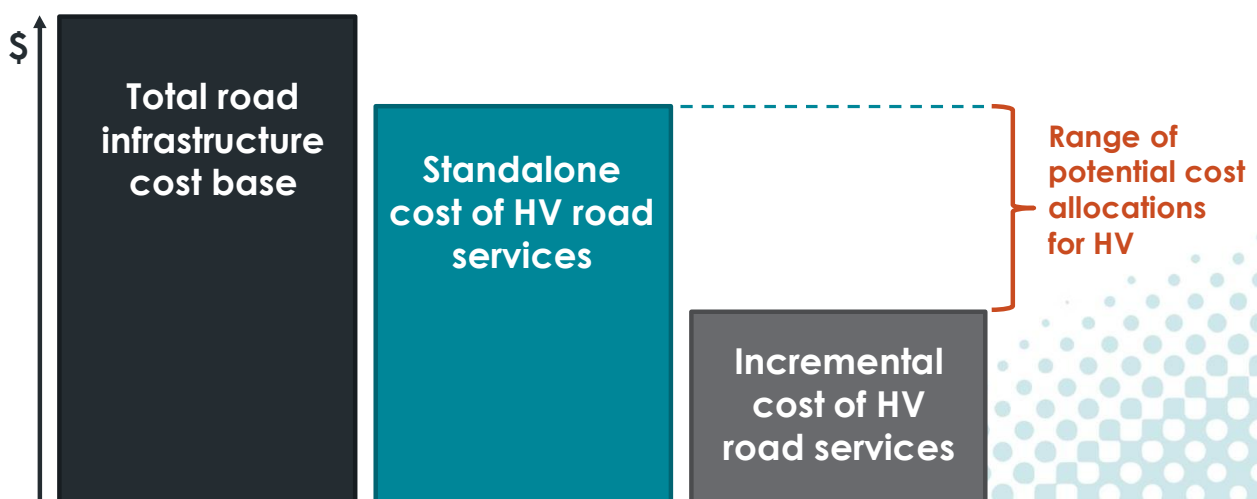
2.3 How these principles can be used to allocate road infrastructure costs

This section outlines how the economic principles of cost allocation can be applied in the context of allocating road infrastructure costs to heavy vehicles.

2.3.1 Estimating the avoidable cost of heavy vehicle road use

The lower bound established by the principle of avoidable costs necessitates that heavy vehicles are allocated at a minimum, the costs for which they are causally responsible. In other words, what are the costs that would be avoided were it not for heavy vehicle road use?

These costs will comprise:

- direct costs – where heavy vehicle road use is solely responsible for the incurrence of particular cost items, those costs should be allocated to heavy vehicles in full; and

- shared costs – where heavy vehicle road use is causally responsible in part for the incurrence of particular cost items, those costs should be apportioned between heavy vehicles and other vehicles.

Example of these costs are highlighted in Box 1 below.

Box 1　　　　Examples of direct and shared costs in the calculation of avoidable cost

Heavy vehicle enforcement costs are an example of direct costs, which should be allocated to heavy vehicles in their entirety since they would not exist absent heavy vehicle road use. It follows that these costs are a component of the avoidable cost of providing heavy vehicle road services.

Consider now the cost of constructing a bridge, where the design standard of that bridge was improved to accommodate use of that bridge by heavy vehicles. Those bridge construction costs are shared costs, of which some proportion could have been avoided if the bridge was not used to provide heavy vehicle road services. The calculation of the avoidable cost of heavy vehicle road services in these circumstances requires an allocation of bridge construction costs to heavy vehicles equal to the costs associated with improving the design standard.

Where heavy vehicle road use is causally responsible in part for the incurrence of shared costs, a degree of judgement is required to determine the proportion of those costs for which heavy vehicle road use is causally responsible. There are myriad potential approaches to allocating these costs.[10]

Nevertheless, the guiding principle in the determination of these avoidable costs is the degree to which the applicable shared costs would reduce without heavy vehicle road use. Potential allocation methodologies for shared costs include those based on:

- the relative contribution of heavy vehicles to the cost driver, or drivers, of the applicable costs; or

- some measure of cost, say:
    - > the relative magnitude of direct costs for heavy vehicle road services, as compared with that for other vehicle classes; or
    - > the relative magnitude of standalone costs for heavy vehicle road services, as compared with that for other vehicle classes.

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[10] Kahn, A. E., *The Economics of Regulation: Principles and Institutions*, 1988, p.150.

2.3.2 To what extent should heavy vehicles bear a level of cost in excess of avoidable cost

The extent to which heavy vehicles bear a level of cost in excess of avoidable cost ultimately rests on how the cost-advantages of shared road use are intended to be shared amongst road users. By way of context, a cost allocation to heavy vehicles:

- equal to their standalone cost would afford heavy vehicles no share of the cost-advantages of shared road use; or

- equal to their avoidable cost would endow on heavy vehicles the cost-advantages of shared road use in its entirety.

Subject to the bounds established by standalone and avoidable cost, the extent to which any particular class of road user should enjoy the cost-advantages of shared road use is largely a matter of judgement, to be guided by the applicable pricing principles.

Box 2   Illustrative example of this framework

Pavement maintenance costs are shared costs since they are incurred in the provision of road services to heavy vehicles and other vehicles. Now, consider circumstances where pavement renewal costs comprise:

- costs caused by heavy vehicle road use;

- costs caused by other vehicle road use;

- costs that arise independent of road use, eg, due to climatic factors.

This illustrative example of renewal costs is presented in the figure below.
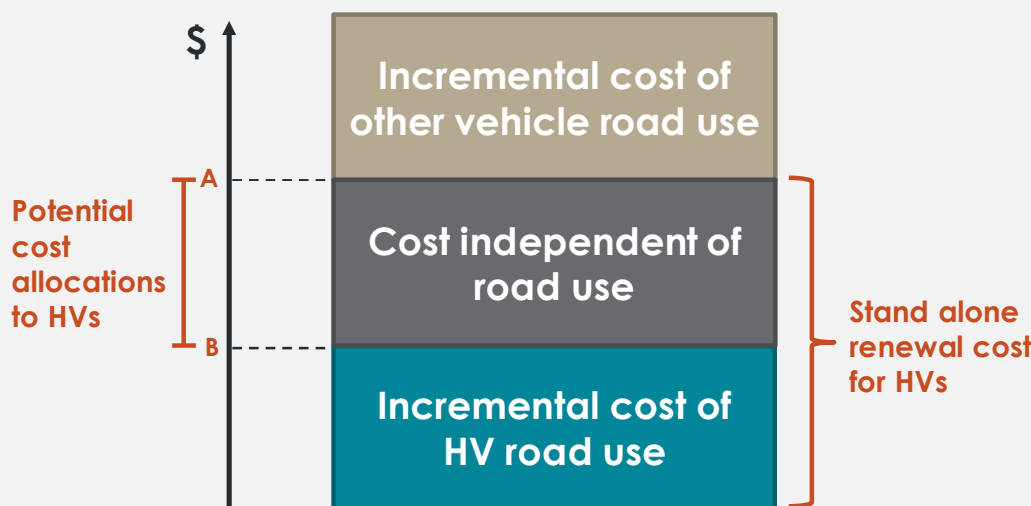
The economic principles of standalone and incremental cost require the allocation of the abovementioned renewal costs to fall between points A and B in the figure above. That said, the degree to which the allocation of cost to heavy vehicles lies closer to point A or B will reflect, respectively, a relatively lesser or greater share for heavy vehicles of the cost-benefits of shared road use.

We have explained that the extent to which the allocation of cost falls closer to the bounds established by the standalone and avoidable cost, is largely a matter of judgement, to be informed by reference to the pricing principles. In this regard, potential considerations could include:

- the extent to which different vehicle classes use road services;

- the extent to which efficiency is promoted by encouraging road use by one or other road use;

- the extent to which heavy vehicles and other vehicles are willing to pay for road services;

- the cost of providing road services to different users, eg, standalone cost or long run marginal cost (LRMC);[11] and

- whether it is equitable for one class of user to bear a disproportionately large share of those costs and, in so doing, afford other users a disproportionately large share of the cost-advantages of shared road use.

Of course, this is not an exhaustive list of potential considerations to inform the exercise of judgement in determining the precise allocation of cost, subject to the bounds established by standalone and avoidable cost. Rather, it is intended to provide context only.

2.4 The PAYGO framework in light of these principles

We interpret the construction of the PAYGO framework to be directed at achieving an allocation of road expenditure to heavy vehicles that falls within the bounds established by the principles of standalone and avoidable cost.

Under the PAYGO framework, attributable costs are costs directly related to road use, ie, they are costs that would, in principle, be avoided if there was no road use. The PAYGO framework implicitly:

- identifies the 'attributable' portion of the total road infrastructure cost base;

- then separates those costs into:

  > costs attributable to heavy vehicle road use – which are allocated to heavy vehicles; and

  > costs attributable to other (not heavy) vehicle road use – which are not allocated to heavy vehicles.

By ensuring that costs attributable to road use by other vehicles – the avoidable cost of other vehicle road use – are not allocated to heavy vehicles, the PAYGO framework ensures that the road expenditure recovered from heavy vehicles is no more than the standalone cost of heavy vehicle road use.[12] On the other hand, by allocating to heavy vehicles the attributable cost of heavy vehicle road use, the PAYGO framework ensures that heavy vehicles bear at least the avoidable cost of heavy vehicle road use.

In other words, the construction of the PAYGO framework is directed at allocating to heavy vehicles no more than the standalone cost of heavy vehicle road use, and at least the avoidable cost of heavy vehicle road use.

When viewed through this lens, the allocation of some proportion of common costs to heavy vehicles determines the extent to which the heavy vehicle cost base is closer to the standalone or avoidable cost of heavy vehicle road use. For example, allocating to heavy vehicles no common costs would give rise to a heavy vehicle cost base that reflects just the avoidable cost of heavy vehicle road use.

By way of illustration, the above interpretation of the PAYGO framework suggests the indicative standalone and avoidable cost levels for heavy vehicles of $7.4 and $2.3 billion in 2015-16, respectively. Importantly the approximately $3 billion of total revenue[13] collected from heavy vehicles in that year fell between those bounds, as illustrated in Figure 4 on the following page.

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[11] LRMC is a forward-looking concept, which measures the incremental change in the stream of future costs (both operating costs and new road infrastructure investment costs) arising from a small but permanent change in road usage by the class of road user being considered (eg, heavy vehicles).

[12] The standalone cost of heavy vehicle road use can be calculated equal to the total road infrastructure cost base less the avoidable cost of other vehicle road use. See section 2.2.2.

[13] NTC, *Annual Report 2015–16*, p.73-75, Table F4, combined with road user charge of 25.9c/litre.

Figure 4   Indicative standalone and avoidable cost of heavy vehicle road use 2017-18[14]
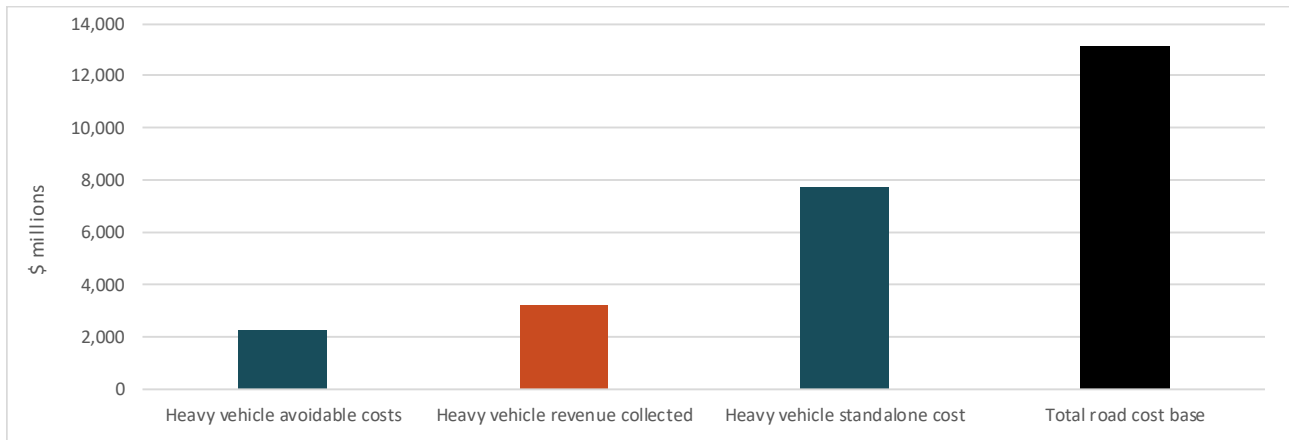
2.5   Heavy vehicle price structures

It is instructive in this context to comment briefly on the economic principles applicable to setting the structure of heavy vehicle charges for road infrastructure since they can, themselves, give effect to an implicit allocation of costs.

However, we note that there is currently insufficient data available to apply those principles to the provision of road infrastructure services – as is the case in a number of other sectors. Nevertheless, it is important to be cognisant of these theoretical principles when considering any future reform relevant to charges for the provision of road infrastructure services.

From a purely theoretical perspective, in the presence of a full cost recovery constraint, economic efficiency of road infrastructure would best be promoted by means of a pricing arrangement that charges road users:

- at least the long run marginal cost (LRMC) arising from the use of a road; and
- an amount to recover an allocation of the residual level of cost – the difference between the avoidable costs recovered from all users and total costs incurred in the provision of road infrastructure services.

The specific road user price structure can include a fixed and variable component (such as the implicit current arrangement for heavy vehicles, which involves a road user charge (existing fuel excise) and a vehicle registration charge). Alternatively, a mark-up could be applied to the level of variable charge implied by the LRMC of the relevant service, consistent with the principles of Ramsey pricing (see Box 3 below).

The preferred balance between fixed and variable components requires a consideration of the implications for road use decisions, fleet mix choices, and considerations of bill impact to road users.

For completeness, we briefly explain the economic concepts of LRMC and Ramsey pricing in Box 3 on the following page.

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[14] Calculated by reference to total allocable road expenditure for the 2017-18 annual adjustment for each expenditure category and the 2015/16 road use parameters. Avoidable cost of heavy vehicle road use calculated equal to heavy vehicle share of attributable costs. Stand alone cost of heavy vehicle road use calculated equal to total road common costs plus avoidable cost of heavy vehicle road use. NTC, *Annual Report 2015–16*, p.73-75.

Box 3   Long run marginal cost and price elasticity of demand

Long run marginal cost

LRMC is a forward-looking concept and amounts to a measure of the additional cost incurred as a result of an incremental (or relatively small) increase in output, assuming all factors of production are able to be varied. As a matter of principle, setting prices equal to LRMC will promote efficient use and production of goods and services because:

- it ensures that consumers face price signals that reflect the resource cost of providing services, which encourages demand for services only when the benefit to consumers exceeds the cost of their provision; and

- it provides signals to infrastructure providers as to how much users value additional capacity, and thereby plays an important role in financing that capacity.

The forward-looking nature of LRMC arises from the observation that historical costs cannot be affected by changing current behaviour. However, future costs pertaining to the expansion of a network can be affected by changes in demand, namely by means of bringing forward or delaying any expansion in capacity.

LRMC is the basis for setting other network infrastructure usage-based charges, including for water and electricity network infrastructure services.

In principle, road usage charges should be set at least at the long run marginal cost of providing road infrastructure services. How such a charge is 'averaged' across the network, will depend on the extent to which road users can be expected to respond through changing the use of particular routes as a consequence of providing more granular estimates of the LRMC of using a particular road. In practice, we would expect that LRMC-based road pricing could be implemented with a high level of averaging across the road network.

Ramsey pricing

The Ramsey price approach – sometimes referred to as the inverse elasticity rule – is a second-best pricing methodology[15] that seeks to maximise efficiency subject to a constraint that a business recovers its costs.[16] It involves setting prices at a level of mark-up above LRMC that varies according to the differing willingness to pay of different customers (or groups of customers), thereby minimising the extent of distortion to consumer behaviour (as compared with prices that are set at marginal cost).

Put simply, Ramsey pricing achieves this by applying a higher mark-up above marginal cost to consumers that are the less responsive to price changes, ie, consumers with less elastic demand. Ramsey pricing principles could be used to set road usage charges in excess of those that might otherwise be applied simply by estimating LRMC.

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[15] Setting prices equal to marginal cost results in a more efficient outcome, but may not permit cost recovery.

[16] Ramsey (1927) first solved the problem of maximising welfare subject to a profitability constraint in the context of optimal taxation and the result was later applied to natural monopolies by Boiteux (1956) and Baumol and Bradford (1970), see: Ramsey, F., 1927, "*A Contribution to the Theory of Taxation*", Economic Journal, Vol 37 No. 145, page 47 to 61; Boiteux, M., 1956, "*Sur la Gestion des Monopoles Publics Astreints à l'Equilibre Budgétaire*",Econometrica, 24, page 22 to 40; and Baumol, W. and D. Bradford. 1970. Optimal departures from marginal cost pricing. American Economic Review, 60, 265-283.

2.6   Principles for cost allocation and heavy vehicle charging structures

It follows from the discussion in the above sections that there are a number of principles that are relevant to a consideration of cost allocation and heavy vehicle charging, namely that:

- road charges to all road users including both heavy and light vehicles should be set so as to recover the total costs of providing and operating the road network, less any contributions resulting from charges to other beneficiaries of road infrastructure;

- heavy vehicle road users should pay at least the costs caused by having access to the road network, which include:

  > road wear and tear related maintenance costs directly caused by heavy vehicle road use;

  > the incremental capital costs of new road infrastructure that could otherwise have been avoided if heavy vehicles (hypothetically) did not have access to the road (ie, the difference between the costs of building say a bridge to accommodate anticipated heavy vehicle use compared with the costs of building the same bridge assuming that heavy vehicles were not allowed to access the bridge);

- the total revenue expected to be recovered from a particular road user should lie between an upper bound represented by the standalone cost of providing road infrastructure to that road user, and a lower bound represented by the avoidable cost of providing road infrastructure to that road user;[17]

- road user charges should be set with reference to the long run marginal cost of providing road infrastructure services to the user, taking into account:

  > the likely responsiveness of road users to the price signals created;

  > the administrative costs associated with setting establishing different road user charges for specific road users; and

  > the importance of certainty and transparency in pricing for heavy vehicles.

Applying these principles will have the effect of promoting efficient use and provision of road infrastructure services. They are based on well understood economic principles and practices applied in other infrastructure sectors and should guide the allocation of the total cost of providing road infrastructure services to heavy vehicles, including in the context of a forward-looking cost base. We note the application of some of these principles, at least in their theoretical form, may be complicated by a lack of the requisite data, as is the case in a number of other sectors, eg, in the electricity, gas and water sector.

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[17]

3. Review of the cost allocation parameters applied within PAYGO

Our review identified that road cost and use data generally suffers from a number of shortcomings, which contribute:

- to often-conflicting evidence on the relationship between heavy vehicle road use and road costs; and

- to a general lack of industry consensus on fundamental elements of the relationships between heavy vehicle road use and road costs.

It is therefore unsurprising that the empirical evidence in support of both the existing and alternative allocators in the PAYGO matrix all have relative merits and shortcomings. Given the often-conflicting views presented in the empirical evidence, each with relative merits and shortcomings, selection of the appropriate allocators necessarily requires some degree of judgement, taking into account the surrounding circumstances. Indeed, the exercise of judgement in the allocation of infrastructure costs arises in a broad range of sectors, including in the provision of electricity, water and telecommunications network services.

In our opinion, the exercise of such discretion in this context should be guided by generally accepted considerations as applied in other sectors. In the context of conflicting evidence, it is important that a balance is struck between:

- the potential benefit of any changes over the period in which they are expected to be in effect; and

- the potential for changes to the heavy vehicle allocation methodology to cause winners and losers and, in so doing, contribute to uncertainty in heavy vehicle road pricing.

We found that new research on the relationship between heavy vehicle road use and road costs since the last NTC review was insufficient, in and of itself, to support a departure from the current PAYGO allocators. In particular, we identified no sufficiently strong new evidence to support a change to the current allocation for expenditure categories, A, B1, D, E, F1, F3 and G1. Subject to the same conclusion for the remaining B2, C and F3 expenditure categories, it is instructive to note that, in our opinion:

- for the B2 expenditure category, it is open to the NTC to either not change the current allocation or to use one or more weight-based allocation parameters; and

- for the C and F2 (bridge-related) expenditure categories, Austroads suggested a new methodology for allocating those costs using bridge fatigue analysis, but absent that work having been undertaken there is no new evidence to support a change to the current allocation at this time.

Finally, a general observation arising from our review was that further empirical studies may be unlikely to provide meaningful guidance on the appropriate allocation of road costs to road users, namely owing to:

- the complex relationships driving road costs, which significantly complicate the identification of explanatory variables that reflect all the factors driving variability in road costs; and

- the present limitations of road use and cost data.

In this context, any future change in approach, eg, to a FLCB approach, would present an ideal opportunity to revisit the appropriateness of these allocation parameters and the merits of relying on empirical evidence.

The main focus for our study was on evaluating the appropriateness of the current cost allocation
parameters applied within PAYGO. The purpose of this task is to ensure that the cost allocation parameters
to be used under PAYGO reflect the current best available evidence.

Our approach involved reviewing a number of databases and information sources for primary research on
the relationship between heavy vehicle road use and road costs, which included:

- ProQuest ABI/Inform;

- EBSCO Business Source Complete;

- Informit;

- Factiva; and

- the world-wide web.

Our review of these databases and information sources was guided by a number of relevant keywords and
authors, where we reviewed relevant research and followed up on references as they arose. The NTC also
provided us with relevant research for our consideration. A list of the relevant documents we identified and a
description of the databases we searched are included in Appendix A1.

In the remainder of this section we first describe the current approach to the allocation of road expenditure
under the PAYGO methodology, before summarising the primary evidence that was identified as being
relevant to a consideration of how best to allocate road expenditure to each of the current PAYGO
expenditure categories. We conclude the section by setting out the findings from our review.

3.1   Allocation of road expenditure under the PAYGO methodology

Cost allocation is a central part of the PAYGO framework. It determines the basis on which different costs
are allocated to heavy vehicles and so plays a significant role in estimating the heavy vehicle cost base. By
way of context, in its most recent determination the NTC estimated the heavy vehicle cost base to be
approximately $2.985 billion.[18]

The PAYGO framework applied by the NTC involves separating the total cost of providing road infrastructure
services into expenditure categories, and then allocating to heavy vehicles a proportion of the costs
comprising each expenditure category. In particular, the PAYGO framework involves determining, for each
expenditure category:

- the proportion of costs that vary with road use (attributable costs) and the remainder (common costs) that
do not vary with road use;

- allocating to heavy vehicles a proportion of attributable costs on the basis of heavy vehicles' contribution
to the underlying cost driver, or drivers, for that expenditure category; and

- allocating to heavy vehicles a proportion of common costs on the basis of heavy vehicle kilometres
travelled, as compared to other vehicle kilometres travelled.

There are four cost allocators used across the PAYGO matrix, ie:

- vehicle kilometres travelled (VKT);

- passenger car unit equivalent kilometres (PCU);

- average gross mass kilometres (AGM); and

- equivalent standard axle kilometres (ESA).

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[18] NTC, 2014 Heavy Vehicle Charges Determination Regulatory Impact Statement, February 2014, p.63.

The VKT and PCU allocators relate to traffic volumes and road capacity, respectively, whereas ESA and AGM are more closely aligned with road wear.

The choice of cost allocator can lead to a significant reallocation of costs to or from heavy vehicles. For example, selecting a road wear related allocator (eg, ESA or AGM) would allocate almost all costs for the category to heavy vehicles (94 and 82 per cent respectively). In contrast, selecting a volume related allocator (eg, VKT or PCU), would allocate only a small fraction of costs to heavy vehicles (7 and 17 per cent respectively). The current PAYGO cost allocation matrix is presented in Table 3 below.

Table 3   PAYGO cost allocation matrix

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
A: Servicing and operating expenses	100	-	-	-	-	-
B: Road pavement and shoulder maintenance						
B1: Routine maintenance	-	37	-	37	-	24
B2: Periodic maintenance	-	10	-	60	-	30
C: Bridge maintenance and rehabilitation	-	-	-	33	-	67
D: Road rehabilitation	-	-	45	-	-	55
E: Low cost safety/traffic improvement	80	20	-	-	-	-
F: Asset extension/improvement						
F1: Pavement components	-	-	45	-	-	55
F2: Bridges	-	15	-	-	-	85
F3: Land acquisition, earthworks, other extension improvement expenditure	-	10	-	-	-	90
G: Other miscellaneous activities						
G1: Corporate services	-	-	-	-	-	100

3.2   Matters relevant to a review of the evidence

At the outset, it is informative to highlight a number of important contextual matters relevant to our assessment of and conclusions on the allocation methodology in the PAYGO matrix.

3.2.1   The potential for fundamental change in the future

Foremost of these considerations is the potential for an alternative approach to determining the heavy vehicle cost base to be implemented in the future. The NTC recently published a discussion paper setting out nine options for improving the heavy vehicle charging methodology, which included the potential replacement of the PAYGO approach with alternative approaches, eg, a forward-looking cost base.

It is therefore important that, in considering the potential for changes to the existing allocation methodology, a balance is struck between:

- the potential benefit of any changes over the period in which they are in effect; and
- the potential for changes to the heavy vehicle allocation methodology to cause winners and losers and, in so doing, contribute to uncertainty in heavy vehicle road pricing.

3.2.2   Data reliability

It is also relevant to comment on the reliability of the road cost and road use data necessitated by analyses of the relationship between heavy vehicle road use and road costs. In particular, road cost and use data in Australia, as in many other countries, suffers from a number of shortcomings, eg, inconsistent approaches to compiling data and significant aggregation of road use and cost data.

These shortcomings pose a considerable challenge for statisticians, engineers and econometricians endeavouring to evaluate the causal relationship between heavy vehicle road use and road costs. Indeed, these challenges are reflected, in many cases explicitly, throughout the research we identified and provide relevant context to the often-conflicting evidence on the relationship between heavy vehicle road use and road costs.

Notwithstanding these data limitations, and their corresponding implications on the findings of various studies, there exists a general lack of contemporary evidence on the relationship between heavy vehicle road use and road costs. The abovementioned data limitations and the lack of contemporary primary research contribute to a general lack of industry consensus on fundamental elements of the relationships between heavy vehicle road use and road costs.

That said, looking forward there is likely to be merit in focusing allocation decisions for the recovery of road infrastructure expenditure on an in-principle understanding of causal responsibility, with specific decisions about allocations to be based on the principles set out in section 2.

The independence of empirical evidence

We note that the NTC asked us to consider only primary, independent research owing to the scope for different objectives to influence cost allocation methodologies, and potentially studies, applied in other jurisdictions. As ARRB explains:[19]

> The selection of a cost allocation approach has been and still is strongly influenced by many short-term socio-economic objectives, [and] the political process...

The requirement to consider only primary, independent research to a large extent ruled-out consideration of the approaches applied by overseas road authorities. However, we do briefly comment on approaches applied by overseas road agencies by way of context only.

While there is a reasonable level of publicly available information on cost allocation methodologies applied in the United States, we identified a general lack of information on approaches applied in Europe, consistent with the findings of other reviews.[20] A general observation arising from our review was that some methodologies applied overseas, particularly in the United States, tend to adopt a more granular characterisation of costs. This can simplify the selection of the relevant cost allocation parameters to the extent that those more granular cost categories have a single cost driver.

3.2.3   The applicability of overseas research

There exist a number of factors that have the potential to limit the applicability of empirical research conducted overseas on the relationship between heavy vehicle road use and road costs. These include the potential for differences in:

- climatic conditions to contribute to different levels of non-attributable costs;
- the nature and extent of heavy vehicle road use, as well as the definitions of heavy vehicles;
- expenditure categories, and the associated definitions of those categories; and

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[19] ARRB, *Estimates of unit road wear costs*, February 1994, p.25.

[20] NZIER, *Literature review Road use charging & cost allocation,* Report to Ministry of Transport, December 2008 p.18.

- the approaches used to define and measure road use variables.

By way of example, a review of road cost allocation approaches in Europe funded by the European Commission identified significant variation in the approach to measuring the PCU road-use variable, eg, some countries measure road occupancy (PCU) by sole reference to vehicle speeds, whereas others do so by reference to vehicle space or length requirements.[21]

These factors contributed to a general lack of relevant overseas, independent empirical research that could be used to inform an understanding of the relationship between heavy vehicle road use and road expenditure in Australia.

3.2.4   The relative magnitude of expenditure categories

Finally, by way of further context we present below the relative level of expenditure comprising each of the expenditure categories in the PAYGO matrix, along with the proportion of costs in each expenditure category allocated to heavy vehicles. Ultimately, the extent of research effort applied to precisely understanding how costs are affected by the usage characteristics of particular road users should be proportional to the incremental value from improving this understanding.

Table 4   Average road expenditure 2005/06 to 2014/15 and relative shares

Expenditure category	Average annual expenditure (2006/07-2014/15)	Proportion of total average expenditure (2006/07-2014/15)	Proportion of expenditure category allocated to HVs (%)
A: Servicing and operating expenses	1,765	10%	7%
B1: Routine maintenance	1,129	6%	39%
B2: Periodic maintenance	839	5%	53%
C: Bridge maintenance and rehabilitation	459	3%	32%
D: Road rehabilitation	1,865	11%	46%
E: Low cost safety/traffic improvement	1,662	9%	9%
F1: Pavement components	2,324	13%	46%
F2: Bridges	1,489	8%	8%
F3: Land acquisition, earthworks, other extension improvement expenditure	5,113	29%	8%
G1: Corporate services	756	4%	7%

3.3   Allocating non-attributable costs on the basis of VKT

Since non-attributable costs comprise a proportion of a number of expenditure categories, and are always allocated on the basis of relative VKT, it is helpful to address this allocation parameter at the outset of our review, and then not to repeat this discussion for each relevant expenditure category.

The basis for allocating non-attributable costs in the PAYGO matrix can be traced back to a 1989 VicRoads report[22] (the VicRoads report) directed at developing a more rational 'user pays' approach to road-user

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[21] Cost Allocation of Transport Infrastructure Cost, *Cost allocation Practices in the European Transport Sector*, March 2008, p.29-30.

[22] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989.

charging in Victoria (VIC).[23] The VicRoads report highlighted that the allocation of non-attributable expenditure should be based on economic efficiency and equity criteria, explaining that:[24]

> The efficiency criterion would be served by adopting a method that minimised efficiency distortions. Sayers notes that Ramsey pricing principles could be applied if there were an adequate understanding of demand elasticities. However, there are only approximate estimates of these elasticities at present, and consequently this option has not been adopted at this stage.

> Instead the (vehicle.km) parameter has been adopted for distribution of non-separable [non-attributable] costs. This provides a reasonable equitable basis, and includes some measure of consumption.

By definition, the absence of a relationship between road use and non-attributable costs leaves the allocation of non-attributable costs open to considerable judgment. The level of judgement involved in the allocation of these costs is not limited to the road sector but, rather, is common in the provision of infrastructure services. By way of example, on the subject of allocating shared costs in the electricity distribution network sector, the Australian Energy Market Commission recognises a number of possible approaches available to the Australian Energy Regulator (AER), ie, it explains that:[25]

> …the most obvious approach is for the AER to base this on the relative use of the asset for the provision of the different kind of services such as the technical use or physical use. Another possible way could include using the ratio between the proportion of revenue from the asset for standard control services and the proportion of revenue from the asset for other than for standard control services over the current regulatory period. However, this should not be taken as precluding the AER from considering other possible bases for sharing the costs of the asset.

It follows that there are a number of viable allocators available for the allocation of non-attributable costs, namely PCU and VKT. The application of a VKT or PCU allocator for non-attributable costs would give rise to an allocation of non-attributable costs to heavy vehicles of 7 per cent and 17 per cent, respectively.

Box 4 below briefly describes the approach to allocating non-attributable costs applied in the United States.

Box 4   Non-attributable cost allocation methodologies applied in the United States

A review of highway cost allocation studies in the United States explains that:[26]

> There are elements of any transportation agency budget that have no clear relationship to specific vehicle characteristics. These costs include planning and administrative overhead costs. These costs are generally allocated based on either an assignment of responsibility to a specific highway-user class or some general measure of VMT [vehicle miles travelled].

The most recent HCAS for the state of Oregon highlighted that:[27]

> Unweighted VMT is the most general measure of system use and is considered a fair way to assign many types of common costs, that is, costs considered to be the joint responsibility of all highway users. VMT represent a reasonable and accepted measure to assign costs among the members of a subgroup (e.g., the individual vehicle classes within a cost increment),

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[23] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, p.1.

[24] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, pp 2-3.

[25] AEMC, Rule Determination – National Electricity Amendment (Economic Regulation of Network Service Providers) Rule 2012 National Gas Amendment (Price and Revenue Regulation of Gas Services) Rule 2012, November 2012, p.196.

[26] National Cooperate Highway Research Program, *State Highway Cost Allocation Studies – a Synthesis of Highway Practice*, 2008, p.14.

[27] ECONorthwest, 2015-2017 OREGON HIGHWAY COST ALLOCATION STUDY – 2015 – 2017 Biennium, Oregon, p.15.

> especially when members of the subgroup have similar characteristics or when an investment is made to provide a safer highway facility).
>
> The Texas Department of Transport agrees, but also highlights the potential for the use of other allocators, ie:[28]
>
>> Previous highway cost allocation studies have often allocated common costs proportionally to VMT… Other possible allocators include passenger-car-equivalent VMTs (PCE-VMTs) and axle-miles of travel (AMTs).

We note that it has in the past been proposed that non-attributable costs are allocated, at least in part, on the basis of PCU, which could incorporate an additional dimension of road use in the allocation of non-attributable costs. We also note that the Productivity Commission in the past commented that the use of a VKT allocator may be preferable on efficiency grounds.[29]

3.3.1 Conclusion

On the basis that the incurrence of non-attributable costs is not directly related to road use, it is unsurprising that we did not identify primary research on the relationship between heavy vehicle road use and non-attributable cost.

For the reasons set out in the VicRoads report we consider the application of a VKT allocator for non-attributable costs to be appropriate. However, owing to the level of judgement necessarily involved in the allocation of non-attributable costs, we note the potential relevance of a PCU allocator.

In summary, we identified no empirical evidence to support a departure from the VKT allocation parameter used to allocate non-attributable costs. For the sake of brevity, we do not repeat this discussion on the VKT allocator for non-attributable costs for each expenditure category.

3.4 Servicing and operating expenses (Category A)

3.4.1 What costs are in this category?

The 'servicing and operating expenses' expenditure category comprises costs associated with servicing, operating and monitoring the road system, but excludes expenditure on pavements, shoulders and bridges. This includes expenditure in relation to:

- maintenance and cleaning of roadside furniture, including signs;
- roadside and median maintenance, including grass mowing and litter collection;
- maintenance, repairs and operating charges for street lighting and traffic signals;
- cleaning, maintenance and repairs to drains;
- servicing of roadside rest areas and pavement sweeping;
- repainting pavement markings;
- traffic monitoring and recording;
- pavement condition monitoring and recording; and
- surveillance and provision of emergency services on major roads and bridges.

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[28] Texas Department of Transport, *Texas highway cost allocation study*, October 2002, p. 12.

[29] Productivity Commission, *Road and Rail Freight Infrastructure Pricing – Inquiry Report*, December 2006, p.109.

3.4.2 Cost allocation and supporting empirical evidence

The costs that comprise the 'servicing and operating expenses' expenditure category are classified as attributable costs in the PAYGO matrix, and are allocated to heavy vehicles on the basis of relative VKT, as compared with that for other vehicles.

Table 5   Allocation of servicing and operating expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Servicing and operating expenses	100	-	-	-	-	-

The VKT allocator for the 'servicing and operating expenses' expenditure category can be traced back to its former classification as entirely non-attributable costs. In 1989, the VicRoads report adopted the position on 'servicing and operating expenses' that was agreed previously within the Australian Transport Advisory Council (ATAC) working party, ie, that 'servicing and operating expenses' were non-attributable in their entirety.[30] The basis on which the VicRoads report selected the VKT allocator for non-attributable costs is discussed in section 3.3.

Subsequent to the VicRoads report, the classification of 'servicing and operating expenses' was changed from entirely non-attributable to entirely attributable costs, although the VKT allocation key was retained. As to the basis for this reclassification, the NTC explained that:[31]

> Servicing and Operating expenditure is considered to be related to road use but not strongly linked to different vehicle types. In urban areas, the bulk of this expenditure is related to the operation and maintenance of traffic management equipment including traffic signals, line marking and delineation. In rural areas most of the expenditure is related to drainage maintenance and roadside maintenance work, such as litter collection and grass mowing. In both cases a greater level of effort is needed for roads with higher volumes of traffic.

3.4.3 Conclusion

On the basis that the incurrence of 'servicing and operating expenditure' is related to road use, but not strongly linked to different vehicle types, it is perhaps unsurprising that we did not identify primary research on the relationship between heavy vehicle road use and servicing and operating expenditure.

It follows that there is no new evidence to support a change to the current allocation for this expenditure category.

In our opinion, the current VKT allocation parameter used to allocate servicing and operating expenditure remains appropriate because it:

- reflects the usage-related driver of these expenditures, but

- does not discriminate between users by reference to vehicle-type.

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[30] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, Appendix A.

[31] NTC, *Third Heavy Vehicle Road Pricing Determination: Technical Report*, October 2005, p 34.

3.5 Road pavement and shoulder maintenance – Routine maintenance (Category B1)

3.5.1 What costs are in this category?

The 'routine maintenance' expenditure category in the PAYGO matrix is a subset of 'road pavement and shoulder maintenance' and comprises all routine costs incurred in maintaining the roadway and shoulders, but excludes periodic costs incurred on sealed roads. The principal distinction between routine and periodic maintenance activities concerns the frequency at which they occur, ie:[32]

- routine maintenance activities typically occur at a frequency of less than one year; and

- periodic maintenance activities typically occur at a frequency greater than one year.

Examples of routine maintenance activities include:

- pot hole repairs / minor patching less than 500 square metres;

- crack sealing;

- edge repairs;

- shoulder grading; and

- re-sheeting of unsealed roads and shoulders.

3.5.2 Cost allocation and supporting empirical evidence

The approach to allocating 'routine maintenance' costs in the PAYGO matrix is presented in Table 6 below.

Table 6   Allocation of routine maintenance expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Routine Maintenance		38	-	38	-	24

The allocation of routine maintenance costs was informed by research undertaken by The Urban Logistics Group (ULG) at the University of Melbourne, on behalf of the NTC (the ULG Report).[33] The ULG report was directed at identifying statistical relationships between road use and maintenance expenditure.

The data relied upon by ULG in undertaking these analyses is particularly relevant to the interpretation of its findings. ULG sourced data maintenance expenditure data from the ARRB database pertaining to 402 pavement sites from around Australia over a period of 14 years. The sample exhibited a number of limitations, including a heavy weighting on Victorian roads, missing information, and the omission of local roads.

Initially, ULG applied 23 alternatively specified linear models to five years of aggregated, continuous data to estimate the relationship between road use and maintenance expenditure. Specifically, it applied:[34]

- 12 alternatively specified linear regression models to evaluate the relationship between maintenance and ESA; and

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[32] NTC, *2016 NTC Expenditure Template Reporting Guidelines*, p.12.

[33] ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005.

[34] ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005, p.10-11.

- 11 alternatively specified linear regression models to evaluate the relationship between maintenance and AGM.[35]

ULG determined the estimated relationships to be of insufficient strength, owing to the correspondingly low R^2 values,[36] although it did not present the statistical significance of the independent variables.

ULG then sourced disaggregated data from the database over the 1989 to 2001 period. These data comprise 1,656 observations, of which:

- 60 per cent were from Victoria;

- 15 per cent were from Western Australia;

- 13 per cent were from South Australia;

- 7 per cent were from Tasmania; and

- the remaining 4 per cent were from NT, NSW and QLD.

In light of the prevalence of data from Victoria in this sample, ULG analysed the relationship between road use and costs using data from Victoria only, other (non-Victoria) states only and all states. ULG concluded that:[37]

> There was no statistical behavioural difference between the Victorian and other States' data.

The statistical basis on which ULG form this conclusion is unclear, and no results are presented in the ULG report. Generally, we would expect questions of this nature to be evaluated by application of the 'Chow test'.[38]

Model specifications

It is best-practice for the specification of statistical models to be underpinned by a hypothesis with a sound theoretical foundation, eg, there exists a basis in engineering theory for a relationship between weight related road-use variables and pavement deterioration, which suggests the use of AGM and/or ESA as independent variables. Further, the nature of any such theoretical relationship should inform the particular specification of the model, eg, does engineering theory suggest the hypothesised relationship to be linear or non-linear?

However, ULG apply 14 alternatively specified statistical models (nine non-linear and three linear models) with:[39]

- either total maintenance, routine maintenance or periodic maintenance as the dependant variables; and

- PCU, ESA and AGM as the independent variables, either separately or in combination.

The theoretical basis on which ULG selected these alternative model specifications is not clear and ULG did not present statistical results for the model specifications that it set aside. It is therefore difficult to evaluate the relative merits of these model specifications, even setting aside their theoretical basis.

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[35] We note that ULG use the terminology 'gross vehicle mass kilometres' (GVM), which we understand is equivalent to AGM. For consistency, we refer to AGM throughout the remainder of this report.

[36] ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005, p.7-12.

[37] ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005, p.14.

[38] The Chow test is a statistical and econometric test of whether coefficients in two linear regressions on different data sets are equal. The null hypothesis asserts that the coefficients are equal, and that the data sets are best explained by a single linear regression. Rejecting the null hypothesis in favour of the alternate hypothesis that the coefficients are different implies that the data sets are better explained by separate linear regressions. See: Chow, G, *Tests of equality between sets of coefficients in two linear regressions*, Econometrica, 28(3), July 1960, pp 591-605.

[39] Four recommended models and 11 discarded models. See ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005, p.17-18 and Appendix C.

Further, each of the non-linear model specifications assessed by ULG had no constant coefficient (the intercept). We would expect a statistical analysis to omit a constant coefficient only where there exists strong grounds for why the dependant variable would be equal to zero absent the effects of the independent variables. Importantly, we understand it is generally accepted that there would be some degree of pavement deterioration absent road use, which implies the need for a constant coefficient, eg, Martin (2002) notes that:[40]

> Variations in the moisture of sensitive clay subgrades can also cause significant deformation of the pavement (road wear), particularly if the pavement is thin and both the surface and subsurface drainage are inadequate. The road wear in this instance is also independent of the traffic load. Consequently, not all road wear is wholly attributable to heavy vehicle loads for bituminous surfaced arterial roads.

We note that ULG does however note the potential relevance of environmental factors to road deterioration and maintenance.

As to the effect of omitting the constant coefficient, ULG highlight that it:

> …allows more of the variation in the relationship to be explained by the independent variable(s).

And more particularly, that:

> …selecting zero intercepts forced all roads expenditure to be, in statistically terms, totally attributable to the selected dependent variables in the regression.

It is unclear on what basis ULG then infer that:

> …models that did not incorporate a constant value proved to have strong explanatory powers. The implication that can be drawn from this is that there appears to be a strong direct relationship between road use and maintenance expenditure.

It appears counterintuitive that ULG select model specifications on the basis of their strong explanatory power, when that explanatory power arises from a separate decision to omit a constant coefficient.

ULG does not present statistical results for the non-linear models that include a constant coefficient, but notes the 'statistical characteristics' of such models were very poor. It is therefore difficult to independently evaluate the potential validity of those model specifications.

The recommended model for routine maintenance

Nine of the models evaluated by ULG were rejected on the basis of their poor explanatory power or suitability for implementation.

It is relevant to note that the explanatory power of a model, as measured by the 'R-squared' is not a measure of the statistical significance of the independent variables.[41] It is unclear on what basis ULG evaluate 'suitability for implementation',[42] although it does later explain that:[43]

> Although some of these exhibited good statistical behaviour it was difficult to interpret these models for developing road pricing policy.

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[40] Martin T., *Estimating Heavy Vehicle Road Wear Costs for Bituminous-Surfaced Arterial Roads*, Journal of Transportation Engineering, March/April 2002, p 103.

[41] Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011, p.45.

[42] ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005, p.16.

[43] ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005, Appendix C.

Since ULG did not present the statistical results of the non-linear models it discarded, it is difficult to evaluate the basis on which ULG considered the relative statistical merits of alternative model specifications, or the basis on which it considered the extent to which they could be interpreted for road pricing purposes.

It appears the linear models in particular were rejected on the basis of their relatively low explanatory power, eg, the highest 'R-squared' across the linear models was 0.06.[44] Although we note that the ESA, PCU and AGM independent variables in the linear models were statistically significant.[45]

The model for routine maintenance recommended by ULG was:

$$Ln(RM\$) \approx \gamma Ln(GVM) + \alpha Ln(PCU)$$

The statistical results of this model specification are presented in Table 7 below.

Table 7   Model of routine maintenance

	Parametric coefficients	Standard error	t stat	P-value	Lower 95 per cent	Upper 95 per cent
Model for routine maintenance: $Ln(RM\$) \approx \gamma Ln(GVM) + \alpha Ln(PCU)$ R²: 0.982754 Observations: 589						
Intercept	-	-	-	-	-	-
γ	0.451011	0.103919	4.340022	0.00002	0.246913	0.65511
α	0.481466	0.112199	4.291171	0.00002	0.261105	0.701827

On the basis of these results, ULG determines that the relative contribution of AGM and PCU to routine maintenance is 52 per cent and 48 per cent, respectively. It is relevant to note that the omission of a constant coefficient in the recommended model implies that routine maintenance costs are entirely attributable costs.

For the reasons set out above, we interpret the results of the ULG report with a degree of caution. In addition to being unable to independently assess the rationale for a number of methodological decisions by ULG, questions are raised by:

- a lack of statistical evidence to substantiate the appropriateness of a data set comprising 60 per cent data from Victoria;

- the selection of independent variables (allocators) on the basis of the corresponding model's explanatory power, rather than the theoretical basis for the use of those variables and their statistical significance;

- the omission of a constant coefficient in all non-linear models considered, notwithstanding the theoretical basis for the inclusion of a constant coefficient;

- the perceived merit of the relatively higher explanatory power associated with model specifications that lack a constant coefficient; and

- the implication that all routine maintenance costs are attributable costs.

Owing to the theoretical foundation for some degree of road deterioration in the absence of road use, the NTC recommended that 24 per cent of periodic maintenance costs are classified as non-attributable costs,

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[44] ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005, p.16 and Appendix D.

[45] ULG, *Road Track Cost Recovery Database Review: Information Paper*, May 2005, Appendix D.

and allocated on the basis of VKT. The allocation of the remaining attributable costs was informed by the findings of the ULG report set out above.[46]

By way of context, we briefly comment on the approaches to allocating maintenance costs applied overseas in Box 5 below, although we note that most countries do not have separate periodic and routine maintenance expenditure categories.

Box 5   Maintenance cost allocation methodologies applied overseas

In the United States, some states use the National Pavement Cost Model (NAPCOM) to determine pavement deterioration, and so costs, attributable to particular vehicle types. NAPCOM was developed in response to the weak empirical relationship between pavement wear and the ESAL road use variable,[47] and incorporates eleven different pavement distress models.[48]

However, some states adopt a more simplistic approach to allocating maintenance costs, ie:[49]

> In the absence of a more comprehensive pavement model, some states have historically used more straightforward measures that are designed to vary in proportion to the damage caused on the roadway system by vehicle classes. These allocators include:
>
> - axle miles of travel (AMT) – VMT multiplied by the number of axles. Because trucks generally have more axles than cars, sports utility vehicles, or pick-ups, their share of the total AMT on any given highway system will be about double their share of VMT on that system;
>
> - axle weight or axle load – the gross load carried by an axle;
>
> - ton-miles – VMT multiplied by tonnage; and
>
> - equivalent single-axle loads and equivalent single axle load miles – the pavement stress imposed by a single axle with an 18,000lb axle load is termed one ESAL. ESAL-miles are equivalent single-axle loads times miles travelled.
>
> These allocators have been used extensively at the state level to assign specific wear related costs to the highway-user classes.

Our review indicated that European countries generally allocate maintenance costs on the basis of ESALs, although a variety of approaches and allocators are applied. By way of example, the United Kingdom appears to have in the past adopted 16 different maintenance categories allocated by reference to ESAL, AGM and VKT depending on the underlying cost driver.[50]

However, on this subject a review of cost allocation approaches applied in Europe noted the difficulty associated with comparing approaches across jurisdictions, ie: [51]

> Naturally, different definitions of maintenance, rehabilitation and reconstruction, different classification criteria for cost components (type of road work, time horizon, purpose of expenditures) and a varying degree of differentiating these categories further hamper a comparison and generalisation…

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[46] NTC, *Third Heavy Vehicle Pricing Determination – Technical Report*, 2005, p.31.

[47] National Cooperate Highway Research Program, *State Highway Cost Allocation Studies – a Synthesis of Highway Practice*, 2008, p.5.

[48] Federal Highway Administration, *Cost Allocation Study Final Report*, 2000, Chapter five, p.10-11.

[49] National Cooperate Highway Research Program, *State Highway Cost Allocation Studies – a Synthesis of Highway Practice*, 2008, p.13.

[50] Cost Allocation of Transport Infrastructure Cost (CATRIN) – European Commission, *Cost allocation Practices in the European Transport Sector*, March 2008, p.23-27.

[51] CATRIN, *Cost allocation Practices in the European Transport Sector*, March 2008, pp. 29-30.

3.5.3   Conclusion

By assuming some proportion of routine maintenance costs are non-attributable and maintaining the relatively equal roles of the AGM and PCU allocator in allocating attributable costs, the NTC could be said to have adopted a pragmatic approach to addressing potential shortcomings in the ULG report.

In the absence of robust empirical support to the contrary, there exists no strong basis for departing from the existing allocation methodology for routine maintenance at this time.

Nevertheless, given potential shortcomings in the underlying empirical research, there may exist some opportunity in the future to apply an approach to allocating routine maintenance costs guided by theoretical considerations, rather than the results of empirical studies. We discuss this prospect in more detail in section 3.6.3.

3.6   Road pavement and shoulder maintenance – Periodic maintenance (Category B2)

3.6.1   What costs are in this category?

The 'periodic maintenance' expenditure category is a subset of 'road pavement and shoulder maintenance' and comprises costs associated with maintaining sealed roadways and shoulders that are incurred at a frequency of more than one year. Examples of periodic maintenance expenditure include:

- maintenance reseals / enrichments;

- thin asphalt overlays (less than 25 mm);

- asphalt retreatment and regulation; and

- administrative and supervision costs associated with the above types of works.

3.6.2   Cost allocation and supporting empirical evidence

The approach to allocating 'periodic maintenance' costs in the PAYGO matrix is presented in Table 8 below.

Table 8   Allocation of periodic surface maintenance expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Periodic Maintenance		10	-	60	-	30

The approach to allocating periodic maintenance in the PAYGO matrix was informed by the results of the same ULG report that informed the allocation of routine maintenance, as discussed in the previous section. Consequently, the underlying empirical analysis suffers from the same shortcomings as are explained in section 3.5.2, ie:

- there are limitations with the data used;

- the rationale for selecting alternative model specifications is unclear;

- the statistical results for only some of the alternative models are presented;

- the non-linear statistical models evaluated included no constant coefficient (intercept); and

- some elements of the recommended model and conclusions lack a clear foundation in engineering theory.

ULG determined that the appropriate model to be used in the allocation of periodic maintenance was:

$$Ln(PM\$) \approx \gamma Ln(GVM) + \alpha Ln(PCU)$$

The statistical results of this model are presented in Table 9 below.

Table 9   Regression results

	Parametric coefficients	Standard error	t stat	P-value	Lower 95 per cent	Upper 95 per cent
**Recommended model for periodic maintenance: $Ln(PM\$) \approx \gamma Ln(GVM) + \alpha Ln(PCU)$** R^2: 0.98702 Observations: 1067						
Intercept	-	-	-	-	-	-
γ	1.115357	0.099828	11.17278	0.00000	0.919475	1.311239
α	(0.19038)	0.107882	(1.76469)	0.077902	(0.40206)	0.021307

On the basis of these results, ULG determines that the relative contribution of AGM and PCU to routine maintenance is 87 per cent and 13 per cent respectively. Implicit in ULG's recommended model is a conclusion that periodic maintenance costs are attributable costs in their entirety. As for routine maintenance, we interpret ULG's findings with a degree of caution.

Owing to the theoretical foundation for some degree of road deterioration in the absence of road use, the NTC recommended that 30 per cent of periodic maintenance costs are classified as common costs. The allocation of the remaining attributable costs was informed by the findings of the ULG report set out above.[52]

Our review identified two more recent research reports that evaluate the relationship between road use and periodic maintenance, which we discuss below.

Austroads 2011 report

In 2011, Austroads published an ARRB report that, among other things, evaluated the relationship between road use and road expenditure (the Austroads 2011 report).[53]

Initial classification analyses indicated that different maintenance strategies were in use across jurisdictions, and so a single multivariate model was not suitable to describe all of these strategies. Therefore, a purpose designed inference tool – referred to as the Minimum Message Length National Transport Commission (MML NTC) algorithm[54] – was applied to identify significant families within the data and the significant variables within each family.[55] The Austroads 2011 report explains that MML NTC is:[56]

> …a highly advanced inference analysis which simultaneously looks at grouping the dataset into families, or clusters of data, builds linear regression models for each group by identifying significant

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[52] NTC, *Third Heavy Vehicle Pricing Determination – Technical Report*, 2005, p.31.

[53] Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011.

[54] MML employs an algorithm designed to co-analyse three independent problems. There are three separate components of the MML technique, which involve: (1) dividing data into independent groups or families; (2) within each family identified the significant variables and their associated parameters (ie regression analysis); and (3) within each family identifying outliers which are removed from the parameter estimator problem. See Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011, p.49.

[55] Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011, p.20.

[56] Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011, p.21.

> variables, and, identifies outliers within each family that may bias the estimated parameters of a linear regression analysis.

Of the research we identified, this analysis constitutes the most sophisticated effort to overcome the pervasive data limitations and to distil the complex relationships governing the incurrence of periodic maintenance costs.

Nevertheless, a number of problems appear to have arisen with the data on the Auslink roads segments relied upon by ARRB, and which necessitated an extensive cleaning, standardisation and filtering process.

By way of example, the cleaning and filtering process applied in the ARRB report eliminated approximately 60 per cent of the total raw data provided for Queensland (QLD), New South Wales (NSW), Victoria (VIC) and South Australia (SA), whereas data related to Western Australia (WA), Tasmania (TAS) and the Northern Territory (NT) were not analysed due to incompleteness.

On a similar note, the periodic maintenance expenditure data provided was often aggregated by project and corresponded to very long lengths of road, which required standardisation to dollar per lane per kilometre units. The periodic maintenance data for NSW in particular related to very long segments of road, which contributed to NSW having much lower periodic maintenance values in $/lane-km units, as compared with that of other states. It was concluded that the NSW periodic maintenance values were considered unreliable.[57]

The Austroads 2011 report undertook regression analyses under unconstrained and constrained pavement conditions, where the latter involved the removal of pavement conditions considered to be outliers.[58] The results of this analysis are presented in Table 10 below. It is also relevant to note that ARRB did not consider a PCU independent variable owing to the lack of theoretical basis for a relationship between PCU and periodic maintenance.

Table 10   Statistically significant variables identified by MML NTC tool

	Unconstrained pavement conditions	Constrained pavement conditions
South Australia	• ESA • ESA • None identified • Annual average daily traffic (AADT) • None identified (5 Families)	• Millions of equivalent standard axles (MESA) • None identified • Average annual daily traffic • AGM (Four families with logarithmic dependant variable) MESA (one family without logarithmic dependant variable)
Victoria	Roughness, rutting and AADT	None identified
New South Wales	None identified*	• MESA* • None identified* (Two families)
Queensland	MESA	MESA

* Based on maintenance data considered unreliable

It is relevant to note that the Austroads 2011 report identified ESA as the most significant independent variable for explaining variations in periodic maintenance costs in South Australia. This finding was consistent with that for Queensland. On the other hand, it is noted that the relationships in Victoria and NSW are more complex.

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[57] Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011, p.22.

[58] Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011, p.22.

The Austroads report concluded that:[59]

> …for the Stage 1 Auslink road segments, it was clearly demonstrated across most SRA datasets that the road use wear variable, MESA, was the most appropriate explanatory variable for predicting $B2 based on road wear under 'typical' average pavement conditions. strongly support the use of ESAs/lane/year, or an ESA-km, as the road use allocator of maintenance costs.

Further, the Austroads 2011 report considered this conclusion to be confirmed by further analysis of non-Auslink road data relating to SA and QLD, but that largely relied on data from Queensland.[60]

On the basis of the estimated relationship between ESA and periodic maintenance expenditure for SA, QLD and NSW, and an Australian wide network average ESA/lane/year road use estimate, the Austroads 2011 report estimated that approximately 51 to 64 per cent of periodic maintenance expenditure are attributable costs.

The Austroads 2012 report

In 2012, Austroads published a report by AECOM (Austroads 2012) directed at determining the most appropriate road network classification for heavy vehicle cost allocation and pricing.

The Austroads 2012 report evaluated the relationship between periodic maintenance and heavy vehicle road use. The values for the PCU, ESA and AGM variables used in this report were all derived from AADT values and so, due to the consequent multicollinearity,[61] each independent variable was evaluated in a separate regression. As to the selection of the most appropriate allocator, the Austroads 2012 report highlights that: [62]

> Pavement design is based on forecast ESAs so it is logical that rehabilitation expenditure would be most strongly related to ESA. However, for periodic maintenance it is not obvious which parameter is likely to provide the strongest relationship with surface wear as it only involves resurfacing of pavements. Compared to AGM and ESA, AADT and PCU are likely to be weaker predictors of pavement deterioration and hence pavement maintenance expenditure.
>
> Consequently, it was considered that either AGM or ESA should be adopted as the road use parameter to test different road network classifications for periodic maintenance expenditure. In order to choose between AGM and ESA, the relative fit (measured by the r-square) of the regression equations was considered for both parameters. For all States the fit of the regression equation was considerably higher when using AGM. As a result, AGM was used to test road network classifications for periodic maintenance.

On the basis of an AGM allocation key, the Austroads 2012 report evaluates the proportion of periodic maintenance expenditure that is attributable, and finds that:

> Based on the AGM results, the weighted average attributable share for the four states is 37% which is calculated by weighting the attributable percentage for each state by the total annual category B2 expenditure by each state. This is considerably less than the attributable percentage of 70% (60% to AGM and 10% to PCU) in the current NTC cost allocation template. However, the data limitations discussed in section 2.6 should be noted when interpreting the results.

As noted above, the analysis undertaken in this report faced significant data limitations including:

- expenditure data that does not cover the full pavement life cycle;

- high collinearity between road use parameters; and

- limited data available on the age of pavements or the timing of previous periodic maintenance activities.

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[59] Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011, p.26.

[60] Austroads, *Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis*, April 2011, p.27.

[61] The existence of correlations among the independent variables in a regression model.

[62] Austroads, *Improving Cost Allocation by Road Type*, March 2012, p 20.

A comprehensive discussion of data limitations is included in section 2.7 of the Austroads 2012 report.

3.6.3   Conclusion

It is clear that the available research presents a number of, often opposing, views on the relationship between road use and periodic maintenance costs, each with its respective merits and shortcomings. We summarise these findings in Table 11 below.

Table 11	Summary of relevant findings	
	Total Share of Attributable Costs	**Recommended Allocation Keys**
PAYGO Matrix	**70 per cent**	**AGM (60 per cent)** **PCU (10 per cent)**
The ULG report	100 per cent	AGM (87 per cent) PCU (13 per cent)
The Austroads 2011 report	51 per cent to 64 per cent	ESA
The Austroads 2012 report	37 per cent	AGM

Of principal contention in the research is the share of attributable cost and the appropriate allocator, or allocators, to use in allocating attributable periodic maintenance costs.

The theoretical foundation for some degree of road deterioration in the absence of road use suggests that it is reasonable to treat a proportion of periodic maintenance as non-attributable costs. Given the broad range in the share of attributable costs recommended by each of these reports, it appears appropriate to retain the current 70 per cent (total) share of attributable costs, noting that it reflects an adjustment[63] to the approach recommended by ULG and that it is reasonably close to the upper bound recommended by the Austroads 2011 report.

The other point of contention is what the appropriate allocator should be. There exists a sound theoretical foundation for the use of weight-related variables such as AGM or ESA, as noted in both the Austroads 2011 and 2012 reports. On the other hand, the use of a PCU allocation key, as recommended by ULG and currently used to allocate 10 per cent of periodic maintenance costs, lacks such a theoretical foundation.

Box 6   Potential implications of alternative allocation approaches

In this box we examine the potential revenue implications of adopting the findings of the different research reports. The average annual expenditure on periodic surface maintenance for sealed roads was $839 million over 2005/06 to 2014/15, of which heavy vehicles would be allocated:

- $446 million, or 53 per cent, under the current PAYGO allocation matrix;

- $620 million, or 74 per cent, using the approach recommended in the ULG report;

- $430 to $524 million, or around 51 to 63 per cent, using the approach recommend in the Austroads 2011 report; and

- $291 million, or 35 per cent, using the approach recommend in the Austroads 2012 report.

The current amount allocated to heavy vehicles in the PAYGO matrix falls within the bounds of potential allocations suggested by the empirical research, which range from $291 million to $620 million. Of

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[63] NTC, *Third Heavy Vehicle Pricing Determination – Technical Report*, 2005, p.31.

> particular relevance, the current allocation broadly aligns with that which would result from application of the approach recommended by the Austroads 2011 report.

Given the conflicting views in the empirical evidence, each with relative merits and shortcomings, selection of the appropriate allocator for attributable periodic maintenance costs necessarily requires the exercise of judgement. In our opinion, the exercise of such discretion in this context should be guided by generally accepted in-principle considerations.

However, in the context of conflicting evidence it is important that a balance is struck between:

- the potential benefit of any changes over the period in which they are in effect; and
- the potential for changes to the heavy vehicle allocation methodology to cause winners and losers and, in so doing, contribute to uncertainty in heavy vehicle road pricing.

Against this backdrop, in our opinion it would be reasonable for the NTC to either:

1. maintain the existing allocation approach in the PAYGO matrix; or
2. allocate attributable periodic maintenance costs on the basis of a weight-related road use variable, or variables, eg, ESA.

That latter could be said to reflect the view presented in Austroads 2012 that:

> One possible approach is that, taking into account the cost allocation methodologies employed in other countries and the difficulties and limitations of the analysis presented in this report, a theoretical approach to classifying the road network based on engineering principles may be a more practical way to determine appropriate cost functions for different road network classifications.

In other words, it has the potential to be a pragmatic solution to a difficult and complex problem on which it appears unlikely for a consensus to be reached in the near term. That said, the lack of consensus across the empirical evidence may cast doubt on any perceived benefit changes to the PAYGO matrix, which could support the retention of the status quo.

Notwithstanding the reasonableness of adopting one or other of the abovementioned options, in our opinion there exists no strong evidence for departing from the existing approach to allocating 'road pavement and shoulder maintenance' costs at this time.

There is merit in not changing the current allocation towards weight based measures at this time so as to avoid bill impacts to heavy vehicle users. However, consideration should be given to transitioning to weight-based allocation parameters as part of a transition to a FLCB.

Further empirical studies may be unlikely to provide meaningful guidance

It is instructive at this point to note that the complex relationships driving road costs significantly complicate the identification of explanatory variables that reflect all the factors driving variability in road costs. This, combined with the present limitations of road use and cost data, suggests that further empirical studies may be unlikely to provide meaningful guidance on the appropriate allocation of road costs to road users.

This view is reflected in the 2015 highway cost allocation study undertaken for the Oregon Department of Administrative Services – the state of Oregon conducted the first HCAS in 1937 and has been recognised as

the developer of most of the road cost allocation principles now widely accepted in the United States – which highlights that the relationship between road use and road costs: [64]

> …may be measurable given sufficient data, but the necessary data usually do not exist, so one must calculate the expected relationship based on engineering and economic theory.

3.7 Bridge maintenance and rehabilitation (Category C)

3.7.1 What costs are in this category?

The 'bridge maintenance and rehabilitation' expenditure category comprises costs associated with the maintenance and rehabilitation of bridges and culverts. This includes expenditure relating to:

- bridge maintenance, including painting;
- bridge repairs, including replacement of bridge railings and decking; and
- administrative and supervision costs associated with relevant activities.

3.7.2 Cost allocation and supporting empirical evidence

The approach to allocating 'bridge maintenance and rehabilitation' costs in the PAYGO matrix is presented in Table 12 below.

Table 12　　Allocation of bridge maintenance and rehabilitation expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Bridge Maintenance and rehabilitation	-	-	-	33	-	67

We were not able to identify robust independent empirical evidence in support of this allocation process. Rather, the current approach to allocating 'bridge maintenance and rehabilitation' costs is a product of the former, disaggregated approach to allocating these costs.

At the time of the 1989 VicRoads Report, this cost category was disaggregated into 'load/impact related' expenditure and 'other' expenditure, ie, non-load/impact related expenditure. VicRoads explained that there was:[65]

> ...general agreement within the ATAC working group that load or impact related bridge maintenance and rehabilitation expenditure should be allocated by GVM.km. [Gross vehicle mass kilometres][66]

and

> …general agreement that non-load/impact related bridge expenditure should be allocated wholly as non-separable expenditure

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[64] ECONorthwest, *Highway Cost Allocation Study 2013-2015 Biennium*, Final Report prepared for Oregon Department of Administrative Services, Office of Economic Analysis, p.3-4.

[65] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, section on 'Attribution of expenditure for different work types' item 3.

[66] We understand gross vehicle mass kilometres to be equivalent to AGM.

For the reasons discussed in section 3.3, the VicRoads report determined that the latter, ie, non-attributable costs, should be allocated on the basis of VKT.

These former expenditure categories were consolidated into a single 'bridge maintenance and rehabilitation' expenditure category in 1993. We understand from the NTC that the approach to allocating the consolidated expenditure category was determined by reference to the relative quantum of expenditure comprising each of the former categories and their corresponding allocator, ie, AGM and VKT.[67]

More specifically, it appears that at the time of the consolidation, the consolidated expenditure category comprised:

- 33 per cent 'load/impact related' expenditure – previously allocated entirely by reference to AGM; and

- 67 per cent other expenditure – previously allocated entirely by reference to VKT.

The same 33 per cent and 67 per cent weightings are currently applied, respectively, to the AGM and VKT allocators for 'bridge maintenance and rehabilitation' expenditure.

Our review also identified a subsequent paper prepared by ARRB and published by Austroads on the subject of bridge cost allocation (the Austroads 2010 report). We discuss this report in more detail in section 3.11.2 on 'bridge improvement' costs but, for completeness, it is relevant to note at this point that it proposes:[68]

> … to replace the current cost allocation rules with one rule that effectively allocates the total maintenance costs for all bridges to all vehicles considered as a group. The total maintenance costs can then be apportioned to individual vehicle types in the vehicle group, including passenger cars, and heavy vehicles based on their share of the fatigue damage caused to bridges. These costs can be apportioned to vehicles, including passenger cars and heavy vehicles, by using the proposed fatigue analysis method.

The Austroads 2010 report details a general alternate methodology for allocating bridge costs, rather than specific recommendations on the allocation parameters to be applied in the PAYGO matrix. Therefore, the proposal in the Austroads 2010 report is not sufficiently developed or tested, at this time, so as to be considered for immediate implementation in the PAYGO matrix. In our opinion, further research and analysis would be required before the merits of the fatigue analysis method can be properly evaluated against the existing methodology for allocating bridge costs.

By way of context, in Box 7 below we briefly describe approaches to allocating bridge maintenance and/or rehabilitation costs applied overseas.

Box 7   Bridge maintenance and rehabilitation cost allocation methodologies applied overseas

Bridge-related costs in the United States are generally disaggregated into three expenditure categories, ie, new bridge, bridge replacement and bridge rehabilitation costs. A review of highway cost allocation studies in the United States explains that:[69]

> When allocating bridge rehabilitation costs, load- and non-load-shares are determined.

> …The non-load share of bridge rehabilitation costs is largely allocated to all vehicles on the basis of VMT [vehicle miles travelled].

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[67] Email from Chris Eggar of 25 January 2017.

[68] Austroads, *Investigate cost allocation for bridges in relation to heavy vehicles: Austroads project TS 1399*, February 2010, p.11.

[69] National Cooperate Highway Research Program, *State Highway Cost Allocation Studies – a Synthesis of Highway Practice*, 2008, p.14.

> …The load share of rehabilitation costs is often allocated to heavy-truck classes based on some measure that accounts for the additional stress placed on bridges by heavy vehicles, such as ESAL-miles or heavy-truck VMT.
>
> Our review indicated that the allocation methodologies adopted by European countries generally do not distinguish a bridge maintenance and/or rehabilitation cost category.[70]

3.7.3   Conclusion

Our review identified no relevant empirical evidence addressing the relative shares of attributable and non-attributable costs in bridge maintenance and rehabilitation costs in Australia. Rather, implicit in the current approach is an assumption that the relative share of load/other bridge maintenance and rehabilitation costs today is consistent with that in 1993. We suggest the NTC consider undertaking analyses in the future to assess whether this assumption holds.

As to the allocators used to allocate bridge maintenance and rehabilitation expenditure:

- the AGM allocator for the load-related share of costs has a sound basis in engineering theory; and

- the VKT allocator for the non-load related share of costs reflects equitable principles and the extent of road use.

Against this backdrop, and in the absence of robust empirical evidence supporting an alternate approach, we consider the existing allocation methodology for bridge maintenance and rehabilitation costs to be appropriate.

It is also relevant to note that this expenditure category comprises only 3 per cent of the total road infrastructure cost base.

3.8 Road rehabilitation (Category D)

3.8.1   What costs are in this category?

Road rehabilitation expenditure relates to reinstating failed pavements to existing standards to improve ride quality and/or correct pavement shape, including the provision of a wearing course. Examples of road rehabilitation expenditure include:

- major patching in excess of 500 square metres;

- re-sheeting of sealed roads;

- reconstruction of failed pavements;

- asphalt overlays over 25 mm; and

- administrative and supervision costs associated with above types of works.

3.8.2   Cost allocation and supporting empirical evidence

The approach to allocating 'road rehabilitation' costs in the PAYGO matrix is presented in Table 13 on the following page.

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[70] Cost Allocation of Transport Infrastructure Cost – European Commission, *Cost allocation Practices in the European Transport Sector*, March 2008, p.23-27.

Table 13   Allocation of road rehabilitation expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Road Rehabilitation	-	-	45	-	-	55

This allocation is based on a 1994 report by ARRB (the 1994 ARRB report) that, among other things, estimated the attributable proportion of pavement expenditure, of which pavement rehabilitation is a component. It also identified the appropriate allocation key to be used for those attributable costs.

The 1994 ARRB report selected an ESA/lane allocation key because conventional pavements are designed on the basis of ESA/lane, and because of its greater statistical significance for evaluating pavement expenditure, as compared with other potential design variables, eg, AGM and PCU.[71]

The ARRB report determined that 45 per cent of pavement expenditure was attributable based on a statistical analysis of the relationship between pavement expenditure and ESA/lane. To this end, ARRB relied on 47 new road construction samples from NSW, VIC, QLD and WA.

The proportion of attributable pavement expenditure was estimated by reference to the ratio of variable to total pavement expenditure, where pavement expenditure was expressed as a polynomial function of ESA/lane.[72] ARRB found that:[73]

> Based on the statistical relationships derived for the samples, each state has its own distinctive pavement expenditure relationships which is probably due to particular resource and cost structures within each state.

This finding implies that the proportion of attributable pavement costs differs by state. On the basis of the combined data set, ARRB estimated that 46 per cent of pavement expenditure on Australia's arterial roads is attributable expenditure, using ESA/lane as the design variable.

Further, this estimate was within the, albeit quite broad, 95 per cent confidence interval of an alternative approach implemented by ARRB. This alternative approach (referred to as a two-step incremental cost method) involved estimating the design and costing of six road projects with and without heavy vehicles and then undertaking a statistical analysis of the relationship between attributable costs and ESA/lane.[74]

ARRB highlights that the different sample sizes underpinning the two alternative approaches it applied may contribute to the slightly different level of attributable pavement expenditure estimated.[75] The results of these two analyses are presented in Table 14 on the following page.

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[71] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.39 and 42.

[72] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.41-46.

[73] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.50.

[74] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.39-41.

[75] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.51.

Table 14   Summary of attributable capital expenditure for pavements[76]

Approach	Allocation variable	Estimated proportion of attributable expenditure	95 per cent confidence interval	R²	Number of observations
Statistical relationship between pavement expenditure and design variable	ESA-lane	46 per cent	40 per cent to 52 per cent	0.45	47
Two step incremental cost method	ESA-lane	35 per cent	18 per cent to 51 per cent	0.82	6

The current cost allocation reflects ARRB's findings in that approximately 45 per cent of road rehabilitation costs are treated as attributable costs and allocated across vehicles on the basis of an ESA allocator.

Our review identified no robust empirical evidence supporting an alternative approach to allocating road rehabilitation expenditure.

3.8.3   Conclusion

The approach to allocating road rehabilitation costs in the PAYGO matrix is based on the empirical findings of the 1994 ARRB report. In the absence of robust empirical evidence in support of an alternative approach, there exists no strong basis for departing from the current approach to allocating these costs at this time.

3.9   Low-cost safety and traffic improvements (Category E)

3.9.1   What costs are in this category?

The 'low cost safety/traffic improvement' expenditure category comprises costs associated with minor improvements undertaken primarily to improve road safety or traffic flow. Examples of such activities include:

- the installation or relocation of road furniture;
- the provision of new painted road markings;
- the installation of new traffic signals, including provision of new traffic signal linking systems;
- the installation of new pedestrian crossings;
- the installation of new raised pavement markers;
- the installation of rail crossing boom barriers;
- the installation of new street lighting;
- junction improvements;
- blackspot safety improvements; and
- administrative and supervision costs associated with above types of works.

3.9.2   Cost allocation and supporting empirical evidence

The approach to allocating 'low cost safety/traffic improvement' costs in the PAYGO matrix is presented in Table 15 on the following page.

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[76] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p 50.

Table 15   Allocation low cost safety/traffic improvement expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Low cost safety/traffic improvement	80	20	-	-	-	-

This approach is based on recommendations in the 1989 VicRoads report, which explained that:[77]

> As this work is arising as a result of various use considerations, it is suggested that 80% of this expenditure be distributed by Veh.km [vehicle kilometres] and 20% by PCU.km to account for capacity considerations giving rise to this work.

Consistent with this logic, the VicRoads report highlighted that:[78]

> The Passenger Car Unit is a measure of road space requirement and is used in relation to road capacity and congestion considerations.
>
> And that the vehicle km parameter… provides a reasonably equitable basis, and includes some measure of consumption.

No empirical support was presented in support of the existing allocation methodology for 'low cost safety/traffic improvements'. Similarly, our review identified no robust empirical evidence either for or against the existing allocation methodology.

By way of context, in Box 8 below we briefly comment on methodologies for allocating similar costs applied in the United States.

Box 8   Low cost safety & traffic improvement cost allocation methodologies applied in the United States

The FHWA in the United States explains that:[79]

> Traffic operations/TSM [Transportation system management] projects are undertaken primarily to improve highway level of service, reduce congestion, and otherwise improve highway system efficiency. Therefore, construction costs are allocated based on the basis of PCE-weighted VMT to reflect the contribution of different vehicle classes to congestion and diminished level of service.
>
> Construction costs for safety improvements also are allocated using PCE-weighted VMT. While the relationship between PCEs, level of service, and safety improvements is not as clear as for TSM improvements, large trucks contribute more need to the need for certain safety improvements than do automobiles and light trucks, and some additional safety improvements may be incurred to accommodate the operational characteristics of heavy trucks.

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[77] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, Appendix A.

[78] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, p.3 and Appendix A.

[79] Federal Highway Administration, *Cost Allocation Study Final Report*, 2000, Chapter five, p.19.

3.9.3   Conclusion

Our review identified no robust empirical evidence either for or against the approach to allocating low-cost safety and traffic improvement costs in the PAYGO matrix. However, the existing allocators reflect equitable principles and different dimensions of road use, ie, measures of distance travelled and road capacity.

Against this backdrop, we identified no strong support for departing from the existing approach to allocating low-cost safety and traffic improvement costs at this time.

3.10 Pavement improvements (Category F1)

3.10.1   What costs are in this category?

The 'pavement improvements' expenditure category is a subset of 'asset extension/improvements' and comprises costs associated with improving the design standard of an existing roadway or the provision of new roadways. This includes expenditure in relation to:

• pavement widening;

• road realignment;

• new auxiliary lanes;

• road duplication;

• sealing unsealed roads;

• new routes; and

• administrative and supervisory costs associated with providing pavements.

3.10.2   Cost allocation and supporting empirical evidence

The approach to allocating 'pavement improvement' costs in the PAYGO matrix is presented in Table 16 below.

Table 16   Allocation of pavement improvement expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Pavement improvements	-	-	45	-	-	55

The approach to allocating 'pavement improvement' costs is based on the analysis of pavement expenditure in the 1994 ARRB report, as discussed in section 3.8. Rather than repeating that discussion, we briefly summarise the key findings below.

ARRB determined that 45 per cent of pavement expenditure was attributable based on a statistical analysis of the relationship between pavement expenditure and the relevant design variable, which it identified as ESA-lane. An ESA allocator was identified as being appropriate since it is the basis on which conventional pavements were designed and because of superior statistical significance, as compared with other allocators.

Our review identified no robust empirical evidence in support of an alternative approach to allocating pavement improvement expenditure.

3.10.3 Conclusions

The approach to allocating road rehabilitation costs in the PAYGO matrix is based on the empirical findings of the 1994 ARRB report. In the absence of new evidence to support an alternative approach, there exists no strong basis for departing from the current approach to allocating these costs at this time.

3.11 Bridge improvements (Category F2)

3.11.1 What costs are in this category?

The 'bridge improvement' expenditure category is a subset of 'asset extension/improvements' and comprises costs associated with new bridges and culverts and with improving existing bridges and culverts to a higher design standard. This includes expenditure in relation to:

- constructing new and replacement bridges;
- bridge duplications;
- bridge widenings; and
- administrative and supervision costs associated with providing new or improved bridges.

3.11.2 Cost allocation and supporting empirical evidence

The approach to allocating 'bridge improvement' costs in the PAYGO matrix is presented in Table 17 below.

Table 17   Allocation of bridge improvement expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Bridge improvement	-	15	-	-	-	85

The approach to allocating 'bridge improvement' costs is based on the findings of the 1994 ARRB report.

As for pavement expenditure, the 1994 ARRB report estimated attributable bridge expenditure by means of two alternative approaches, ie, an incremental cost approach and a statistical analysis of the relationship between bridge cost and design variables.

For the purpose of implementing the two-step incremental cost approach, ARRB acquired five bridge construction expenditure samples from NSW and Victoria and estimated the re-designed cost of each bridge if it were for light vehicles only. A non-linear cost function was then developed to estimate the relationship between the additional bridge cost arising from heavy vehicle use and the relevant design parameter. ARRB selected PCU as the relevant design parameter because: [80]

> …Australian bridge design practice (Austroads 1992b) varies live loading with bridge width (a PCU effect) rather than with heavy vehicle class (a GVM effect).[81]
>
> …the design variable, CPCU/lane/day [cumulative passenger car units/lane/year], is statistically significant because in Australian bridge design practice (Austroads 1992b) the total live load applied to the bridge deck depends on the number of standard width lanes it occupies from kerb

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[80] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.32-33.

[81] We understand gross vehicle mass kilometres (GVM) to be equivalent to AGM.

to kerb. As a consequence, the live load/lane (LL/lane) becomes a function of bridge deck width which is PCU effect rather than the conventional GVM [gross vehicle mass kilometres][82] measure.

The results of this approach are presented in Table 18, which follows the below discussion.

For the purpose of implementing the statistical approach, ARRB acquired 35 bridge construction expenditure samples from VIC, NSW, QLD and WA, of which six were in urban locations.

ARRB estimated the proportion of bridge expenditure attributable to heavy vehicles by reference to the ratio of variable to total bridge expenditure, where bridge expenditure was expressed as a non-linear function of heavy vehicle PCU/lane. ARRB found that:

…the NSW, WA and QLD bridge expenditure relationships are quite distinct from the Victorian bridge expenditure relationship.

This implies that the share of attributable costs is different in Victoria, as compared with NSW, WA and QLD.

ARRB then estimated the relationship between bridge expenditure and heavy vehicle PCU/lane on a combined basis, where the samples from each state were combined on the basis of their respective shares of Australian heavy vehicle road use. ARRB then estimated attributable bridge expenditure for Australia's arterial road bridges using this estimated relationship and a representative design value of PCU/lane/day.

The results of these analyses are presented below.

Table 18   Summary of attributable capital expenditure for bridges[83]

Approach	Attribution variable	Estimated attributable expenditure	Lower 95 per cent confidence interval	Upper 95 per cent confidence interval	R^2	Number of observations
Two step incremental cost method	PCU	16 per cent	13 per cent	19 per cent	0.9	5
Statistical relationship between pavement expenditure and design variable	PCU	11 per cent	6 per cent	16 per cent	0.15	35

Although ARRB does not present detailed statistical results for the underlying regressions, it notes that:

Although the supporting data is diverse and difficulty was experienced in developing prediction models that adequately fit the data, all the relationships used in estimating attributable expenditure are statistically significant. Consequently, the study provides a sound, objective and fully documented basis of the attribution of arterial road track expenditure in Australia.

On the basis of these results, ARRB concludes that:[84]

Bridge expenditure is estimated to be 15% (+-5%) attributable to vehicles on the basis of PCU.km for the Australia's arterial roads. The estimated 15% attributable bridge expenditure falls within the 95 per cent confidence limits of both the statistical and incremental cost estimates of attributable bridge expenditure.

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[82] We understand gross vehicle mass kilometres to be equivalent to AGM.

[83] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.50.

[84] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.52-53.

The approach to allocating bridge improvement expenditure in the PAYGO matrix was based on these findings.

Our review also identified a subsequent paper published by Austroads that considered the allocation of bridge costs (the Austroads 2010 report). This report finds that:[85]

> …the use of the Passenger Car Unit (PCU), when defined as the amount of road space occupied by a passenger car, is not considered appropriate for the attribution of bridge costs to passenger car use. A method based on the fatigue damage caused by passenger cars as proportion of damage due to other vehicles is considered more appropriate…

The Austroads 2010 report also proposes the use of gross vehicle mass allocator for allocating attributable bridge improvement costs, since it is considered to be more directly related to the carrying capacity of a vehicle.[86]

We briefly summarise the key recommendation of this report in section 3.7.2, ie, the consolidation of all bridge costs into a single expenditure category, to be allocated across vehicle classes using a fatigue analysis method.

Box 9 below presents a brief description of approaches to allocating bridge improvement costs applied overseas.

Box 9   Bridge improvement cost allocation methodologies applied overseas

In the United States, cost allocation studies are undertaken at the Federal level – by the Federal Highway Administration (FHWA) – and also at the state level. Both of the last two federal 'highway cost allocation studies' allocated new and replacement bridge construction costs using the incremental method, ie:[87]

> …costs for constructing the base facility of a new bridge are allocated to all vehicle classes in proportion to the PCE-VMT. Incremental costs to provide the additional strength needed to support heavier vehicles are assigned to vehicle classes on the basis of the additional strength required on account of their weight and axle spacings.

The FHWA explains that:[88]

> …all vehicles in any specific design increment are allocated the costs associated with that increment based on their relative VMT compared to the other vehicles in the design increment. The VMT is considered the most equitable factor upon which to allocate bridge design costs among vehicles in each increment.

Our research indicated that a number of European countries allocate bridge costs on a consolidated basis, with no consistent approach to the allocation of bridge costs. Although the information we identified appears to be somewhat dated, the allocators used to allocate total bridge costs in European countries are diverse and include AGM, VKT, PCU and ESAL.[89]

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[85] Austroads, *Investigate cost allocation for bridges in relation to heavy vehicles: Austroads project TS 1399*, February 2010, p.16.

[86] Austroads, *Investigate cost allocation for bridges in relation to heavy vehicles: Austroads project TS 1399*, February 2010, p.45.

[87] Federal Highway Administration, Cost Allocation Study Final Report, 2000, Executive summary.

[88] 88 Federal Highway Administration, Cost Allocation Study Final Report, 2000, Chapter V. Highway Cost Responsibility.

[89] Cost Allocation of Transport Infrastructure Cost (CATRIN) – European Commission, *Cost allocation Practices in the European Transport Sector*, March 2008, p.23-27.

3.11.3 Conclusion

The approach to allocating the bridge improvement costs is based on empirical findings of the 1994 ARRB report.

Our review identified a more recent Austroads 2010 report that proposes the use of a bridge fatigue analysis approach to allocating bridge costs. As explained in section 3.7.2, it appears this proposal is not sufficiently developed or tested, at this time, so as to be considered for immediate implementation in the PAYGO matrix. In our opinion, further research and analysis would be required before the merits of the fatigue analysis method can be properly evaluated against the existing methodology for allocating bridge costs.

We note that applying a bridge fatigue analysis would mean no longer using PCU as the basis for allocating attributable bridge costs. In our opinion, absent further consideration of a bridge fatigue analysis, the basis for the PCU allocator recommended by ARRB and used in the PAYGO matrix appears sound, provided that the basis on which it is founded holds in the present day, ie, that:[90]

> …Australian bridge design practice (Austroads 1992b) varies live loading with bridge width (a PCU effect) rather than with heavy vehicle class (a GVM effect).

In other words, if capacity considerations drive the design standard, and so cost, of bridges then there exists a sound basis for allocating attributable bridge costs on the basis of a road use measure that reflects road capacity.

On this basis, we identified no new evidence to support departing from the existing approach to allocating bridge improvement costs at this time.

3.12 Land acquisition, earthworks, other extensions / improvement expenditure (Category F3)

The 'land acquisition, earthworks, other extensions / improvement' expenditure category is a subset of 'asset extension/improvements' and comprises costs associated with land acquisition, earthworks, and expenditure arising from road construction or improvements. This includes expenditure in relation to:

- land acquisition costs associated with future road improvement projects;
- maintenance costs of acquired land for future road improvement projects;
- plant purchase or hire, as well as maintenance and repair costs;
- project planning and design costs, including public consultation costs;
- landscaping;
- provision of road furniture;
- construction of footbridges;
- roadside re-vegetation and/or landscaping; and
- administrative and supervision costs associated with works in this category.

This expenditure category comprises approximately 29 per cent of total road costs.

3.12.1 Cost allocation and supporting empirical evidence

The approach to allocating 'land acquisition, earthworks, other extensions / improvement' costs in the PAYGO matrix is presented in Table 19 on the following page.

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[90] ARRB, *Estimating Australia's attributable road track costs: Research Report ARR 254*, November 1994, p.32-33.

Table 19   Allocation of land acquisition, earthworks, other extensions / improvement expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
land acquisition, earthworks, other extensions / improvement	-	10	-	-	-	90

The approach to allocating 'land acquisition, earthworks, other extensions / improvement' expenditure is based on the recommendations of the 1989 VicRoads report.[91] The VicRoads report does not present empirical evidence in support of this recommendation.

Implicit in the recommendation of the 1989 VicRoads report is an assumption that ten per cent of these costs are driven by road space requirements, as reflected in the PCU variable,[92] with the remaining costs being unrelated to road use, and so allocated by reference to VKT, which:[93]

> …provides a reasonable equitable basis, and includes some measure of consumption.

Our review did not identify any other analyses of the relationship between road use the costs that comprise this expenditure category.

3.12.2 Conclusion

In the absence of empirical evidence as to the drivers of these costs, the application of PCU and VKT allocation keys reflect a pragmatic approach to allocating costs, consistent with a general understanding of the applicable cost drivers and equitable principles.

Consequently, in the absence of new evidence to support an alternative allocation, there exists no strong basis for departing from the current approach to allocating 'land acquisition, earthworks, other extensions / improvement' costs at this time.

3.13 Corporate services (Category G1)

3.13.1 What costs are in this category?

The 'corporate services' expenditure category comprises non-road related costs associated with the provision of corporate services. This includes expenditure in relation to:

- corporate public/community services programs;
- corporate information and computer services;
- corporate human resource and financial management;
- cost of provision and maintenance of corporate buildings;
- strategic road planning at a state or regional level;
- accident / safety research; and
- insurance premiums relating to road and bridge infrastructure.

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[91] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, Table 2 and Table 2(a).

[92] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, p.3 and Appendix A.

[93] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, p.3.

3.13.2 Cost allocation and supporting empirical evidence

The approach to allocating 'corporate services' costs in the PAYGO matrix is presented in Table 20 below.

Table 20   Allocation of corporate services expenditure

Expenditure category	Attributable costs					Common costs
	VKT	PCU	ESA	AGM	Heavy vehicle VKT	VKT
Corporate services	-	-	-	-	-	100

This approach is based on the findings of the 1989 VicRoads report.[94] VicRoads recommends the application of a VKT allocator for non-attributable costs because it:[95]

> …provides a reasonable equitable basis, and includes some measure of consumption.

Our review did not identify any other analyses of the relationship between road use the costs that comprise this expenditure category.

3.13.3 Conclusion

Owing to the absence of a clear nexus between the incurrence of these corporate services costs and road use by heavy vehicles, it is appropriate for these costs to be classified as non-attributable in their entirety.

Further, in these circumstances an allocation based on equitable principles and a measure of consumption is appropriate. Therefore, there exists no strong basis for departing from the existing approach to allocating corporate services costs at this time.

We discuss the appropriateness of a VKT allocator for non-attributable costs section 3.3.

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[94] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, p 3.

[95] VicRoads, *Road Cost Recovery: A review of the basis for establishing road user charges in Victoria*, December 1989, p.3.

3.14 Summary of our review findings

Table 21 below provides a summary of the findings of our review.

Summary of findings on PAYGO allocators

Expenditure category	Current allocation	Basis for current allocation	HoustonKemp findings
A: Servicing and operating expenses	100% attributable to VKT	Evidence to suggest costs are related to traffic volumes but not vehicle types	No new evidence to support a change to the current allocation at this time
B1: Routine maintenance	38% attributable to PCU, 38% attributable to AGM and 24% non-attributable	Based on analysis conducted by the Urban Logistics Group (ULG) and inference that some costs are non-attributable	No new evidence to support a change to the current allocation at this time
B2: Periodic maintenance	10% attributable to PCU, 60% attributable to AGM and 30% non-attributable	Based on analysis conducted by ULG and inference that some costs are non-attributable	New analysis undertaken by Austroads is an improvement on earlier studies, but still suffers from data limitations which likely affect the reliability of results. Austroads makes an in-principle case for the use of weight-based allocation parameters. In our opinion, it is open to the NTC to either: • not change the current allocation; or • use one or more weight-based allocation parameters. In arriving at its preferred choice, the NTC should take into account the likely benefits from a change (which may be limited), compared against the implications for heavy vehicle charges. In our opinion, there is merit in not changing the current allocation towards weight based measures at this time so as to avoid bill impacts to heavy vehicle users. We therefore conclude that, notwithstanding the reasonableness of adopting one or other of the abovementioned options, in our opinion **there exists no strong evidence for departing from the existing approach to allocating 'road pavement and shoulder maintenance' costs at this time.** However, consideration should be given to transitioning to weight-based allocation parameters as part of a transition to a FLCB.
C: Bridge maintenance and rehabilitation	33% attributable to AGM and 67% non-attributable	Based on historical spending on costs that are load/impact related and other expenditure unrelated to load/impact	Austroads has suggested a new methodology for allocating bridge costs, using bridge fatigue analysis. Absent that work having been undertaken there is no new evidence to support a change to the current allocation at this time.
D: Road rehabilitation	45% attributable to ESA and 55% non-attributable	Based on analysis conducted by ARRB	No new evidence to support a change to the current allocation at this time
E: Low cost safety/traffic improvement	80% attributable to VKT and 20% PCU	Based on analysis conducted by VicRoads	No new evidence to support a change to the current allocation at this time
F1: Pavement components	45% attributable to ESA and 55% non-attributable	Based on analysis conducted by ARRB	No new evidence to support a change to the current allocation at this time
F2: Bridges	15% attributable to PCU and 85% non-attributable	Based on analysis conducted by ARRB	Austroads has suggested a new methodology for allocating bridge costs, using bridge fatigue analysis, which would not use PCU as a basis for allocating attributable costs. Absent that work having been undertaken there is no new evidence to support a change to the current allocation at this time.
F3: Land acquisition, earthworks, other extension improvement expenditure	10% attributable to PCU and 90% non-attributable	Based on analysis conducted by VicRoads	No new evidence to support a change to the current allocation at this time
G1: Corporate services	100% non-attributable	Based on analysis conducted by VicRoads	No new evidence to support a change to the current allocation at this time

4. Expenditure categories for a forward-looking cost base

A FLCB approach would align the approach to determining the heavy vehicle cost base with that applied in other infrastructure service sectors, eg, the electricity, gas and water sectors, where it is applied as a matter of best practice. It is widely accepted that the existing expenditure categories are not compatible with a FLCB.

Since the development of expenditure categories to facilitate a FLCB is being undertaken in the very early stages of considering the potential application of a FLCB, it is important to bear in mind that these expenditure categories constitute a starting-point, for exploration and consideration by stakeholders. This is particularly relevant in selecting the number of expenditure categories, where there is a trade-off between:

- the potential for more expenditure categories to improve accuracy and transparency; and
- the administrative burden placed on road agencies required to undertake this categorisation.

Against this back-drop, we propose a reasonably detailed level of categorisation as a starting point, but note that there exists a significant opportunity to refine this initial categorisation subject to further engagement with stakeholders. By way of example, the consolidation of the initially proposed separate renewal and development category groups, or the sub-categories contained therein, would significantly reduce the extent to which road agencies are required to break down road expenditure for reporting purposes.

Table 22 below presents the proposed level of sub-categories in each expenditure group for reporting purposes. Importantly, there exists the potential for the number of initially proposed categorisations to be significantly reduced, but we consider a more granular categorisation to be appropriate as a starting point for engaging stakeholders.

Table 22   Initial number of expenditure categories for reporting purposes

Expenditure Group	Sub-categories for reporting purposes
Operating	5
Maintenance	3
Renewal	15
Development (upgrade and expansion)	17
Total	**40**

A detailed list of the proposed expenditure categorisation for road agency reporting purposes is presented in section 4.3.

The NTC is investigating a number of alternative methodologies to PAYGO for determining heavy vehicle charges, to address a number of limitations with the current methodology. In this context, the NTC has asked us to propose a categorisation of road expenditure to facilitate the implementation of a FLCB approach.

To this end, we drew upon the road asset management experience of Opus, combined with our own experience in designing and implementing forward looking cost bases in other infrastructure sectors (eg, the electricity, gas and water sector), to identify cost categories that would be appropriate to facilitate implementation of a FLCB. Opus prepared a separate technical report provided to the NTC that explains technical aspects of the methodology applied and the proposed categorisation, eg, the engineering definitions of each proposed category.

In the remainder of this section we discuss why new expenditure categories would be needed to facilitate a FLCB approach, explain the approach applied to developing proposed new expenditure – as developed by and agreed between Opus and HoustonKemp – and present the proposed expenditure categories to facilitate a FLCB.

4.1   Why are new expenditure categories required?

The principal distinction between the PAYGO approach and a FLCB approach is that:

- the PAYGO approach is directed at recovering expenditure in the period in which it is incurred; whereas

- a FLCB approach recovers some costs in the year in which they occur, but recovers the remaining costs over the useful life of the corresponding assets

Of particular relevance to the task at hand, the need to recover some costs over the useful life of assets necessitates the collection of information on the useful life of assets that comprise the asset base. Consequently, a FLCB approach ideally requires particular costs to be categorised by reference to the relevant asset life.

The PAYGO expenditure categories were not designed for implementation with a FLCB approach, for example, some PAYGO expenditure categories:

- comprise costs that would be recovered over different periods under a FLCB approach, whereas the different treatment applied under a FLCB approach necessitates the separation of these costs; and

- do not distinguish between costs relating to assets with different useful lives, whereas the FLCB approach requires this information to ensure those costs are recovered over the useful life of the corresponding asset.

4.2   Our approach to developing new expenditure categories

The two above observations reflect two foundational principles that guided the development of expenditure categories for a FLCB, ie:

- There needs to be a distinction between cost items to be recovered in the year in which they are incurred and those to be recovered over the useful life of the corresponding asset (generally more than one year);[96] and

- costs to be recovered over the useful life of the corresponding asset should be separated into categories relating to assets with similar useful lives.

Although we have not been asked to consider potential parameters for allocating costs to heavy vehicles under these prototype expenditure categories, it is relevant to note that there also exists scope to develop expenditure categories that comprise costs with similar costs drivers. This could potentially simplify and improve the transparency and operation of the cost allocation methodology under a FLCB.

In addition, some costs should ideally be categorised based on those relating to heavy vehicles specifically, and those that are not. This may warrant splitting maintenance expenditure into sub-categories if the cost

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[96] Sometimes referred to in other industries as operating expenditure and capital expenditure, respectively.

allocation should differ based on the category, as is currently done for periodic and routine maintenance expenditure.

In addition, the development of our expenditure categories was also guided by the following inter-related principles, ie:

1. **Practicality** – the requisite information should reflect expectations as to the availability of road cost data;

2. **Relevance** – costs not relevant to the provision of road infrastructure services to heavy vehicles should be excluded;

3. **Causality** – to the extent possible, expenditure categories should comprise costs with a similar cost driver, or drivers, so as not to unnecessarily complicate the allocation of costs;

4. **Transparency** – the reasons for any year-to-year changes in the costs allocated to heavy vehicles should be clearly identifiable; and

5. **Simplicity** – the expenditure categories should establish a framework for an allocation of costs that is straight-forward to implement and simple for stakeholders to understand.

4.2.1 What costs should be included in the FLCB?

It is instructive to note that a FLCB should comprise only costs related to the provision of road infrastructure services that are not otherwise recovered through other fees and charges, or that are unrelated to heavy vehicle road use. We propose information on both revenue and costs for registration and licensing is collected so as to allow explicit consideration of any associated under- or over-recovery.

This principle applies equally to the PAYGO approach, which excludes certain costs from heavy vehicle charges, including costs related to:[97]

> expenditure recovered through other fees and charges (administering registration and licensing systems and expenditure on roads financed through tolls);
>
> interest on borrowings;
>
> a proportion of local road expenditure to account for other services provided by these roads — local access and amenity, for example; and
>
> heavy vehicle enforcement expenditure.

4.2.2 Good practice information sources

Our proposed expenditure categories were developed based on an in-principle assessment and industry best-practice guidelines, ie:

- the Data Standard for Road Management and Investment in Australia and New Zealand (Austroads 2016), which is used as the basis for identifying Asset Groups; and

- the Australian Infrastructure Financial Management Manual (IPWEA 2015), which is used as the basis for identifying Work Categories.

The Austroads Data Standard for Road Management and Investment in Australia and New Zealand covers a variety of data categories, albeit much of the detail contained therein has limited relevance to the task at hand. The Australian Infrastructure Financial Management Manual focus on integrating the disciplines of financial management and asset management.

These best-practice guidelines were used on the presumption that they will be adopted by road agencies in the future.

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[97] Productivity Commission, *Road and Rail Freight Infrastructure Pricing – Inquiry Report*, December 2006, p.95.

4.2.3 These expenditure categories represent a starting-point

Given the development of these expenditure categories is being undertaken in the very early stages of considering the application of a FLCB, it is important to bear in mind that these expenditure categories constitute a starting-point, for exploration and consideration by stakeholders.

In our view, in these early stages of development it is appropriate to place an emphasis on presenting first-best expenditure categories that reflect first-best principles of cost allocation, but note that there are likely to remain a number of practical considerations to be worked through by stakeholders.

That said, in developing these expenditure categories we endeavoured to address practical limitations where they were identified, based on our industry knowledge.

Similarly, in selecting the number of categories there is an inherent trade-off between:

- the potential for relatively more expenditure categories to improve the accuracy and transparency of the allocation methodology; and
- the administrative burden placed on road agencies required to undertake this expenditure categorisation.

Again, our approach to selecting the number of categories placed an emphasis on the most preferable level of granularity, but we note there exists a significant opportunity to refine this initial categorisation subject to further engagement with stakeholders.

4.3 The proposed expenditure categories

Application of our approach identified that, as a starting point, a categorisation of road expenditure to facilitate the implementation of a FLCB would involve the following high-level groupings of expenditure, ie:

- operating;
- maintenance;
- renewal; and
- development.

The operating and maintenance categories comprise costs to be recovered in the year in which they are incurred.[98] The separation of these costs into two categories reflects the different underlying cost drivers.

On the other hand, the renewal and development categories comprise costs to be recovered over the corresponding asset's useful life. The separation of these costs reflects the different underlying planning and funding drivers, as well as the different service outcomes, and will assist in facilitating industry discussion on the different types of costs caused by heavy vehicle road use.

As noted above, a FLCB approach necessitates a further separation of certain costs into categories comprising assets with similar asset lives. At one extreme, this could be undertaken by applying an assumption to separate each of the abovementioned groups into the applicable sub-categories, although this may significantly compromise the accuracy of the allocation process. On the other hand, road agencies could be required to separate expenditure for every single asset, but this would likely impose a significant administrative burden on road agencies.

With this trade-off in mind, we propose, as a starting point, a further disaggregation of these cost groups consistent with that presented in Table 23 on the following page.

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[98] We note that costs in the periodic maintenance category (B2) under the current PAYGO approach would be categorised as renewal, rather than maintenance, under the proposed approach.

Table 23 Initial number of expenditure categories for reporting purposes

Expenditure Group	Sub-categories for reporting purposes
Operating	5
Maintenance	3
Renewal	15
Development (upgrade and expansion)	17
Total	40

Importantly, there exists the potential for the number of initially proposed categorisations to be significantly reduced by either, consolidating expenditure groups, eg, renewal and development, or by consolidating some of the sub-categories that comprise each group. As explained above, assumptions could be used to disaggregate expenditure categories that are consolidated for reporting, although this may comprise the accuracy of the resulting allocation. Nevertheless, we consider a more granular categorisation would be good practice to support stakeholder engagement as part of the heavy vehicle charge determination process.

A full list of expenditure categories for reporting purposes is presented in Table 24 on the following page. Further, we present a potential further disaggregation for the NTC's consideration in Appendix A.2.

Finally, we note that Opus provided to the NTC a separate technical report that explains technical aspects of the methodology applied and the proposed categorisation, eg, the engineering definitions of each proposed category.

Table 24   Proposed categorisation of road expenditure for reporting purposes

Group	Categorisation	Reference
A - Operating	Asset Servicing and Operating Expenses	A1
	Corporate Services	A2
	Corporate Services - separately recovered	A3
	Heavy Vehicle Regulatory Costs	A3-1
	Vehicle Registration	A3-2
	Driver Licencing	A3-3
B - Maintenance	Maintenance - significantly impacted by heavy vehicle dynamic loads	B1
	Maintenance - Pavement and Pavement Surfacing (including Parking)	B1 -1
	Maintenance - Bridges and Major Culverts	B1 -2
	Maintenance - minimal or nil impact by heavy vehicle dynamic loads	B2
C - Renewal	Pavement (including Parking)	C1
	Concrete	C1-1
	Flexible	C1-2
	Unsealed	C1-3
	Renewal - Pavement Surfacing (including Parking)	C2
	Asphalt	C2-1
	Sprayed Seal	C2-2
	Delineation	C3
	Roadside	C4
	Drainage	C5
	Structures	C6
	Bridges	C6-1
	Major Culverts	C6-2
	Retaining Walls and (Other) Structures	C6-3
	Tunnels	C6-4
	M&E, ITS and Lighting	C7
	Non Infrastructure Assets	C8
	Plant and Equipment	C8-1
	Land and Buildings	C8-2
D - Development (Upgrade and Expansion)	Land Under Roads and Enabling Works	D1
	Land Under Roads	D1-1
	Enabling Works	D1-2
	Pavement (including Parking)	D2
	Concrete	D2-1
	Flexible	D2-2
	Unsealed	D2-3
	Pavement Surfacing (including Parking)	D3
	Asphalt	D3-1
	Sprayed Seal	D3-2
	Delineation	D4
	Roadside	D5
	Drainage	D6
	Structures	D7
	Bridges	D7-1
	Major Culverts	D7-2
	Retaining Walls and (Other) Structures	D7-3
	Tunnels	D7-4
	M&E, ITS and Lighting	D8
	Non Infrastructure Assets	D9
	Plant and Equipment	D9-1
	Land and Buildings	D9-2

A1. Information sources and documents reviewed

A1.1 Information sources

The information sources we reviewed included:

- **ABI/INFORM Global** – which is one of the most comprehensive business databases on the market. It includes in-depth coverage for thousands of publications, most of which are available in full text and the latest business and financial information for researchers at all levels.

- **EBSCO Business Source** Complete – this multi-disciplinary database provides full text for more than 4,600 journals, including full text for nearly 3,900 peer-reviewed titles. PDF backfiles to 1975 or further are available for well over one hundred journals, and searchable cited references are provided for more than 1,000 titles,

- **Informit** – which provides online access to indexes and full text databases of Australasian scholarly research – Informit provides access to over 80 databases covering a wide range of subjects – Content, which is sources from publishers, associations and peak professional bodies, focuses on regional perspectives and includes contributions from international authors

- **Factiva –** is a business information and research tool owned by Dow Jones & Company Factiva aggregates content from both licensed and free sources, and provides organizations with search, alerting, dissemination, and other information management capabilities – Factiva products provide access to more than 32,000 sources (such as newspapers, journals, magazines, television and radio transcripts, photos, etc.) from nearly every country worldwide in 28 languages, including more than 600 continuously updated; and

- the **world-wide web**.

A1.2 Documents reviewed as a result of our search

Our review encompassed the following documents, ie:

- AASHTO, International Scan: Reducing Congestion & Funding Transportation Using Road Pricing, April 2010.

- Acil Allen Consulting, Land Transport Funding: Report to the Australian Automobile Association, June 2016.

- Albalate, D. & Bel, G., What Local Policy Makers Should know about Urban Road Charging: Lesson from Worldwide Experience, Public Administration Review Vol. 69, No. 5 Sept –Oct 2009, pp 962-975.

- Al-Kaisy, A., Passenger Car Equivalents for Heavy Vehicles at Freeways and Multilane Highways: Some Critical Issues, Institute of transportation Engineers Journal, Vol. 76, 3 l, March 2006,.

- Applied Research Associates, Estimation of Road Cost Allocation between Light Vehicles and Heavy Vehicles in Canada, Final Report, 2007.

- Arizona Department of Transportation, Implementation of the Simplified Arizona Highway Cost Allocation Study Model, March 2001.

- Australia Rural Industries Research Development Corporation, The Costs of Road and Rail Freight, by Access Economics, November 2007.

- Australian Government Department of Infrastructure and Regional Development, BITRE Information Sheet 75, 2016.

- Australian Automobile Association, Road and Rail Freight Infrastructure Pricing, Submission to Productivity Commission Inquiry, May 2006.

- Australasian Railway Association, Future of freight 2005, Paper Prepared by Port Jackson Partners and Access Economics 2005.

- Australasian Railway Association, Road Pricing Reforms in Australia: Why Road Pricing is Vital to Australia's Economic Prosperity, 2010.

- Austroads, Investigate cost allocation for bridges in relation to heavy vehicles: Austroads project TS 1399, February 2010.

- Austroads, Establishment of a New Pavement Maintenance Database – Stage 1 and 2 Analysis, April 2011.

- Austroads, Improving Cost Allocation by Road Type, March 2012.

- Austroads, Further Development of Probabilistic Road Deterioration Modelling: Pilot Application, 2015.

- Austroads, Improving High Productivity Vehicle Access through Potential Charging Regimes AP-R504-15, 2016.

- ARRB, Estimating Australia's attributable road track costs: Research Report ARR 254, November 1994.

- Calvert, F., A Discussion of Road Use Charging Mechanisms, Proceedings 15th ARRB Conference Part 4 1990.

- Cost Allocation of Transport Infrastructure Cost (CATRIN) – European Commission, Cost allocation Practices in the European Transport Sector, March 2008.

- CESifo, DICE Road User Charging (Toll) in the EU under Eurovignette Directives, 2014.

- Chih-Peng C. & Tsai, J.-F., Road Pricing Models with Maintenance Cost, Transportation, Nov 2004.

- European Commission, Evaluation of the legislation on the European Electronic Toll Service (EETS) – Directive 2004/52/EC and Decision 2009/750/EC.

- Federal Highway Administration, Cost Allocation Study Final Report, 2000.

- Ghaeli, M. R., Pavement and Bridge Cost Allocation Analysis of the Ontario Intercity Highway Network, Thesis presented to the University of Waterloo Canada, 1997.

- Gupta, D., & Chen, H.-W., Highway Cost Allocation and Determination of Heavy Freight Truck Permit Fees, Final Report, July 2012.

- Harvey, M. O., Optimising Road Maintenance, International Transport Forum, Discussion paper No. 2012-12, October 2012.

- Hensher, David A and Mulley, Corinne Complementing distance based charges with discounted registration fees in the reform of road user charges: the impact for motorists and government revenue, Transportation, Vol. 41 2014 pp.687-715.

- Hjelle, Harald M, A model for estimating road wear on in-service roads, International Journal of Pavement Engineering Vol 8 No 3 September 2007, pp.237-244.

- Hong, Feng,; Prozzi, Jorge A & Prozzi, Jolanda, A new Approach for allocating Highway Costs Journal of the Transportation Research Forum, Vol. 46 No 2 (Summer 2007) pp.5-19.

- Jack Faucett Associates, 2001 Oregon Highway Cost Allocation Study, Vol 11, Issue papers, Feb 2001.

- Kentucky Transportation Center, 2000 Highway Cost Allocation Update, 2000.

- Kilsby, D; Laird, P & Bowers, D., Australian Transport Infrastructure: Fit for Purpose?, Written on behalf of The National Committee for Transport of Engineers Australia October 2004.

- Koh, A. & Shepherd, S., Issues in the Modelling of Road User Charging, Appendix A, Accessed February 2017 www.distillate.ac.uk/outputs/Deliverable%20F%20**Appendix**%20A.pdf

- Laird, P., *Submission re Public Infrastructure, Presented to the Productivity Commission,* December 2013,.

- Laird, P., *Submission re the M5 Corridor,* March 2010.

- Laird, P., *Freight transport cost recovery in Australia,* Australasian Transport Research Forum, 2006.

- Laird, P., *Freight Transport Subsidies in New South Wales, Forum Papers,* Australasian Transport Research Forum. 1987, pp.125-146.

- Levinson, D., Paying for Fixed Cost of Roads, Journal of Transport Economics and Policy, Vol 39, No. 3, The Economics of Cost Recovery in Transport, 2005, pp.279-294.

- Lin, Kuo-Liang & Lin, Chien-Liang, Applying Utility Theory to Cost Allocation of Pavement Maintenance and Repair, International Journal of Pavement Research and Technology, Vol.4 N. 4 July 2011.

- Lindsey, R., Reforming Road User Charges: A Research Challenge for Regional Science, Journal of Regional Science, Vol 50, No. 1 2010, pp.471-492.

- Luskin, D. and others, A Framework for Texas Highway Cost Allocation, Study Research Report 0-1810-1 June 2001.

- Manning, I., Cost recovery and greenhouse emission abatement in land freight transport, ND.

- Martin, L., External Accident Costs of Motor Vehicles, Staff paper to 28th Australasian Transport Research Forum, September 2005.

- Martin, T., Australian Road Track Cost Allocation, Australian Road Research Board 1991.

- Martin, T. & Choummanivong, Lith; Calibration of HDM04 Road Deterioration Models and Development of Works Effects Models for Australian Conditions, 23rd ARRB Conference Adelaide Australia, 2008.

- Martin, T.C. Commentary: Estimating Heavy Vehicle Attributable Road Wear Costs (marginal cost of road wear), Road & Transport Research, Vol. 9 No. 1, 2000, pp.84-91.

- Martin, T.C, Estimating heavy vehicle road wear costs for bituminous-surfaced arterial roads, Journal of transportation Engineering, March/April 2002.

- Martin, T and Choummanivong, L., The benefits of Long Term Performance (LTPP) research to funders, 6th Transport Research Areana, April 2016, pp.2477-2486.

- Martin T.C. The effect of climate on the cost of road maintenance in Australia, ARRB Transport Research. Research Report No. 353.

- Misui, Y. & Nemoto, T., Policy Issues Associated with Road Capacity Optimization through Social Marginal Cost Charging, Hitotsubashi Journal of Commerce and Management, Vol. 45, No.1 Oct 2011 pp. 39-57.

- Newbery, D. M., Cost Recovery from Optimally Designed Roads, Economica, New Series, Vol. 56, No. 222, 1989, pp.165-185.

- Newbery, D. M & Santos, G., Road Taxes, Road User Charges and Earmarking, Fiscal Studies, Vol 20, No. 2,June 1999, pp.103-132.

- Newbery, D. M., Pricing and Congestion: Economic Principles Relevant to Pricing Roads, Oxford Review of Economic Policy, Vol. 6, No. 2, Transport, 1990 pp.22-38.

- New Zealand Transport Agency, Road User Charges: Handbook, December, 2015.

- Nash, C., Road Pricing in Britain, Journal of Transport Economics and Policy, Vol. 41, No. 1 January 2007, pp.135-147.

- Naude, C., Toole, T., McGeehan, E., Thoresen, T. & Ropper, R., Revised Vehicle Operating Cost Models for Australia, Australian Transport Research Forum, 2015 Proceedings, 30 September – October 2015.

- NTC, Third Heavy Vehicle Road Pricing Determination: Technical Report, October 2005.

- Oregon Department of Administrative Services, Office of Economic Analysis, Highway Cost Allocation Study Biennium 2013-2015, Prepared by ECONorthwest, 2013.

- O'Shannassy, S. & Seary A., Heavy Vehicle Charges Methodology Review: Transport for NSW Submission to the National Transport Commission, April 2013.

- Owusu-Ababio, S. & Schmitt, R. L. Framework for Estimating Industry-Specific Truck Traffic Volume for Pavement Damage Quantification, Transportation Research Board, 94th Annual Meeting. No. 15-2095. 2015.

- Pienaar, W.J., Road cost allocation and recovery. Working paper WP 1/03. Stellenbosch: Department of Logistics, Stellenbosch University, 2005.

- Pridmore, A. & Miola, A., Public Acceptability of Sustainable Transport Measures: A review of the Literature Discussion paper European Commission – Joint Research Centre, 2011.20.

- Productivity Commission, Road and Rail Freight Infrastructure Pricing – Inquiry Report, December 2006.

- Queiroz, C., Uribe, A., Blumenfeld, D., Mechanisms for Financing Roads: A Review of International Practice, Infrastructure and Energy Sector Multilateral Investment Fund, Technical Note, No 1102 December, 2016.

- Road Controlling Authorities Forum, NZ Inc., The Impact of Heavy Vehicle Traffic on Road Pavement, ND pp.14.

- Road User Charges Review Group NZ, An Independent Review of the New Zealand Road User Charging System, March, 2009.

- Roberts, JD & Martin, T. C., Recommendations for Monitoring Pavement Performance. ARRB Transport Research, Research Report ARR 293, September 1999 pp.74.

- Russell, P. R., States Test Alternative Road Funding, ENR November28/December 5 2016, pp.3.

- Saleh, W. & Farrell, S., Road-user Charging and the Modelling of Revenue Allocation, Transport Policy,Vol. 12 Issue, 5 September 2005 pp. 431-442.

- Schlotjes, M., The development of a diagnostic approach to predicting the probability of road pavement failure, Ph.D. thesis, University of Birmingham, 2013.

- Smart, M. & Game, S., Two case Studies on Road vs. Rail Freight Costs, Prepared by CRA International, May 2006.

- Stanley, J., Pricing opportunities for Australia: Paying Our Way in Land Transport, Policy Paper 1, Business School, University of Sydney, March 2014.

- Swier, G., Heavy Vehicle Road Charging and Investment Reform in Australia, ACCC/AER Regulatory Conference, 8 August 2014.

- Tooth, R., The Cost of Road Crashes: A Review of Key Issues, Australasian Railway Association, 2010.

- UK Government, HGV Road User Levy Act 2013 Chapter 7,2013.

- ULG, Road Track Cost Recovery Database Review: Information Paper, May 2005.c.

- U.S Department of Transportation Federal Highway, Cost Allocation Study Final Report, 1997.

- Velaga, N.R. & Pangbourne, K., Achieving Genuinely Dynamic Road User Charging; Issues with a GNSS-based approach, Journal of Transport Geography, Vol.34, pp.243-253.

- VicRoads, Road Cost Recovery: A review of the basis for establishing road user charges in Victoria, December 1989.

- Victoria Transport Policy Institute, Transportation Cost and Benefit Analysis: Techniques, Estimates and Implications, January 2009.

- Victoria Transport Policy Institute, Using Road Pricing Revenue: Economic Efficiency and Equity Consideration, May 2011.

- Volovski, M., Bardaka, E., Zhang, Z., Agbelie, B., Labi, S. & Sinha, K.C., Indiana State Highway Cost Allocation and Revenue Attribution Study and Estimation of Travel by Out-of-State Vehicles on Indiana Highways, 2015.

- Vuong, B. and Mathias, C., Estimates of Unit Road Wear Cost, ARRB Transport Research. Research report ARR361,2004.

- Wallis, I.P.& Chandler, N., The New Zealand Surface Transport Costs and Charges Study, 28th Australasian Transport Research Forum, 2005.

- Yusuf, Juita-Elena (Wie) & O'Connell, Lenahan, The Crisis in State Highway Finances: Its Roots, Current Effects, and some Possible Remedies, Journal of Public Budgeting, Accounting & Financial Management, 25 (3), pp.502-521.

A2. Disaggregated categorisation of road expenditure

We present on the following page a significantly disaggregated categorisation of road expenditure to facilitate a FLCB. This constitutes a reference point for the NTC in considering the level of categorisation for reporting purposes, as well as the extent to which assumptions may be required to disaggregate those costs to account for assets with different useful lives or costs with different underlying cost drivers. Shaded cells indicate a category currently proposes for reporting purposes.

Table 25   Disaggregated potential categories to facilitate a FLCB (continues on next page)

		Level 1		Level 2
(A) **Operating**	A1	Asset Servicing and Operating Expenses		
	A2	Corporate Services		
	A3	Corporate Services - separately recovered	A3-1	Heavy Vehicle Regulatory Costs
			A3-2	Vehicle Registration
			A3-3	Driver Licencing
(B) **Maintenance**	B1	Maintenance - significantly impacted by heavy vehicle dynamic loads	B1-1	Pavement and Pavement Surfacing (incl. Parking)
			B1-2	Bridges and Major Culverts
	B2	Maintenance - minimal or nil impact by heavy vehicle dynamic loads	B2-1	Delineation, Roadside and Drainage
			B2-2	Structures (excl. Bridges and Major Culverts)
			B2-3	M&E, ITS and Lighting
			B2-4	Non Infrastructure Assets
(C) **Renewal**	C1	Renewal - Pavement (incl. Parking)	C1-1	Concrete
			C1-2	Flexible
			C1-3	Unsealed
	C2	Renewal - Pavement Surfacing (incl. Parking)	C2-1	Asphalt
			C2-2	Sprayed Seal
	C3	Renewal - Delineation	C3-1	Linemarking
			C3-2	Signs
			C3-3	Traffic Management Devices
	C4	Renewal - Roadside	C4-1	Amenities
			C4-2	Bins
			C4-3	Fences
			C4-4	Public Toilets
			C4-5	Road Barriers
			C4-6	Shelters
			C4-7	Slopes
			C4-8	Landscaping and Trees
	C5	Renewal - Drainage	C5-1	Kerb and Channel (incl. Vehicle Crossings)
			C5-2	Pits
			C5-3	Table Drains
			C5-4	Culverts Minor (Pipes)
	C6	Renewal - Structures	C6-1	Bridges
			C6-2	Major Culverts
			C6-3	Retaining Walls and (Other) Structures
			C6-4	Tunnels
	C7	Renewal - M&E, ITS and Lighting	C7-1	Mechanical and Electrical
			C7-2	ITS Assets
			C7-3	Traffic Signals
			C7-4	Lighting
			C7-5	Poles
	C8	Renewal - Non Infrastructure Assets	C8-1	Plant and Equipment
			C8-2	Land and Buildings

	D1 Development - Land Under Roads and Enabling Works	D1-1	Land Under Roads
		D1-2	Enabling Works
	D2 Development - Pavement (incl. Parking)	D2-1	Concrete
		D2-2	Flexible
		D2-3	Unsealed
	D3 Development - Pavement Surfacing (incl. Parking)	D3-1	Asphalt
		D3-2	Sprayed Seal
	D4 Development - Delineation	D4-1	Linemarking
		D4-2	Signs
		D4-3	Traffic Management Devices
	D5 Development - Roadside	D5-1	Amenities
		D5-2	Bins
		D5-3	Fences
		D5-4	Public Toilets
		D5-5	Road Barriers
		D5-6	Shelters
(D) Development (Upgrade and Expansion)		D5-7	Slopes
		D5-8	Landscaping and Trees
	D6 Development - Drainage	D6-1	Kerb and Channel (incl. Vehicle Crossings)
		D6-2	Pits
		D6-3	Table Drains
		D6-4	Culverts Minor (Pipes)
	D7 Development - Structures	D7-1	Bridges
		D7-2	Major Culverts
		D7-3	Retaining Walls and (Other) Structures
		D7-4	Tunnels
	D8 Development - M&E, ITS and Lighting	D8-1	Mechanical and Electrical
		D8-2	ITS Assets
		D8-3	Traffic Signals
		D8-4	Lighting
		D8-5	Poles
	D9 Development - Non Infrastructure Assets	D9-1	Plant and Equipment
		D9-2	Land and Buildings
(E) Other road related payments	E1 Loan Servicing		
	E2 Financial Assistance to councils for work on council managed arterials		
	E3 Payments to councils for contract work on state managed roads		
	E4 Spending on local access roads in unincorporated areas		
	E5 Direct spending on council managed local access roads		
	E6 Any other direct state spending on local access roads		

* Shaded cells indicate a category currently proposed for reporting purposes.

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