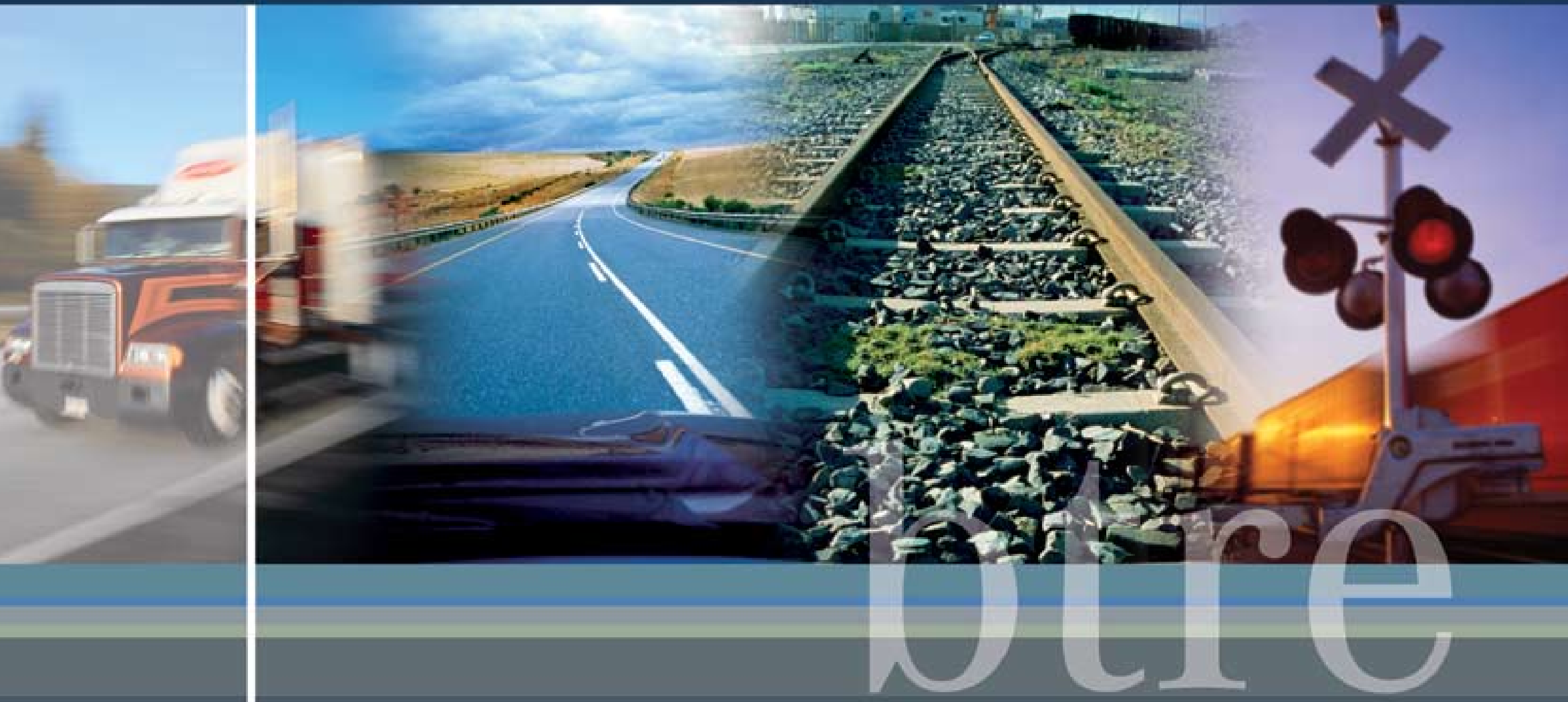
Australian Government

Department of Transport and Regional Services

Bureau of Transport and Regional Economics



Submission to the Productivity Commission road and rail freight infrastructure pricing inquiry

August 2006

Australian Government

Department of Transport and Regional Services
Bureau of Transport and Regional Economics

SUBMISSION TO THE PRODUCTIVITY COMMISSION ROAD AND RAIL FREIGHT INFRASTRUCTURE PRICING INQUIRY

August 2006

Contents

Introduction

This submission draws on previous and current BTRE research in addressing issues covered by the inquiry.

The submission commences with a brief general discussion of the economics of road and rail infrastructure and some implications for pricing; examines the relationship between estimates of road infrastructure costs attributable to Australian heavy vehicle operators and charges paid, both at the aggregate level and for particular road corridors; discusses issues in improving the efficiency of both road and rail freight infrastructure pricing, and finally considers the question of charging for freight externalities.

1. What should freight infrastructure users pay for?

In principle, there are two key objectives of infrastructure pricing. These are, firstly, to promote efficiency of use, so that users do not impose greater costs on society than they are willing to pay for in the short-run and, secondly, to promote efficiency in investment, so that total costs for society over the longer run are minimised through adequate and timely investment. In the absence of a certain supply of external funding, the latter objective will imply that prices charged should cover total long-run costs.

In applying these objectives to road and rail freight infrastructure, it is necessary to take account of two complicating factors, firstly, economies of scale and/or of density, where the marginal cost of providing the service is less than the average cost and, secondly, the phenomenon of joint or multiple use of the infrastructure, with its implication that many costs will be effectively joint or common and unlikely to be appropriate to allocate in entirety to one type of user or another.

1.1 Paying for road freight infrastructure

Road infrastructure provides two types of services: pavement durability and the basic carrying capacity of traffic. Pavement durability exhibits significant economies of scale—"a pavement that is eleven inches thick is twice as durable as one that is nine inches thick, yet costs only a fraction more to build" (Gomez-Ibanez 1999). Pavement wear increases exponentially, at either the third or fourth power of axle weight. It follows from this that, for higher standard roads at least, efficient or marginal cost pricing of road wear (which is caused by heavy vehicles and the passage of time and barely at all by cars) will recover only a small proportion of the total costs of providing and maintaining roads. Consistent with this, Small et al. (1989) found that optimal (axle loading-based) charging of heavy vehicles on urban arterial roads in the United States would recover less than 2 per cent of the long-run cost of these roads.

These authors nevertheless found that overall returns to scale in urban road infrastructure are nearly constant. Substantial returns to scale in pavement durability are offset by the diseconomies of scope arising from jointly providing the two products of traffic volumes and traffic loadings (i.e. other costs such as land aside, it costs more to provide a road suitable for both cars and trucks, rather than separate roads for each vehicle type). Thus twin marginal cost pricing of road wear (for heavy vehicles) and congestion (for all vehicles in peak periods or at other times when roads are congested) respectively could cover at least 80 per cent of long-term capital and maintenance costs for urban roads. In addition, these authors concluded that, despite its limited contribution to cost recovery, optimal pricing of road wear would promote optimal investment in road durability, with significant long-term savings.

On non-urban roads in Australia, where there may be limited or no congestion, road infrastructure will exhibit some economies of scale. Consequently, charging users to achieve cost recovery is likely to entail prices that substantially exceed the short-run marginal cost of use (Harvey 1999). An efficient road wear charge for heavy vehicles is still an appropriate, in principle starting point on these roads. However, there is no single definitive approach for assigning joint capacity costs to different classes of vehicles for the purpose of additional or 'top-up' charging. Gomez-Ibanez (1999) suggests that capacity costs can be assigned on a basis of passenger car unit-kilometres, with accordingly higher unit prices for heavy vehicles than are (notionally) assigned to light vehicles. Such an approach may be appropriate to the extent that there is in fact congestion in the non-urban environment (a short-run marginal cost consideration), or alternatively that capacity expansion costs reflect specific requirements of heavy vehicles (e.g. wider lanes or longer, less steep grades) as distinct from the requirements of all vehicles, which, as indicated in Figure 1.1, are predominantly cars (i.e. from a long-run marginal cost perspective). However, to the extent that congestion can be discounted and capacity requirements are unaffected by heavy vehicles, assigning costs on some other basis may be preferred.

To minimise efficiency losses when seeking full cost recovery, actual pricing mechanisms should also, in principle, be informed by willingness to pay, which will vary for different users. Ramsey (inverse elasticity) pricing, where different users are charged amounts that vary according to their different estimated relative abilities to pay—that is, paying for benefit received as opposed to costs imposed—is, in principle, the most efficient approach. Ramsey pricing can run into difficulties of sufficient information, public justification and instability (the latter given the incentives users who are paying high mark-up prices will have to look for alternative services (Gomez-Ibanez 1999)). Ramsey pricing is necessarily also infeasible for an infrastructure network where, toll roads aside, only heavy vehicles are being considered for direct user pricing. Nevertheless, it is important to keep in mind the efficiency losses that may result from alternative average cost pricing approaches.

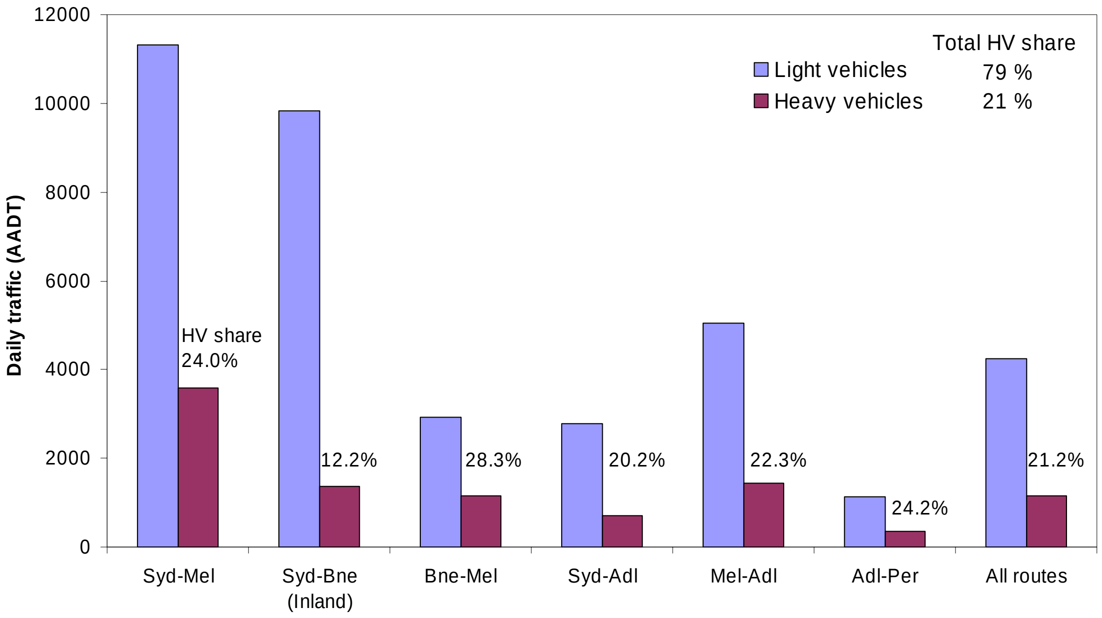
1.2 *Paying for rail infrastructure*

Rail infrastructure exhibits high fixed costs irrespective of traffic levels and thus marginal costs are very significantly below average costs. Railways have very strong economies of density in both above and below-rail operations, implying that incremental traffic volume will have a significant effect in reducing the financial gap.

Public access rail freight infrastructure in Australia is generally priced to recover at least the incremental cost of infrastructure use, which will include the marginal cost of track maintenance. Modal competition is an important factor in pricing. In the inter-capital non-bulk freight market, the primary market where the two modes compete (see Appendix I), rail freight is generally regarded as a 'price taker' from road freight. Here there may be limited capacity for rail infrastructure to recover long-term capital costs. In contrast, in coal and other bulk mineral markets, where there is generally no economic alternative to the use of rail, rail infrastructure can be priced to recover long term costs.

Regulatory arrangements and industry structure may also affect the approach to pricing. Integrated railways have traditionally used price discrimination between different types of customer as a key strategy in recovering capital costs. To the extent that non-discrimination is either required by regulation or considered a necessary business strategy for an 'open access' vertically separated rail infrastructure manager, long-term cost recovery is likely to be impeded.

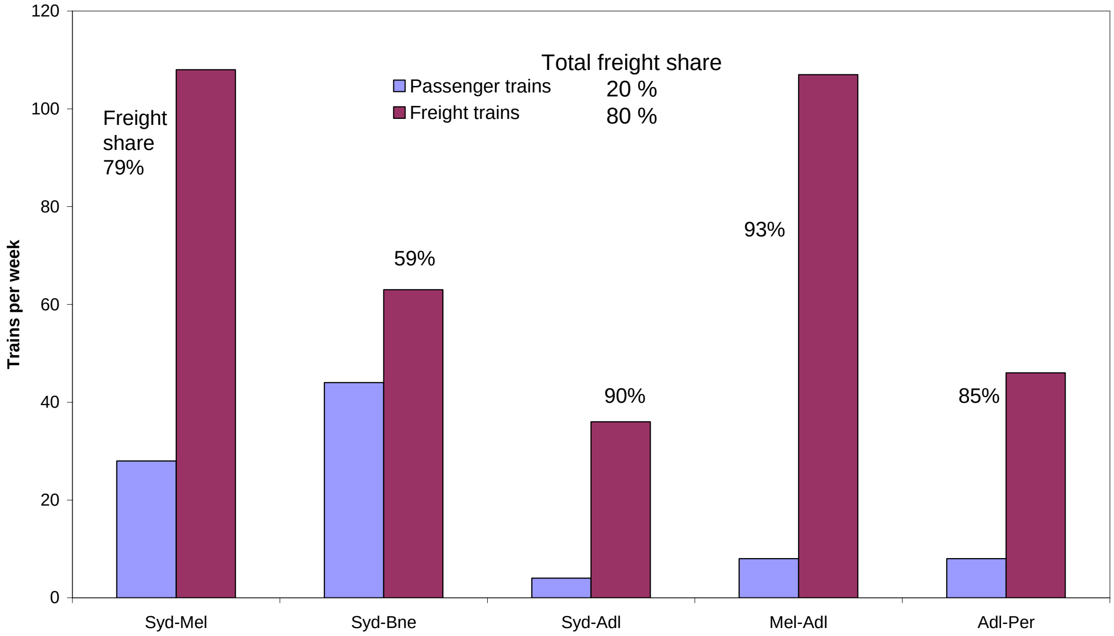
FIGURE 1.1 AVERAGE DAILY TRAFFIC COUNTS ON MAJOR INTER-CAPITAL ROAD CORRIDORS, 2001



Source BTRE (2006b).

Rail freight infrastructure in Australia also operates within a comparatively limited passenger market with which to share its fixed costs. Whereas nearly 80 per cent of traffic on roads between major Australian capital cities comprises light vehicles, the comparable figure for passenger trains on interstate network inter-capital routes is only 20 per cent (see Figures 1.1 and 1.2).

FIGURE 1.2 WEEKLY LONG-DISTANCE TRAIN NUMBERS ON INTER-CAPITAL RAIL CORRIDORS, 2003–04



Source ARTC timetables, available at www.artc.com.au.

2. Do road freight charges cover the cost of infrastructure?

2.1 Do existing heavy vehicle charges cover the cost of road wear?

Expenditure allocation approaches

Estimates in BTE (1999) suggested that total revenue paid by six-axle semi-trailers, the major road freight vehicle configuration on long-distance and inter-capital freight routes at the time, for use of the Australian arterial road network exceeded the total estimates of attributable road maintenance expenditure on these roads. This was the case under both the then National Road Transport Commission's (NRTC) pricing approach and a notional alternative BTE approach, which explored the use of different cost allocation parameters with consequently higher expenditure allocated to heavy vehicles.

The BTE (1999) approach allocated $376 million in annual avoidable (rehabilitation and maintenance) costs for arterial roads to six axle semi-trailers (BTE 1999, pp. 41–44). Consistent with the understood relationship between axle loading and road wear, the BTE approach involved greater use of the equivalent standard axle kilometre parameter and less use of gross vehicle mass kilometres and passenger car equivalent unit kilometres than in the NRTC methodology ($231 million). Estimated total annual revenue paid by six-axle articulated trucks was approximately $475 million, comprising $337 million in fuel-based revenue and $139 million in registration charges (BTRE 2003a, p. 8). Total estimated road use revenue therefore exceeded the BTE's total estimated road wear-related costs by approximately $100 million.

In unit cost terms, BTE (1999) estimated the average avoidable cost of a six-axle articulated truck travelling on the arterial road network to be 0.63 c/net tonne kilometre (tkm)—equivalent to 12.6 c/km for a six-axle articulated truck carrying an average load of 20 tonnes. Under the then prevailing fuel-based and vehicle registration charges, the average charge for a six-axle articulated truck, carrying an average load of 20 tonnes and travelling a fleet-average distance of 110 000km, was approximately 13.6 cents/km—10 cents/km in fuel-based charges and 3.6 cents/km the average per kilometre registration charge.

Life-cycle costing based road wear estimates

Life-cycle model[1] based cost estimates suggest that current charges (fuel excise and registration) significantly exceed the marginal cost of road wear on high standard roads, e.g. highways between some major capital cities, but fall short of road wear costs on lower standard roads. BTE (1999) also estimated the marginal cost of heavy vehicle use across separate segments of the former National Highway System (NHS), using estimates of future road maintenance expenditure requirements derived from a life-cycle model of pavement expenditure.[2] On the major inter-capital corridors, BTE (1999) estimated that the marginal road wear cost of heavy vehicle travel was quite low—between 2.4 and 4 cents per vehicle kilometre, at 1997–98 prices, for a six-axle articulated truck travelling between the mainland Eastern State capital cities, and up to 10 cents per vehicle kilometre between Adelaide and Perth (see table 2.1). On more remote parts of the NHS, which are arguably built to a lower standard and carry less heavy vehicle traffic, marginal road wear costs were estimated to range from 10 cents per vehicle kilometre to as much as 80 cents per vehicle kilometre. By way of comparison, the fuel-based heavy vehicle charge, of approximately 20 cents per litre, equated to around 9 to 10 cents per vehicle kilometre for a six-axle articulated truck, depending on terrain and load.

---

[1] Pavement life-cycle cost models estimate the optimal timing and mix of different pavement construction and maintenance strategies—minimising the discounted present value of total future road user and total road agency costs for given future traffic levels.

[2] The life-cycle model expenditure results were based on the World Bank HDM-III pavement deterioration algorithm (Paterson 1987), modified to Australian conditions (see BTCE (1990, 1992) for further details).

TABLE 2.1 BTE (1999) MARGINAL ROAD WEAR COST ESTIMATES—SELECTED CORRIDORS

Corridor	*Marginal cost*	*Marginal cost, six-axle articulated truck*
	(cents per ESA-km)[a,b]	*(cents per km)*[a,b]
Sydney–Melbourne	1.2	2.4
Sydney–Brisbane	2.1	4.2
Sydney–Canberra	1.5	3.0
Melbourne–Adelaide	1.5	3.0
Adelaide–Perth	4.2	8.4
Toowoomba–NT border	16.4	32.7
Perth–NT border	13.3	26.7

a. Estimates at 1997–98 prices.

b. The marginal costs estimates for a six-axle articulated truck assume an average of 2.0 ESA per vehicle, which was based on NRTC (1998).

Sources BTE (1999, p. 56), NRTC (1998) and BTRE estimates.

Importantly, the marginal road wear costs presented in BTE (1999) include non-pavement related routine maintenance expenditure, which could not be separated from pavement-related maintenance expenditure. Non-pavement related routine maintenance expenditure (which includes servicing of roadside rest areas, mowing verges, maintenance of street lighting and traffic furniture and general administrative costs) is a common cost of maintaining the road, which would be more appropriately shared across both light and heavy vehicle classes. Consequently, the BTE (1999) marginal road wear cost estimates will overstate the avoidable road wear costs attributable to heavy vehicles. More recent BTRE analysis (BTRE forthcoming), which uses the latest empirical evidence on Australian pavement performance, suggests that the avoidable cost of road wear varies between 1 and 2 cents per kilometre (at 2002–03 prices), for typical inter-capital articulated truck combinations on the major inter-capital corridors[3], and up to 8 cents per kilometre between Adelaide and Perth. These more recent estimates are lower than the BTE (1999) estimates due to differences between the pavement deterioration algorithms used in the two analyses and the exclusion of non-pavement related maintenance costs from avoidable maintenance costs in the more recent analysis.

2.2 Do existing heavy vehicle charges cover total infrastructure costs?

Expenditure allocation approaches

BTE (1999) also compared the total cost attributed to six-axle articulated trucks travelling on the arterial road network against total charges. Under the NRTC

---

[3] The BTRE (forthcoming) estimates are based on the average mix of six-axle articulated trucks and B-doubles travelling on inter-capital corridors.

cost allocation template used for the Second Heavy Vehicle Charges Determination, BTE (1999) estimated that the average total cost for a six-axle articulated truck, carrying an average load of 20 tonnes, and travelling an average of 189 000km per annum on arterial roads was approximately 0.60 cents per net tkm, equivalent to an average cost of 12c/km. By way of comparison, the average per kilometre charge for the same vehicle would be approximately 12.1 c/km. That is, for six-axle articulated trucks carrying a typical average load and undertaking relatively high VKT on arterial roads, average charges approximate average costs.

Under an alternative BTE cost allocation template (BTE 1999, table II.4, p. 45), however, the total average cost for a six-axle articulated truck, carrying an average load of 20 tonnes and travelling an average of 189 000km per annum on arterial roads, was estimated to be 19.4 cents per km, 60 per cent higher than the 12.1 c/km average heavy vehicle charge. The BTE approach allocated non-separable expenditure predominantly using PCU-km, in preference to the then NTRC approach of predominantly using VKT. Accordingly, the BTE approach allocated approximately 47 per cent of total arterial road expenditure to heavy vehicles, whereas the NRTC approach allocated 29 per cent of total arterial road expenditure to heavy vehicles.

Average replacement cost estimates

BTE (1999) also provided indicative estimates of the replacement cost of selected inter-capital highways, and used these to estimate an average capital cost per heavy vehicle kilometre for these highways (BTE 1999, table II.8, p. 57). Highway replacement costs were calculated using the road capacity standard, prevailing in 1996, on each inter-capital highway and national average per kilometre construction costs used in BTCE (1997).[4] Importantly, the assumed average construction cost of divided carriageways (between $4.2 million and $6.4 million per kilometre) is an order of magnitude higher than that of single carriageways (approximately $230 000 per kilometre).[5] In calculating the average per kilometre capital cost, the BTE assumed that 46 per cent of total cost was attributable to heavy vehicles[6] — on most inter-capital highways heavy vehicle represent between 10 and 20 per cent of total traffic, or between 30 and

---

[4] The average construction cost estimates used in BTCE (1997) were based on information supplied by State and Territory road authorities. The average construction costs will tend to over-state construction costs in some places and under-state them in others.

[5] The much higher capital costs of four-lane divided carriageways reflects allowances for the upgrading of bridges and construction of interchanges, and more general improvements in the gradient, alignment and quality of the road.

[6] The share of capital costs allocated to heavy vehicles was based on BTE allocation (BTE 1999, table II.4, p. 45) of non-separable road expenditure to heavy vehicles.

40 per cent of total PCU-km. For a six-axle articulated truck carrying an average load of 20 tonnes, the estimated average capital cost varied from around 3.2 c/km for the Melbourne–Brisbane corridor to 5.5 c/km for the Sydney–Brisbane (via New England Highway) and Sydney–Adelaide corridors—corridors predominantly consisting of single carriageway highways—to approximately 14 cents per kilometre for the Sydney–Melbourne, Melbourne–Adelaide and Adelaide–Perth corridors—the former two consisting of significant amounts of dual carriageway, while the Adelaide–Perth corridor is a very long corridor with relatively little traffic.

Table 2.2 presents average total cost estimates of heavy vehicle road use, for some selected corridors, using the above assumptions. The results suggest that on all corridors, other than the Sydney–Brisbane corridor, the then average charge for a six-axle articulated truck—12.1 cents per kilometre—was below the average total cost of articulated truck use. (BTE (1999) did not estimate the marginal cost of heavy vehicle road use for the Melbourne–Brisbane and Sydney–Adelaide corridors, so it is not possible to compare average total costs with charges for these corridors.) On the Sydney–Melbourne and Melbourne–Adelaide corridors, the average heavy vehicle charge was below the average cost. On the Adelaide–Perth corridor, the average capital cost is relatively high (and exceeded the average charge) due to the long distances and relatively low level of traffic on this corridor. And on more remote roads (not competing with rail), like Toowoomba–NT border and Perth–NT border, the average capital cost is even higher under these allocation rules, and when added to the high cost of road wear, implies that the average cost of heavy vehicle use of these roads is significantly higher than on the major inter-capital corridors. It is not known to what extent recent changes in road conditions, mix of heavy vehicle types and overall traffic levels may have altered these findings.

The proportion of capital costs allocated to heavy vehicles has a significant impact on whether, under current charges, heavy vehicles fully recover costs on inter-capital routes. If, for example, capital costs were allocated on the basis of VKT, closer to the then NRTC's approach for the Second Heavy Vehicle Charges Determination, average capital costs would be less than one-third the size of the estimates in table 2.2, with the consequence that charges would exceed average costs on all mainland state inter-capital corridors, and approximate average costs on the Adelaide–Perth corridor. Gomez-Ibanez (1999) suggests allocating capital costs on a passenger car equivalent unit (PCU) as the appropriate basis for recovering fixed road capacity costs. On a PCU basis, the estimated average capital costs would be approximately 70 per cent of the estimates presented in table 2.2, with the implication that the average charge would equal or exceed average total costs on all mainland state inter-capital corridors other than Adelaide–Perth.

TABLE 2.2 BTE (1999) TOTAL COST RECOVERY ESTIMATES – SELECTED CORRIDORS

Corridor	*Marginal cost* *(cents per km)*[a,b]	*Average capital cost* *(cents per km)*[a,b]	*Average total cost* *(cents per km)*[a,b]
Sydney–Melbourne	2.4	13.7	16.1
Sydney–Brisbane	4.2	5.5	9.7
Sydney–Adelaide	na	5.7	na
Melbourne–Brisbane	na	3.2	na
Melbourne–Adelaide	3.0	13.0	16.0
Adelaide–Perth	8.4	14.1	22.5
Toowoomba–NT border	32.7	20.2	52.9
Perth–NT border	26.7	37.6	64.3

na not available.

a. Estimates at 1997–98 prices.

b. The marginal costs estimates for a six-axle articulated truck assume an average of 2.0 ESA per vehicle, which was the based on NRTC (1998).

Sources BTE (1999, p. 56), NRTC (1998) and BTRE estimates.

Choosing between cost allocation approaches

The expenditure allocation and average replacement cost estimates, presented above, allocate the share of non-avoidable costs attributable to heavy vehicles based solely on different measures of vehicle use. These approaches do not necessarily produce an efficient allocation of fixed costs between different road users. Ramsey (inverse elasticity) pricing principles can be applied to derive a more efficient allocation of fixed costs between different road users. However, the information requirements for a Ramsey pricing type cost allocation remain significant, due to the variety of users and breadth of the network. The degree of market segmentation may have a significant impact on the efficiency of the allocation and the cost allocated to different users, as the demand for road use varies across users and different parts of the road network. For example, road use could be segmented by vehicle type, area of use — e.g. urban and non-urban — and road type — e.g. national highways, arterial roads and local roads. This might result in a higher share of fixed costs allocated to heavy vehicles on some parts of the network, e.g. on national highways, than others.

It is doubtful whether heavy vehicle charges could actually be levied on a Ramsey pricing allocation basis, firstly because of the difficulty in differentiating charges across different users and secondly because the charges would be 'heavy vehicles only', i.e. excluding light vehicles. The implication is that it may continue to be necessary to choose between what are effectively sub-optimal allocation alternatives, such as those described above. These issues are discussed further in section 4.

3. Do rail freight charges cover the cost of infrastructure?

A trait that is widespread amongst common-user railways across the world is that the level of freight being moved is insufficient to recover the long-run economic costs of the railway, where economic costs are the accounting costs (including depreciation) and the return on investment (the opportunity cost of capital).

3.1 Do existing rail charges cover marginal infrastructure costs?

Railways in North America provide an exception to the generally poor financial return experienced by railways. The exception arises for three primary reasons:

- the use of Ramsey pricing in setting shipper tariffs;
- the high volumes of traffic;
- the long distances over which freight is transported.

The volume of traffic is particularly important because railways have very strong economies of density. These economies occur in both above-rail operation (hence the benefits of operating "long" trains) and below-rail operation. The economies of density in below-rail operation arise for two reasons. First, there are very high fixed costs of infrastructure provision; secondly, the marginal costs from track use are very low and decline over a wide range of output (traffic). Economies of density in below-rail and above-rail operation mean that incremental traffic volume will have a significant effect in reducing the financial gap. ZETA-TECH (2000, p. 3), for example, have estimated that, until (annual) train volumes exceed 25 million gross tons, track maintenance costs increase less than the growth in traffic. This figure compares with, for instance, around 5 million gross tonnes for through traffic between Melbourne and Adelaide.

Understanding marginal costs of infrastructure usage is essential in rail infrastructure pricing when setting the floor (or minimum) price for the charges. The floor price in the different Australian access regimes is, however, set as the incremental cost of provision; this is somewhat greater than the marginal cost. The incremental costs can be considered to be the avoidable cost, which includes the marginal costs of infrastructure use (such as maintenance expenditure arising from track use) and overhead costs (such as signalling and head office costs) that would otherwise be avoided.

Thus, rail infrastructure charges are normally set at a level that incorporates cost items supplementary to marginal costs. However, specific calculations of the marginal costs, for each type and condition of railway line, are not normally undertaken. Perhaps reflecting the inexact science of its measurement, as well as the varying track condition and track maintenance regimes, it has been found that there is a very broad range of marginal costs. This arises both because there are varying standards of infrastructure quality (which changes the marginal costs from usage) and because there are varying interpretations of marginal costs. For instance, Scherp (2002, pp. 2–10) notes that marginal cost estimates in Europe varied by a ratio of 1 to 20. So, we cannot actually be certain of the level of marginal costs and, therefore, of incremental costs.

3.2 Do existing rail charges cover total infrastructure costs?

Whether total costs are covered is primarily a function of the type of freight moved. There are three key types of freight. The geographical dispersion of goods, and its ease of conveyance, strongly influences rail's competitiveness. This tends to determine the level and structure of railway infrastructure pricing and cost recovery. The three main freight categories (see appendix I for information on relative volumes) are:

- *bulk* freight (excluding seasonal grain movements), notably iron ores and coal;
- *non-bulk* freight (container and louvre-van traffic); and
- *bulk seasonal* grain movements.

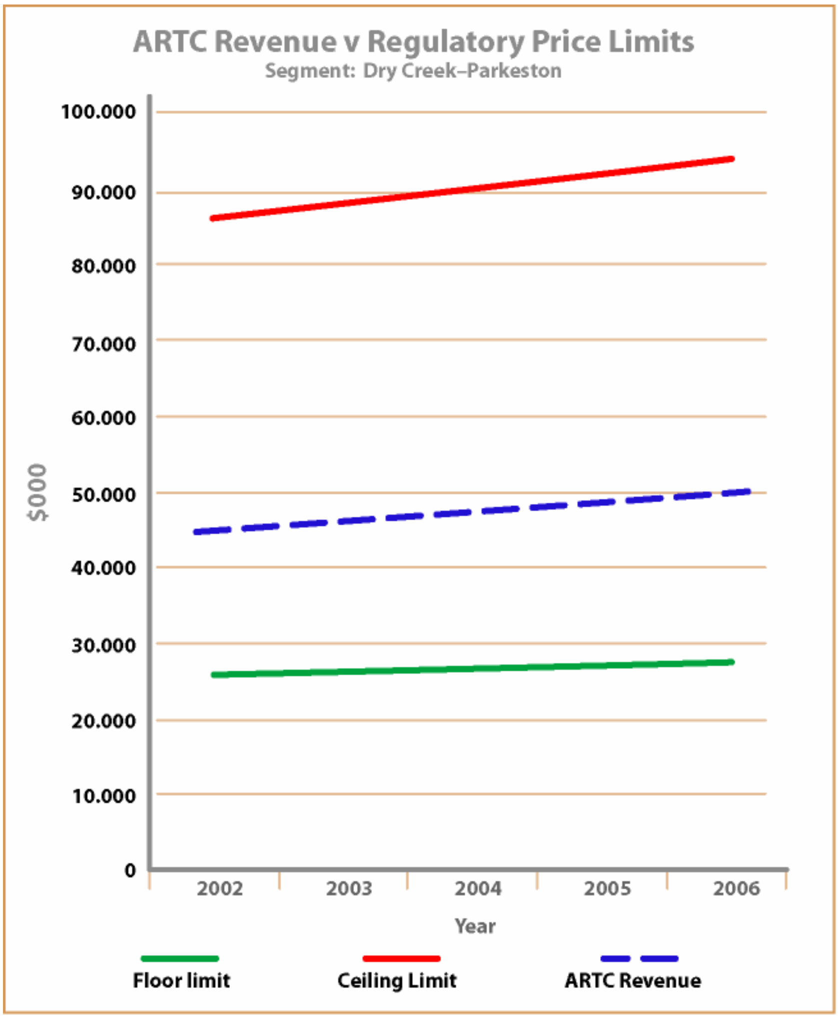
Irrespective of the jurisdictional access regime, only the use of bulk freight infrastructure tends to be priced at a level that achieves long-run economic cost recovery. In such circumstances, there is often close regulatory oversight to ensure that infrastructure is efficiently provided and that revenue does not exceed the cost recovery ceiling.

Often the railway is prevented from pricing at a level to cost recover because it faces strong competition from road freight; this is particularly the case with non-bulk and grain freight where rail is a price taker. This is a key parameter in the Australian Rail Track Corporation's (ARTC) rail access charges: while charges are usage-based, the level of charges is set with a view to maintaining the competitiveness of the infrastructure manager's train customers, relative to road freight.

As noted above, the volume of traffic on a line segment is particularly important in capturing the strong economies of density. These economies enable the train operators to set low shipper tariffs. However, more generally, railway viability depends on high volumes of traffic. For most railways—certainly, virtually all grain and non-bulk railways—the level of freight being moved is insufficient to recover the long-run economic costs of the railway.

By way of illustration, ARTC has the latitude to set its access charges—but, because of the strong competition from road and the relatively low level of traffic, the prices do not generate sufficient revenue for long-run economic cost recovery. Figure 3.1 illustrates that the resulting revenue for an essentially non-bulk section of the interstate network lies below the ceiling revenue limit (i.e. the long-run economic costs).

FIGURE 3.1 ILLUSTRATIVE COST RECOVERY ON CORE ARTC LINE SEGMENT



Source: ARTC (2001 p. 83).

Thus, unless railways are insulated from road competition and move large traffic volumes (typically, but not exclusively associated with bulk, non-grain freight), railways do not recover long-run economic costs. Unit costs of moving freight by rail decline as economies of density are captured. Very large traffic volumes are required for railways to actually generate returns at, or above, the cost of capital. These volumes can be assumed to be far greater than is available for Australian train operators—even if train operators captured 100 percent of the market.

4. Improving the efficiency of heavy vehicle infrastructure charges

Under the current NTC administered heavy vehicle charges, approximately 70 per cent of total heavy vehicle road use revenue is derived from fuel-based charges and 30 per cent from registration charges (BTRE 2003). Current heavy vehicle charges recover, from users, the total costs (current expenditure) attributed to them, albeit with over-recovery from smaller heavy vehicles, in aggregate, and under-recovery from larger heavy vehicles, in aggregate (BTRE 2003a). The life-cycle model based empirical evidence presented in section 2, however, implies that the costs of heavy vehicle road use vary significantly according to road standard and the volume of heavy vehicle traffic. On higher standard roads avoidable road wear costs are much lower than current charges; while on many rural roads current charges probably under-recover avoidable road wear costs.

Benefits of differentiated charges

Arguably, then, net benefits from reforming heavy vehicle charges would result from:

i. varying charges across the road network according to axle load and road standard/location—providing heavy vehicle operators with more accurate signals about the cost of their road use; and
ii. linking (heavy vehicle) road-use related revenue more directly to road investment.

The gains from an axle-loading based road wear charge that varied with road standard would mainly arise from changes in the distribution of heavy vehicle road use across the network and changes in the axle configuration of heavy vehicles.

For the United States, Small et al. (1989) estimated that most of the economic gains obtained from charging heavy vehicles on the basis of axle loads derived from increased use of vehicles with more axles. For Australia, the potential gains from changes in the heavy vehicle mix, arguably, would be smaller because existing heavy vehicle mass and dimension regulations, together with the importance of fuel costs in overall operating costs, already provide strong regulatory and financial incentives to use optimal axle configurations for larger masses. On non-urban highways, for example, six-axle articulated trucks and, increasingly, B-doubles are the most common vehicle configurations, and probably the most efficient axle–mass combinations.

Potentially larger gains may be derived from shifts in the pattern of heavy vehicle road use—away from lower standard, higher marginal cost roads to higher standard, lower marginal cost roads—induced by application of differentiated axle-load road wear based charges. Such charges may have significant flow-on effects for industries that rely heavily on road transport services on higher cost roads, particularly the agricultural sector, where heavy vehicles must use lower standard rural roads to transport produce from farm gate to market.

Shifts to more appropriate axle–mass vehicle configurations and changes in pattern of heavy vehicle road use, away from higher cost to lower cost roads, may engender further savings in future road investment needs. Increased investment in more durable pavements, on roads used more intensively by heavy vehicles, could, because of economies of scale in durability, result in greater savings in pavement maintenance costs. Potentially, there could also be some savings in otherwise warranted future investment expenditure on roads which experienced reductions in heavy vehicle traffic. However, the potential gains here may also not be large, as current road investment practices already aim to minimise the present value sum of current construction and future road maintenance costs, subject to current budget constraints and expected future heavy vehicle traffic volumes.

The BTRE has not estimated the net benefits of implementing axle-load based heavy vehicle charges in Australia.

Presently, there is no direct link between revenue from (heavy vehicle) road user charges and road expenditure—revenue from the road user charge is treated as part of general government revenue and road expenditure funded from annual appropriations. In principle, the benefits from explicitly linking road use revenue to investment could come from two principal sources. Firstly, more timely investment—for example, under the current approach, road investment may be sub-optimal due to government budget constraints. Linking road charges to investment and allowing road managers to borrow against future revenue would arguably permit not only more timely, but also more appropriate investment, in terms of pavement durability. Secondly, financial discipline on road project investment—that is, only road investment projects where costs could be recovered from users would be undertaken. For those roads deemed socially desirable but unable to recover costs, explicit government financing would be required.

This issue is broader, however, than just heavy vehicle charging and would entail significant changes to the current institutional arrangements governing the management of roads.

Charging for cost recovery

Specific axle-load related road wear charges will not recover all of the costs of administering and maintaining roads, nor the cost of providing the road. On high standard roads, road wear is only a small share of total costs and full cost recovery will necessarily require an additional charge. However, there is no unambiguously correct rule, from a cost perspective, for allocating joint fixed costs between road users, and a range of cost recovery options are available. Economic theory recommends Ramsey (inverse elasticity) pricing as the most efficient means of recovering fixed costs from across different users, however, as already highlighted in sections 1 and 2, strict Ramsey pricing, with its high information requirements, is unlikely to be feasible. Nevertheless, there are charging options that may be less distorting than others. Some more notable options include:

- Retaining the fuel excise charge to recover common costs.

BTRE (2003a) emphasised that the fuel-based road use charge does not provide a good signal to optimise road wear. Fuel excise is, however, an effective road cost recovery instrument as it is administratively simple to collect and may also be an approximate indicator of capacity to pay—total heavy vehicle operating costs increase with vehicle size, albeit at a decreasing rate, hence a fuel excise based cost recovery charge would be proportionately higher on larger vehicles. (Appendix II outlines approximate Ramsey pricing approaches used to recover costs in other transport modes, and discusses the fuel excise in this context.)

- A distance–capacity (PCU-km) charge

A PCU-km based charge is another option for recovering fixed costs from heavy vehicles. Such a charge might be more easily understood by road users as an infrastructure cost related charge and, arguably, also reflect the higher capacity to pay of heavy vehicles. In addition, to the extent that there is congestion in the non-urban environment, the charge can be viewed as reflecting short-run marginal costs. However, a PCU-km charge would be more administratively difficult to collect than a fuel excise based charge and it is arguably less efficient.

- A distance-based (VKT) charge

A purely distance-based (VKT) charge is yet another option for recovering fixed costs from heavy vehicles. It will increase proportionally with vehicle use, but not vary with vehicle size and so be less efficient than a fuel excise based charge. It too is also likely to be more administratively difficult to collect than a fuel excise based charge.

- Role of registration charges.

Registration charges are likely to still be required to ensure continuity with State/Territory based registration charges for light commercial vehicles. Additionally, public safety concerns mandate some minimum standard of vehicle roadworthiness, and so vehicle registration charges, that at least cover the administrative costs of registration, are likely will remain a component of charges paid by heavy vehicles. Current heavy vehicle registration charges, which increase progressively with vehicle size, are not necessarily an accurate indicator of willingness to pay and may lead to sub-optimal vehicle choice, especially amongst low utilisation vehicles where the registration charge will be a much higher proportion of total road use charges. Recovering costs primarily through vehicle registration is likely to be less efficient than fuel excise based charges.

Implementation issues

Implementing axle-load related road wear charges, differentiated by road type/location would require further research into the costs of heavy vehicle use across the network and application of technology to measure both axle loads and specific road use.

Finely differentiated axle-load related road wear charges are unlikely to be feasible in the near term. In the medium to long-term, advances in technology may improve the feasibility of differentiated charging, although some degree of aggregation, across road types, is still likely to be necessary. Possible options might include differentiating between high and low standard roads and using some type of mass-based charge to approximate axle-load road wear costs, like the New Zealand Road User Charges scheme. Even differentiating roads into low/high standard roads would require some form of location–measuring technology, such as Global Positioning System technology, to accurately charge vehicles for use of different standard roads. Using mass as a proxy for axle load is also far from perfect[7] and some form of graduated mass-distance charge—like the New Zealand Road User Charges scheme—would be required. Structuring mass-distance charges correctly within and between heavy vehicle classes would be important to ensure that the scheme provided operators with incentives to choose the most appropriate axle configuration, yet not over-charge heavy vehicles.

User acceptance could be a significant issue if charges were to be based on 'life-cycle model' results. Current expenditure is clearly understood and, notwithstanding differences in definitions across jurisdictions, reasonably accurate. Model-based estimates, however, depend greatly on empirical estimates of the relationship between pavement performance and (heavy vehicle) road use, and assumptions about unit maintenance costs and optimal road maintenance strategies. The distributional implications of mass-distance charges, which would imply higher charges on lower standard roads—including most rural roads—would further complicate user acceptance of life-cycle based charges.

5. Improving the efficiency of rail freight infrastructure charges

Rail infrastructure prices are set in an environment that, historically, has been totally different from road-user charges. The mandating of access, and the railway and train operator privatisations of the 1990s, have had two consequences for comparing rail and road infrastructure charges. First, the mandating has sharpened the focus on developing principles for levying charges on "external" users. The system of levying charges has brought the management of railway infrastructure closer to that applied to roads, by setting explicit charges for infrastructure use—a concept that had previously been buried within railway accounting.

---

[7] Weigh-in-motion data shows that even for heavy vehicles of the same total gross mass, the distribution of the load can change the total axle-load by more than a factor of two.

Railway privatisations over the past decade have highlighted the practical, commercial and policy issues in recovering costs through explicitly calculated infrastructure charges. However, the privatisations have highlighted a key difference between road and rail: that, as indicated above, the generation of railway revenue results in a return on investment that is too low to justify infrastructure renewal on most of the railway network. For this reason, it is crucial for the railway infrastructure charges to balance efficiency in production and efficiency in consumption. In reality, charges that would facilitate production are compromised by the mandated access policy objective. That is, regulations that facilitate third-party access to infrastructure may undermine the objectives of cost recovery, through siphoning off the benefits of investment to third parties.

A related issue is that, in some cases, structural regulation has split the ownership of integrated railways. Here, the infrastructure manager sets the access charges and invests in the infrastructure for the benefit entirely of third parties. However, while the access charging signals may direct the use of the infrastructure in specific ways, there is no guarantee that the train operators will respond to the investment in the way that is intended. Put another way, the below-rail economics may signal that infrastructure managers undertake specific investment and encourage complementary track usage. However, under vertically-separated structures, the return on investment may be sub-optimal unless train operators respond exactly in the way assumed by infrastructure managers.

6. Freight externalities

6.1 Issues in charging for externalities

Any consideration of whether to impose charges for freight externalities involves a number of important questions. These include:

- Is the conceptual basis of the externality sufficiently clear and agreed?
- Is charging most appropriate? That is, is it likely to generate a more efficient outcome than existing approaches, is it consistent with other policy settings and can it be applied equitably to all relevant infrastructure users?
- Can the externality be measured and valued with sufficient accuracy to sustain a pricing approach?
- Is charging technically feasible?

The next section assesses each of the four major freight externalities against the background of these questions. In doing so, it expands on the brief discussion along these lines in BTRE (2003a). Most of the discussion relates to road freight externalities, often the main focus of policy and general interest. However, many of the issues apply similarly to rail freight externalities.

Accidents

A number of approaches have been taken in identifying and measuring the external cost of road accidents. However there is no clear consensus at this time on the nature of the externality, with the consequence that there is likely to be an insufficient basis for both reliable measurement and charging. This is quite apart from the question of whether charging is likely to represent a least cost approach to change externality-causing behaviour (Martin 2005). Some of the main rationales are as follows.

'Human capital' cost of accidents less the cost of insurance

As indicated above, BTE (1999) assumed the external accident cost of inter-capital road freight transport was 50 per cent of the total human capital resource costs of accidents, as derived from BTCE (1994). This proportion was the assumed difference between the financial cost of insurance and the total cost estimate. The human capital approach involves measuring output or productivity loss resulting from accidents. Nevertheless, as noted by Gomez-Ibanez (1997), most of the productivity losses and pain and suffering from road crashes are in fact borne collectively by motorists and their families. While these losses may 'flow through' to the wider economy in a range of ways, characterising all of the measured non-insurance cost of road accidents as an externality is likely to imply double-counting.

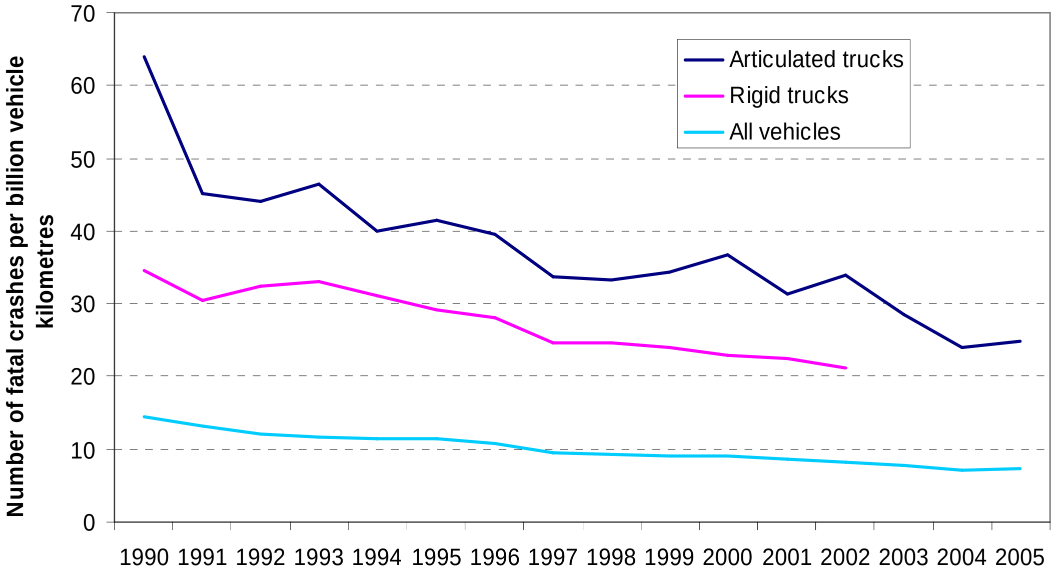
"Road users ignore risk and consequences to themselves or others"

An alternative approach would be to argue that road users systematically underestimate the riskiness of driving and so impose entirely unanticipated costs on themselves and others. While this may be true of individuals–and these individuals may be more likely to belong to some age groups rather than others—it is not clearly so for road users as a whole. Meyrick (1994) argues that such an approach underestimates costs internalised by drivers, at least most of whom have already weighed up the difference between the true cost they may incur in a traffic accident and the compensation that they would receive through the insurance system, in making the decision to drive. Meyrick argues that a value below 20 per cent of the total cost of accidents is necessary to avoid any double-counting, with pedestrians and motor vehicle passengers (but not drivers) assumed not to have taken account of the risk of crash involvement.

"Trucks cause a disproportionate number of accidents"

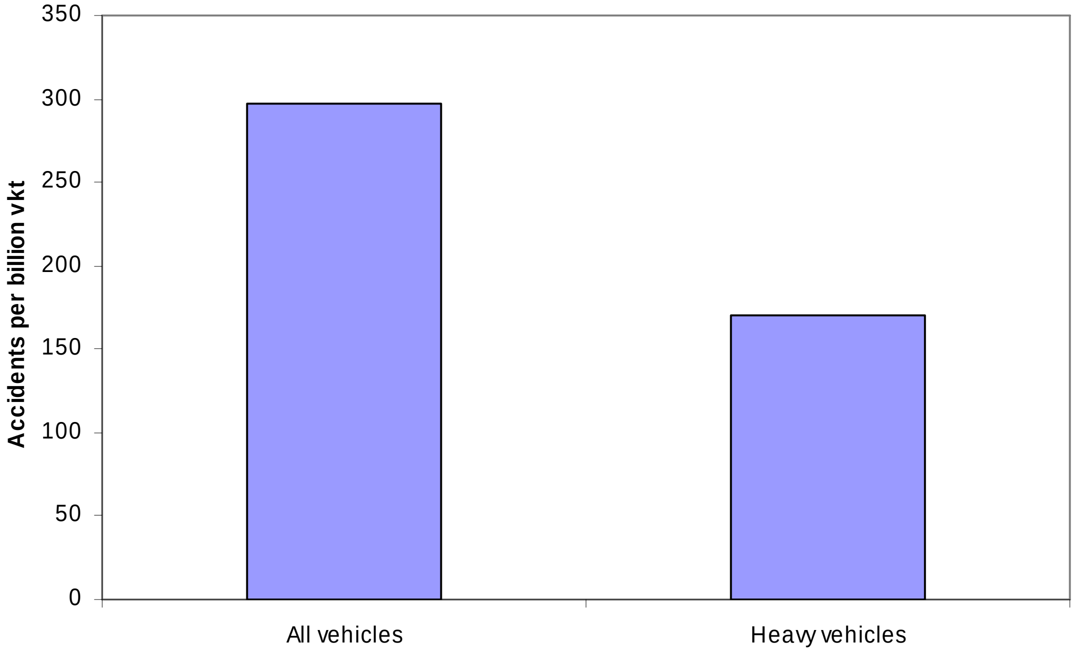
Across the entire road network, the rate of involvement in fatal accidents is significantly higher for heavy vehicles than for other vehicles (Figure 6.1). However, this is attributable to the relative mass and size of heavy vehicles in a multi-user road system. Evidence suggests that heavy vehicle involvement in accidents on major inter-capital corridors is well below that of all vehicles (Figure 6.2).

FIGURE 6.1 FATALITY ACCIDENT INVOLVEMENT, 1989–2005



Source ATSB (2006).

FIGURE 6.2 TOTAL ACCIDENT RATES ON INTER-CAPITAL CORRIDORS, 1997–2001/04



Source Data from state road agencies collected for BTRE forthcoming.

Nevertheless, regardless of issues of cause and fault, it is reasonable to argue that heavy vehicles impose an external cost on other road users, if the costs of accidents involving heavy vehicles fall disproportionately on those other users. Victorian data, accessed for BTRE (forthcoming), suggests that around 10 per cent only of private costs are directly borne by the occupants of heavy vehicles.

Arguably, part of this disproportionate distribution of direct costs will be redistributed through legal and criminal sanctions and through insurance.

"Accident rates are a function of increasing traffic"

Do accident rates increase with traffic levels? If so, then arguably the additional vehicle imposes an additional expected accident cost on all other vehicles in the traffic stream, in a similar manner to congestion. While higher accident rates can be related to higher traffic levels, accidents are multi-factorial in character (i.e. any and all of road environment, vehicle, road user behaviour and driving condition factors may be involved) and are also comparatively rare as events, relative to the number of traffic movements. In addition, there is some evidence that accident severity reduces as accident rates increase, due to declining road speeds and congestion. This would complicate any estimation of the external cost involved.

BTRE (forthcoming) estimates the external accident costs of heavy vehicle inter-capital road use, based on two main assumptions. The first is that, on non-urban roads, multiple vehicle accidents are proportional to the number of vehicle pair interactions.[8] The second assumption is that, on average in accidents involving heavy vehicles, the cost to each heavy vehicle operator is less than the average total cost of such accidents divided by the average number of vehicles involved in the accident (see discussion above). The study estimates an external accident cost of less than 1 cent per heavy vehicle kilometre on four-lane divided roads and between 3 and 6 cents per heavy vehicle kilometre on two-lane single carriageway roads. The analysis also assumes constant speeds as traffic volumes increase. No estimates are made for urban environments, where speeds slow as road space becomes congested and average accident severity may, as a result, be lower.

This analysis suggests that heavy vehicle externalities as a function of increasing traffic may merit further investigation as a rationale for pricing. However, the significant variation in cost between divided and undivided roads points up the importance of location- or road type-specific rather than aggregated charging.

Greenhouse

Notwithstanding some ongoing debate among climate scientists, the concept of a greenhouse gas or climate change externality is readily understood as the unpriced impact of carbon dioxide equivalent emissions on the climate patterns that future generations around the world will experience—'global warming'.

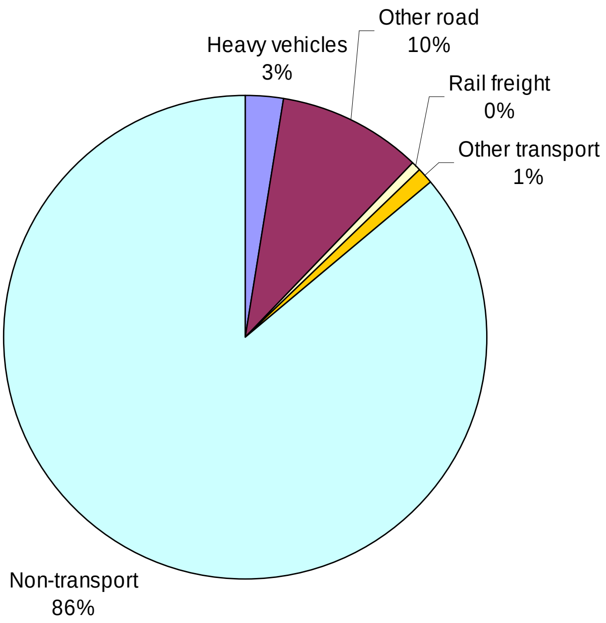
Measurement of greenhouse gas emissions from transport is comparatively straightforward. Greenhouse emissions are a direct function of fuel use and so

---

[8] Single vehicle accidents are assumed proportional to the number of vehicles.

monitoring of fuel use can provide a basis for reliable estimates (BTRE 2005a). Heavy vehicles contribute 14 per cent of total transport sector greenhouse emissions (3 per cent of total Australian emissions), while rail freight contributes less than half of one per cent (AGO 2006, BTRE 2005a).

FIGURE 6.3 AUSTRALIAN GREENHOUSE EMISSIONS, 2003



Source BTRE (2005a) and AGO (2006).

Valuation is more problematic, in the absence at the present time of a well-established international market for carbon dioxide equivalent emissions. Without consensus on the likely economic cost associated with future climate change—a preferred approach—values may reflect the estimated cost of meeting a given abatement target and are subject to change, both with change in the magnitude of the target and the pace of technological innovation. CSIRO/ABARE/BTRE (2004, p. 26) used a value of $10 a tonne, in order to assign a notional value to greenhouse gas reductions associated with increased biofuels use. This value was considered consistent with the upper bound of the cost to government of abatement purchased under round 1 of the Australian Government Greenhouse Gas Abatement Program. Other generally higher values are also quite commonly used. Australasian Railway Association (2005) chose a value of $20 a tonne, "in an attempt to take a more forward-looking view".

Uncertainty and potential arbitrariness of valuation would be one of the threshold issues in considering a pricing approach. However, the central and closely related issue is that charging for freight transport greenhouse emissions could only take place within a suitably comprehensive agreed international and national greenhouse pricing framework.

Pollution

As with greenhouse, the concept of a transport pollution externality is clearly articulated as the impact on community health (i.e. additional morbidity and mortality) arising from additional transport activity.

However, in contrast to greenhouse, the impact of local pollutants such as nitrogen oxides and particulate matter is not a constant function of fuel use. Accurate measurement is therefore a more challenging question. Pollution exposure varies by location, with population density the major factor and also with differences in driving conditions and behaviour, weather conditions, engine type and maintenance performance. Nevertheless, Watkiss (2002) provides exposure estimates for Australian cities (on an inner capital city, outer capital city, other urban and non-urban basis) and BTRE (2005b) provides aggregate estimates for metropolitan and regional Australia (albeit that both are based heavily on international source estimates, as indicated below).

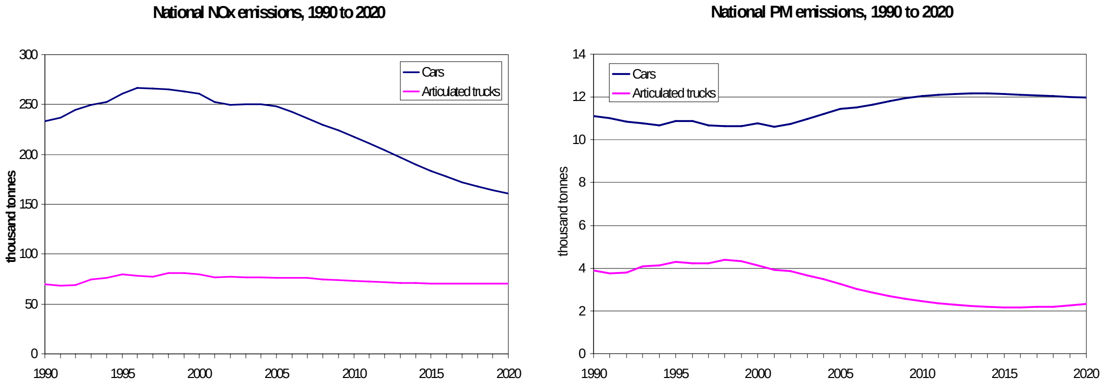
Valuing the community health impact of pollution exposure involves both epidemiological modelling and economic valuation of additional mortality and morbidity. BTRE (2005b) adapts to the Australian context a model developed using international data, in order to estimate lower and upper bounds for the health impact of motor vehicle pollution.

For accurate pollution charging to be feasible, it would be necessary to track vehicle movements with considerable accuracy. Otherwise there would be no option for road users to alter their behaviour to minimise the charge. If, in the future, area congestion charging were to be implemented on a national basis, involving, say, the fitting of Global Positioning System-type technology to individual vehicles, there could be potential for accurate pollution charging as an add-on feature.

The existing Australian policy approach involves regulating a level of road transport emissions through vehicle and fuel standards, progressively tightening these standards through alignment with international practice. Regulations must pass a cost-benefit test, i.e. that benefits to society exceed costs to society. It would be necessary to ensure careful dovetailing between any future charging system and the ongoing regulatory regime. In particular, this underscores the importance of accuracy in measurement of external costs. If, for example, non-urban road users were proposed to be charged, it would first be necessary to establish that they are not ‘overcharged’ currently, in complying with nationally uniform regulations that target what is primarily an urban pollution problem.

Road transport is the principal source of nitrogen oxides and carbon monoxide in capital city airsheds and a significant source also of particulate matter emissions (BTRE 2005). Nevertheless, consistency in policy approach with regard to non-transport sources of local pollution would also be a necessary consideration. In addition, the importance of the light vehicle contribution to road transport-sourced pollution (see Figure 6.4) could make any charging approach that applied only to heavy vehicles difficult to sustain.

FIGURE 6.4 NITROGEN OXIDES AND PARTICULATE MATTER EMISSIONS FROM CARS AND ARTICULATED TRUCKS



Source BTRE (2003b).

Finally, would even accurate charging be a least cost approach in addressing inefficiently high pollution? Research conducted in New Zealand suggests that other approaches to supplement regulation could also be considered. With 10 per cent of the vehicle fleet contributing 40 per cent or more of carbon monoxide (NIWA Science, 2004), hydrocarbon and nitric oxide emissions, the cost-effectiveness of improved emission monitoring might also be investigated.

Congestion

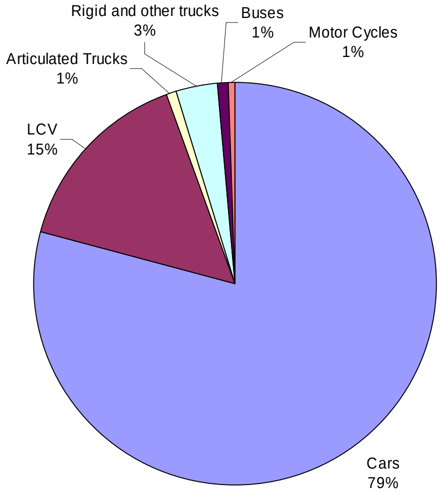
The marginal external cost of congestion is well established in the economics literature as the cost that an additional road user entering a congested traffic stream imposes on all other road users.

In effect, what is measured is the contribution the individual vehicle makes to the delay experienced by all road users. Using engineering concepts such as the speed-flow curve and economic concepts including that of the value of time, the marginal external cost of congestion can, in principle, be reliably measured. While in practice real-time location-specific network monitoring is necessary to measure changes in levels of congestion, this may become the norm in Australian cities over the next decade.

Charging is also technically feasible, given advances in technology for tracking vehicles by location. Social and political feasibility is less clear. It has been argued, for example, that the community tolerates the congestion that results from excess travel demand as a trade-off for the perceived advantage of unrestricted access to roads (Bray 2003).

It could, however, be difficult to sustain a case for congestion charging of heavy vehicles, in the absence of an all-vehicles scheme. In metropolitan areas, as shown in Figure 6.5, heavy vehicles account for around 4 per cent of vehicle kilometres travelled (BTRE 2003b). Thus any scheme to charge heavy vehicles only would penalise these vehicles, without providing any opportunity to both pay the charge and benefit from higher travel speeds and faster travel times.

FIGURE 6.5 URBAN VEHICLE TRAVEL BY VEHICLE CLASS, 2002



Source BTRE (2003b).

6.2 *Externality magnitudes*

BTE (1999, Appendix III) estimated the costs of transport for a notional representative inter-city route for rail and road. The estimates included the costs of accidents, congestion, pollution and noise. For rail, the estimated total value of these costs was 0.054 cents per net tonne-kilometre (1997–98 prices). For road, the corresponding estimate was 0.394 cents per net tonne-kilometre. The two estimates comprised, respectively, 1 per cent and 7 per cent of the estimated door-to-door full container load cost (4.82 cents and 5.53 cents per net tonne-kilometre respectively).

The largest component of these estimated costs was accident costs (0.03 cents per net tonne-kilometre for rail and 0.32 cents per net tonne-kilometre for road). The study assumed that, through insurance, trucks meet half of this cost and that similar arrangements apply in rail (see discussion under "Accidents" above). It follows that the estimate of total accident costs not internalised (i.e. not borne by operators) was 0.015 cents per net tonne-kilometre for rail and 0.23 cents per net tonne-kilometre for road, 0.3 per cent and 4.2 per cent of the total cost of hauling freight for rail and road respectively.

BTRE (forthcoming) estimates an average external accident cost of up to 3.4 cents per kilometre (2002–03 prices) on the inter-capital corridors linking the five mainland State capitals. Around 52 per cent of total heavy vehicle kilometres on these corridors are on divided roads. Thus the estimate falls midway between the estimates of 1 cent per kilometre on divided inter-capital roads and 6 cents per kilometre on undivided roads. The estimate is slightly lower than the BTE (1999) estimated external cost of 0.16 cents per net tonne kilometre, which equates to 3.8 cents per kilometre at 2002–03 prices. It is also substantially lower than the estimated external cost estimates of 0.64 cents per net tonne kilometre used in ARA (2005) and BAH (2001).

BTE (1999) did not quantify climate change costs associated with the two modes. BTRE (forthcoming), using an assumed value of $10 per tonne of CO2-equivalent emissions and an articulated truck emission rate of 1.4 kilograms per kilometre, estimates a climate change cost of variously between 1.2 and 1.5 cents per kilometre across the inter-capital highway links, or 0.06 to 0.08 cents per net tonne-kilometre.

In light of the foregoing, there appears no basis at this point to alter the essential implications from this work that, firstly, the external costs of inter-capital heavy vehicle road use are significantly higher than those of inter-capital rail freight and, secondly, both are quite small in comparison with the total costs of moving freight on these routes. A current BTRE project is refining and updating estimates of the costs of all major externalities in the inter-capital freight market, including urban parts of the relevant routes.

6.3 Where to for freight externalities charging?

As accidents, pollution and congestion externalities all vary significantly on dimensions such as location and time of day, any implementation of charging should desirably take place on a customised basis. Failure to do this would significantly blunt incentives to alter externality-inducing behaviour. This consideration, together with the comparatively small size of external costs, suggests that externalities charging of heavy vehicles would most appropriately be implemented in conjunction with a location-specific mass-distance and/or distance-capacity charging regime, rather than separately or in advance of it.

In addition, the concept of a heavy vehicle accident externality that is a function of increasing traffic levels requires further investigation, including extension to the urban environment, before it could be considered as a basis for pricing.

Congestion charging for heavy vehicles would desirably occur as part of any all-vehicles congestion charging scheme for particular locations. A charge for heavy vehicle congestion externalities exclusively would have limited benefits as heavy vehicles are a small proportion of the traffic stream and may already largely avoid peak travel periods. The charge might also be perceived as inequitable if light vehicles were not charged similarly.

REFERENCES

Airservices Australia 2006, *Charges for Facilities and Services*, Standard Contract Terms 1 January 2006. [http://www.airservicesaustralia.com/pilotcentre/avcharge/price/contract2006/std2006_3_jan.pdf]

Australian Bureau of Statistics 2005, *Survey of Motor Vehicle Use, Australia, 12 months ending 31 October 2004*, Catalogue no. 9208.0, ABS, Canberra.

Australian Greenhouse Office, 2006, *Australia's Emissions*, AGO, Canberra. [http://www.greenhousegases.gov.au/about_greenhouse_gases/australia's_emissions.html]

Australasian Railway Association 2005, *The Future for Freight*, Report prepared by Port Jackson Partners Limited and Access Economics.

Australian Rail Track Corporation 2001, *Access undertaking. Explanatory guide.*

Australian Transport Safety Bureau 2006, *Fatal Crash Database*, ATSB, Canberra. [http://www.atsb.gov.au/includes/apps/fatal_crash/fatalCrash.aspx]

Booz Allen Hamilton 2001, *Interstate Rail Network Audit*, Report prepared for the Australian Rail Track Corporation, Adelaide.

Bray, D. 2003, 'Road pricing – issues and options', *Smart Urban Transport*, February.

Bureau of Transport and Communication Economics 1990, *Pavement Management: Development of a Life Cycle Costing Technique*, Occasional Paper 100, BTCE, Canberra.

Bureau of Transport and Communication Economics 1992, *The Cost of Maintaining the Australian National Highway System*, Report 77, BTCE, Canberra.

Bureau of Transport and Communication Economics 1994, *Cost of Road Crashes in Australia – 1993*, Information Sheet 4, BTCE, Canberra.

Bureau of Transport Economics 1999, *Competitive Neutrality between Road and Rail*, Working Paper 40, Canberra.

Bureau of Transport and Regional Economics 2003a, *Land Transport Infrastructure Pricing: An Introduction*, Working Paper 57, Canberra.

Bureau of Transport and Regional Economics 2003b, *Urban Air Pollution from Motor Vehicles: Australian Trends to 2020*, Report for Environment Australia, Canberra.

Bureau of Transport and Regional Economics 2005a, *Greenhouse Gas Emissions from Australian Transport: Base Case Projections to 2020*, Report for the Australian Greenhouse Office, Department of the Environment and Heritage, August.

Bureau of Transport and Regional Economics 2005b, *Health Impacts of Transport Emissions in Australia: Economic Costs*, Working paper 61, Canberra.

Bureau of Transport and Regional Economics 2005c, *Container and Ship Movements through Australian Ports 2003–4 to 2023–24*, Working Paper 65, Canberra.

Bureau of Transport and Regional Economics 2006a, *Freight Measurement and Modelling in Australia*, Report 112, Canberra.

Bureau of Transport and Regional Economics 2006b, *Demand Projections for AusLink Non-urban Corridors: Methodology and Projections*, Working Paper 66, Canberra.

Bureau of Transport and Regional Economics forthcoming, *Road Impacts of Road-Rail Mode Shift Scenarios*.

CSIRO/ABARE/BTRE 2004, *Appropriateness of a 350 Million Litre Biofuels Target*, Report to the Australian Government Department of Industry, Tourism and Resources.

FreightInfo™ 1999, *Database of National Freight Flows 1998–99*, FDF Management Pty Ltd, Melbourne.

Gomez-Ibanez, J. 1997, 'Estimating whether transport users pay their way: the state of the art', in D.L. Greene, D.W. Jones and M.A. Delucchi (eds), *The Full Costs and Benefits of Transportation: Contributions to Theory, Method and Measurement*, Springer, New York.

Gomez-Ibanez, J. 1999, 'Pricing' in *Essays on Transportation Policy and Economics*, Brookings Institution, Washington DC.

Harvey M, 1999, *Road Pricing and Cost Recovery: An Economic Viewpoint*, Paper presented at the Road Funding, Pricing and Taxation Seminar, Adelaide, September 1999.

Martin, L. 2005, *External Accident Costs of Motor Vehicles Revisited*, Paper delivered to the 28th Australasian Transport Research Forum, 28-30 September 2005, Sydney.

Meyrick, S. 1994, 'Objectives of Road Pricing' in Cox, J. ed, *Refocusing Road Reform*, Business Council of Australia, Melbourne.

Meyrick and Associates, 2006, *National Intermodal Terminal Study*, prepared for the Department of Transport and Regional Services.

National Road Transport Commission 1998, *Updating Heavy Vehicle Charges: Technical Report*, September 1998, NRTC, Melbourne.

NIWA Science 2004, *On-road remote sensing identifies the worst vehicle polluters*.

Paterson, W. 1987, 'Road deterioration and maintenance effects: Models for planning and management', in *The Highway Design and Maintenance Standards Series*, The John Hopkins University Press, Baltimore, Ch. 9, p. 327–372.

Scherp, J., 2002, 'The new framework for access to the railway infrastructure in the EU', *Rail International*, October, pp. 2–10.

Small, K., Winston C., and Evans, C. 1989, *Road Work: A New Highway Pricing and Investment Policy*, Brookings Institution, Washington DC.

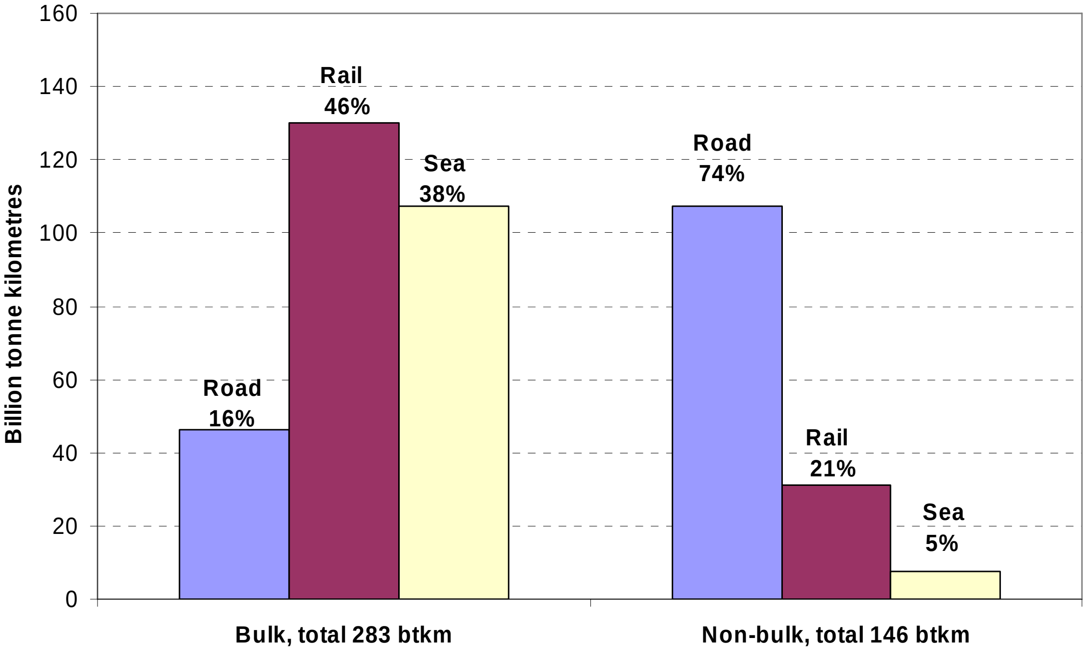
Watkiss, P. 2002, *Fuel Taxation Inquiry: The Air Pollution Costs of Transport in Australia*, Report No. ED44525 to Commonwealth of Australia, AEA Technology Environment, Oxford.

ZETA-TECH, 2000*, Trackshare - ZETA-TECH's model for determining and negotiating shared costs or open access charges on railway lines*. [http://www.zetatech.com/CORPQIII44.htm]

APPENDIX I HOW LARGE ARE AUSTRALIAN 'ROAD-RAIL' MARKETS?

The bulk commodity transport task, primarily minerals, totalled 283.4 billion tonne-kilometres in 2002–03 (BTRE 2006a). As Figure I.1 shows, rail and sea combined transported 84 per cent of this freight (BTRE 2006a). In coal and other mineral markets, modal competition at the margin occurs largely between rail and sea, rather than between rail and road. In contrast, in agricultural and other non-mineral markets (e.g. livestock, timber and fertiliser), rail has historically lost mode share, mostly to road and often to a point where it would be unrealistic to characterise the current market as a 'road–rail' one. The exception is grain, where rail remains dominant, despite its share having decreased from 80 per cent to 65 per cent (in tonnage terms) between 1960–61 and 1999–2000 (BTRE 2006a). Growth in grain production is now largely absorbed by road.

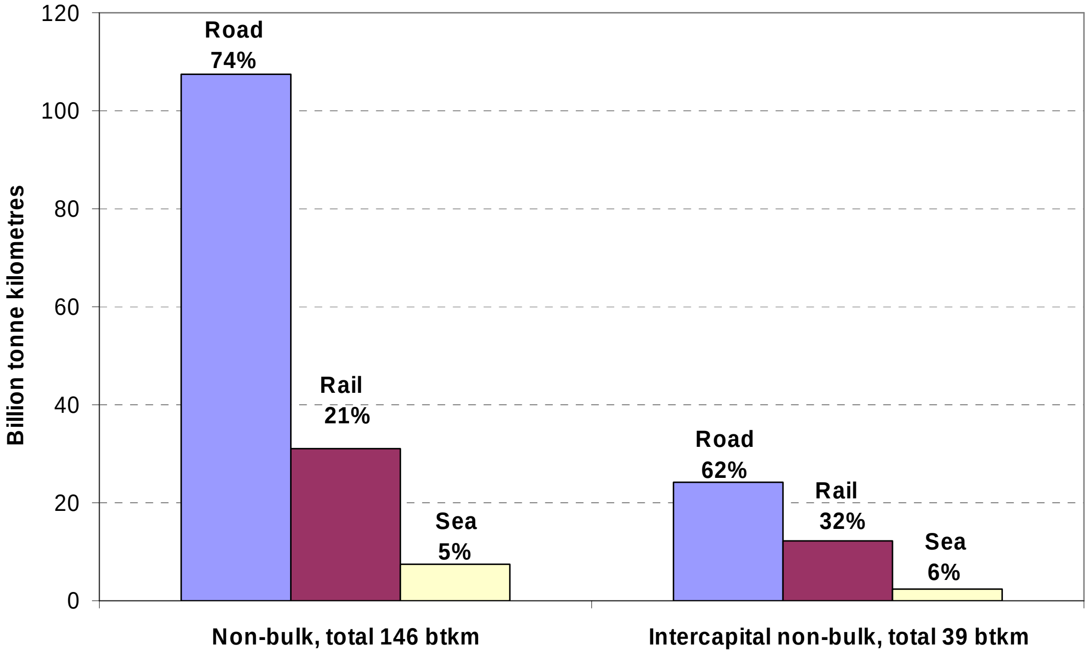
FIGURE I.1 BULK AND NON-BULK FREIGHT, 2003



Source BTRE (2006a).

Road transports an estimated 73.5 per cent of the smaller Australian domestic non-bulk freight task (146.3 billion tonne-kilometres in 2002–03), with rail, sea and air shares comprising 21.2 per cent, 5 per cent and 0.2 per cent respectively (Figure I.2). Where it exists, most modal competition occurs between road and rail, although sea is significant in the 'east-west' market between eastern seaboard capital cities and Perth. In addition, air freight is important for low-volume high-value goods that may otherwise be transported by road.

FIGURE I.2 NON-BULK FREIGHT, 2001



Source BTRE (2006a).

In urban areas, the combination of often dispersed origins and destinations and comparatively short distances provides a natural advantage to an inherently flexible road freight mode, with the consequence that the rail freight share of capital city freight is negligible. However, with stevedoring firms, port authorities and governments planning to increase the use of rail transport between capital city ports and major terminals, the capital city 'import-export' market is a small but growing road-rail market. Total metropolitan freight to and from ports is estimated to be around 807 million tonne kilometres[9], around 2.4 per cent of the total metropolitan freight task and 0.2 per cent of the total national freight market. At present, around 16 per cent of this task is undertaken by rail, primarily in Sydney (Meyrick 2006).

Road transports an estimated 67 per cent of non-urban non-bulk domestic freight. As in the cities, dispersed origins and destinations provide road with a strong competitive vantage point. However, other things equal, rail's competitiveness improves with increasing distance, as there is greater opportunity for relatively lower unit line-haul costs to offset relatively higher pick up, delivery, loading and unloading costs.

---

[9] BTRE estimate based on the amount of freight passing through capital city ports with ultimate destination or origin in that metropolitan area (BTRE 2005c) and assuming that for each city the average distance travelled to/from the port is the same as the average intracity freight distance (from ABS 2002).

The largest non-bulk road-rail (or road-rail-sea-air) market involves inter-capital freight. The six corridor[10] inter-capital freight market comprised an estimated 41.8 billion tonne-kilometres in 2002–03, or 29 per cent of the total non-bulk market. In addition, as not all freight on inter-capital routes is 'city to city' and as inter-capital routes are not the only interstate routes, the inter-capital market can be seen as part of a larger interstate non-bulk freight market (79 billion tonne-kilometres). However, due to the absence of non-inter-capital interstate rail infrastructure, not all of this traffic should be seen as currently contestable between road and rail.

A third non-bulk market type involves intermodal freight on intrastate networks in Queensland particularly, but also in Victoria and to some extent in Western Australia (Meyrick 2006). Rail links in these markets operate on a gauge other than the standard gauge used in the inter-capital market. The total non-bulk freight task in these areas is estimated at around 3 billion tonne kilometres, 2 per cent of the national non-bulk freight task (FreightInfo™ 1999). Around 85 per cent of this freight is on the Brisbane–Cairns corridor.

---

[10] The corridors are Melbourne-Sydney, Sydney-Brisbane, Sydney-Adelaide, Melbourne-Adelaide, Melbourne-Adelaide and Eastern States-Perth. Adelaide-Darwin, where rail services commenced in January 2004, is not included.

APPENDIX II ALLOCATING FIXED COSTS ACROSS HEAVY VEHICLE CLASSES: APPROXIMATE AD VALOREM[11] CHARGES

Ramsey pricing and ad valorem charges

As explained in the submission, after charging heavy vehicles their marginal costs of road wear and congestion, the amount of revenue collected is likely to fall well short of the amount of road costs allocated to heavy vehicles. If the aim is to recover the shortfall from heavy vehicles with the least possible negative impact on the economically efficient resource allocation, 'Ramsey pricing' offers an in principle solution.

To implement Ramsey pricing, the heavy vehicle sector has to be divided into sub-groups having differing demand and/or cost characteristics. Higher charges would then be imposed on sub-groups with greater ability to pay and conversely lower charges on sub-groups with lesser ability to pay. Charging prices above marginal costs reduces economic efficiency (subject to the usual welfare economics caveats). However, by allocating contributions to the revenue target among sub-groups in accordance with their relative levels of ability to pay, the overall impact on resource allocation is kept to a minimum.

Ramsey pricing is the result of solving the constrained optimisation problem: given a set of markets each with its own demand and cost function, what prices should be charged to maximise economic efficiency subject to the constraint that a given amount of revenue be raised on top of costs? In the case where the demand curves are assumed to be independent, the set of Ramsey prices is given by:

$$\frac{p_i - MC_i}{p_i} = -\frac{k}{\varepsilon_i}$$

where:

p_i = price charged to sub-group i

MC_i = marginal cost for sub-group i

ε_i = elasticity of demand for sub-group i

---

[11] Ad valorem — Latin: according to the value. The term is used in commerce in reference to certain duties, called ad valorem duties, which are levied on commodities at certain rates per centum on their value. (http://www.lectlaw.com/def/a155.htm) An ad valorem tax contrasts with an excise which is levied as an absolute amount on the quantity of the good sold.

k = a constant between zero and one set to raise the required amount of revenue. Zero corresponds to competitive changing and one to monopoly charging.

One objection to Ramsey pricing is that it requires accurate knowledge of elasticities of demand to implement. Estimating demand elasticities can be difficult due to data limitations and will be subject to change over time. Perfect Ramsey pricing is certainly impossible, both because of lack of accurate knowledge of demand elasticities and also because of limited ability to segment the market into sub-groups with differing elasticities. However, Ramsey pricing does not necessarily have to be perfect to achieve a more economically efficient outcome than the alternatives.

Another objection is that Ramsey prices can be perceived as being inequitable because the differing treatment accorded to different groups of consumers cannot fully be explained by cost differences.

Demand elasticities for road transport would be expected to be higher for road transport undertaking tasks in competition with rail or coastal shipping. Elasticities would be lower for trucks carrying higher-value freight. It is not possible in practice to sub-divide the industry to take advantage of these differences in elasticities for charging purposes. However, ability to pay varies with costs and revenues as well as with elasticities. Larger trucks, having higher costs, have greater ability to pay, in absolute terms. Vehicle size is a characteristic that is clearly identifiable, and a charge that increases with vehicle size is not likely to appear inequitable.

In the Ramsey price formula, if all sub-groups have the same elasticities the price–marginal cost mark-up, $(p - MC)/p$, would be the same for all-groups. The result would be a constant ad valorem charge on marginal costs. If the charges were levied as fixed dollar amounts for each sub-group, then the amounts, in absolute terms, would be larger for sub-groups having larger marginal costs.

For each size of truck, expansion of the fleet means additional trucks having broadly the same costs. So average and marginal costs for any given vehicle size can be assumed to be constant with respect to fleet size, which implies that marginal cost equals average cost (AC). Hence, if demand elasticities were assumed to be constant across vehicle size classes, the set of prices consistent with the Ramsey formula would be set to keep $(p - AC)/p$ the same for all vehicle sizes.[12]

---

[12] Some may object to using the term Ramsey pricing to refer to a set of charges that varies across vehicle sizes in way that simulates a constant ad valorem charge when the elasticity of demand is assumed not to vary. However, the charges still vary with *ability to pay* and are consistent with the Ramsey price formula. The ability to pay in absolute terms of any

The underlying assumption that elasticity of demand is constant across vehicle sizes is open to question. Smaller vehicles would tend to carry more valuable freight and larger vehicles are more likely to be in competition with rail, which might suggest an increasing elasticity with respect to vehicle size. On the other hand, for larger vehicles, transport costs are smaller on a per-tonne-of-freight basis, which would make for a diminishing elasticity of demand for transport because transport costs are less significant relative to other costs. In the absence of any concrete evidence to the contrary, it could be held that a general assumption that the elasticity of demand is approximately constant across truck sizes for the industry as a whole is not unreasonable.

The shipping and aviation industries provide examples of charges that increase with the size of the transport unit in a way that approximates to ability to pay, without bearing any relationship to the costs of providing the services charged for.

Approximate Ramsey pricing in other transport modes

- Ports charge 'channel fees', to cover the costs of providing shipping channels, based on the gross registered tonnages of ships, each time a ship visits the port. The marginal cost of a ship passing through a channel is zero regardless of the draught of the ship. A charge levied on the gross registered tonnage of the ship reflects the greater ability to pay *in absolute terms* of larger ships. In some cases, discounts may be offered for particular types of ships or ships not carrying cargo, again reflecting differing abilities to pay. Ports justify channel fees that increase with ship size on the grounds that larger ships require a deeper channel. While this argument has no validity from an economic efficiency viewpoint, it appears equitable.
- Airservices Australia levies enroute charges on aircraft using Instrument Flight Rules (IFR) for the safety benefits derived from receiving direction from air traffic control while flying in controlled air space enroute between airports. The charges are levied on distance and weight as follows:
  - For aircraft with a maximum take-off weight up to 20 tonnes: Rate × distance × weight in tonnes / 100.
  - For aircraft with a maximum take-off weight of 20 tonnes or more: Rate × distance × the square root of weight / 100.

The 'rates' differ for the two weight categories (Airservices Australia 2006).

Clearly, aircraft weight bears no relation to the cost of providing the service. The use of the square root of weight for larger aircraft suggests that the variation in rates of charge has been designed to mirror the cost curve for

---

individual production unit is related to the size of the unit, as represented by its marginal cost, as well as the elasticity of demand for the services it provides.

aircraft, which increases at a decreasing rate due to economies of scale. Since neither the operating costs of aircraft nor revenue earned are available to Airservices Australia, it not possible to levy an ad valorem charge. The weight-based charging system provides an approximation to an ad valorem charge.

Practical application to heavy vehicles

The cost curve for heavy vehicles would increase with truck size at a decreasing rate reflecting economies of scale. Measuring truck size (S) by either net or gross tonnage, a curve could be fitted to the costs of a given trip by different sized trucks in the form $Cost = aS^b$ where a is a constant and b is the elasticity of cost with respect to size. The value of b will lie below one and probably above a half. Figure II.1 shows the shape of such a curve.[13]

FIGURE II.1 TRUCK COSTS WITH RESPECT TO VEHICLE SIZE

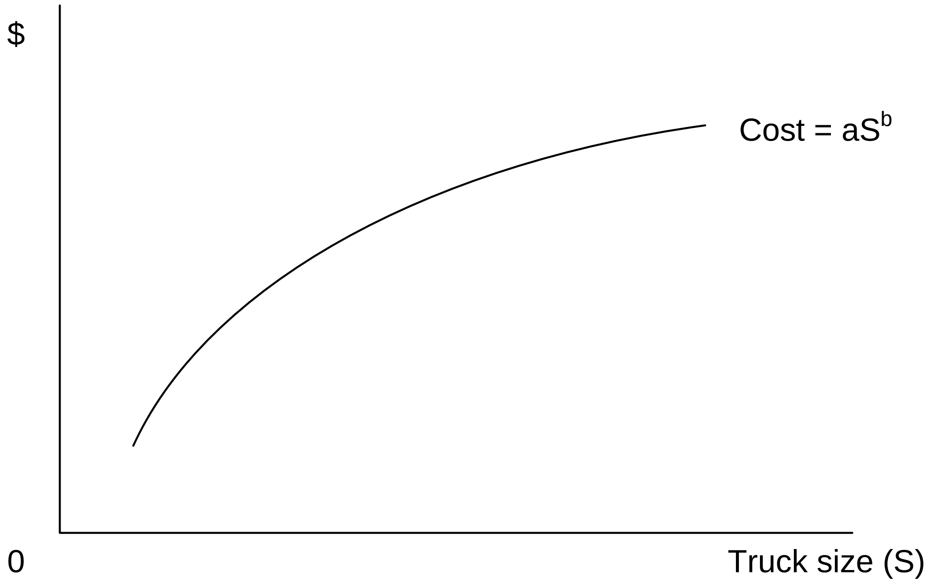


Figure II.2 compares an ad valorem charge levied on truck operating costs with charges levied per vehicle and per passenger car unit (PCU, assumed here to be proportional to tonnage). All three sets of charges are set to raise the same amount of revenue. If the objective was to charge according to ability to pay and the constant elasticity of demand assumption holds, then a per-vehicle charge overcharges small vehicles and undercharges large vehicles. The converse applies to a charge per passenger car unit because it fails to reflect the economies of scale in truck size.

---

[13] Note this curve is for the *total* operating cost of the truck per kilometre. The curve for cost per tonne-kilometre (average cost) would be downward sloping with a coefficient (elasticity) of b–1.

FIGURE II.2 HEAVY VEHICLE CHARGING OPTIONS WITH RESPECT TO VEHICLE SIZE

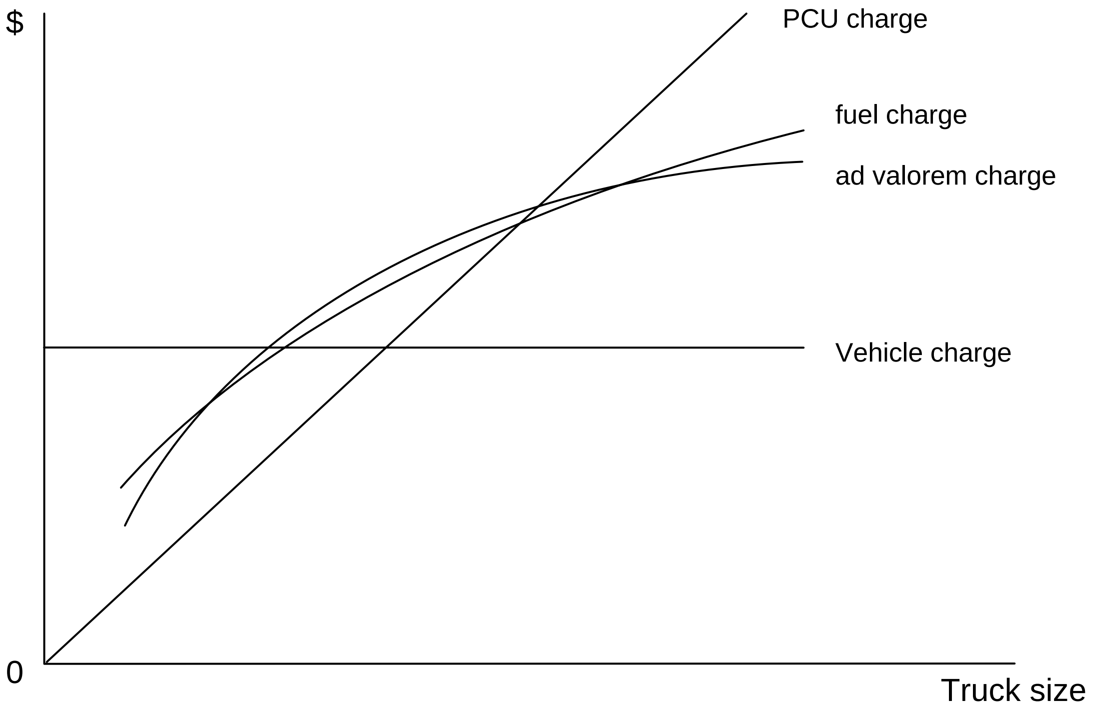
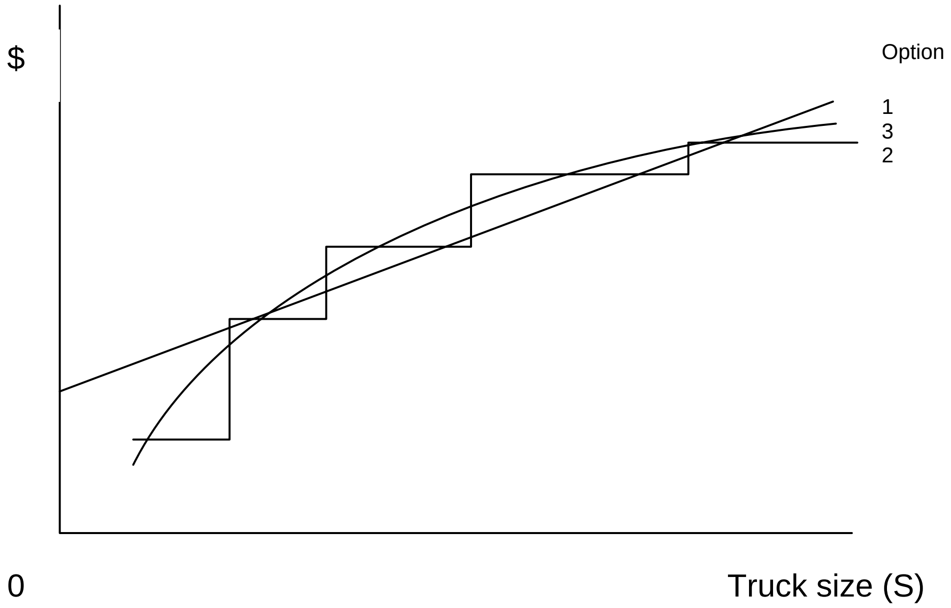


FIGURE II.3 COMPARISON BETWEEN CHARGES



Also shown in figure II.2 is a fourth charge set to raise the same amount of revenue, but levied on fuel consumed. This curve is likely to be similar to the curve based on total costs because fuel consumption increases with vehicle size and there are economies of scale in fuel consumption. It may be that a charge on fuel better approximates how ability to pay changes with vehicle size than a charge per PCU-kilometre or per vehicle-kilometre.

Figure II.3 shows three options for approximate Ramsey charges that increase with vehicle size at a decreasing rate:

1. a charge per tonne-kilometre of vehicle mass (net or gross) plus a fixed amount per kilometre regardless of truck size;
2. a schedule of charges per vehicle-kilometre for different vehicle classes that rises at a decreasing rate with respect to truck size; and
3. an amount per litre of fuel consumed.

Option 1 better reflects the cost curve than a flat charge per vehicle kilometre, but can still overcharge the smallest trucks and undercharge the largest trucks compared with an ad valorem charge.

Option 2 offers the best opportunity for approximating the cost curve, but requires good information on truck costs in order to set the relative rates. It may be the most difficult to justify on equity grounds to operators of trucks of varying sizes.

Option 3 takes advantage of the fact that there are economies of scale in fuel consumption. The amount of fuel consumed for a given trip by trucks of varying sizes could be modelled by a curve cS^f where c is a constant and f is the elasticity of fuel consumption with respect to truck size. The value of f will lie between zero and one. As long as value of f is in a similar ballpark to the value of b, the elasticity for total costs, then a charge on fuel consumption offers a reasonable approximation of ability to pay as it varies with truck size. A charge on fuel has the added advantage that it is easy to collect.

Options 1 and 2 would be levied on a per-kilometre-travelled basis. Option 3 is equivalent because fuel consumption is close to proportional to distance travelled. None of the options makes allowance for the fact that costs per kilometre vary with annual distance travelled. Trucks on shorter routes spend a larger proportion of their time loading and unloading. Supplementing a per-kilometre or per-litre-of-fuel charge with an annual registration charge could improve the approximation to an ad valorem charge.

Such a fixed charge would have to rise with truck size at a decreasing rate reflecting the economies of scale in vehicle size. Since the aim is to achieve an approximation to an ad valorem charge, for each vehicle size category, the relativity between the levels of the fixed and variable components of the Ramsey charge should match the relativity between fixed and variable operating costs with respect to annual distance travelled.

Provided the elasticity of demand is approximately constant across vehicle sizes for the industry as whole, a charge on fuel is likely to be preferable on economic efficiency grounds for recovering the common costs of the road system allocated to heavy vehicles compared with charging on a per-vehicle–kilometre or per-PCU–kilometre basis.

To sum up, the recommended form of charging would consist of:

- a mass-distance charge that varies with axle loading reflecting the marginal cost of damage to road pavements;
- possibly an additional charge to allow for the marginal cost of congestion estimated on a PCU basis. Heavy vehicles on two-lane non-urban roads cause a certain amount of congestion by holding up other vehicles (Gomez-Ibanez, 1999). Whether this amounts to a significant cost is an empirical question. If a charge were to be levied for congestion caused by heavy vehicles, it might be rolled into the either the mass-distance or the fuel charge;
- a fuel charge set to cover the difference between revenue recovered from a marginal cost charges and the total road cost allocated to heavy vehicles;
- possibly an annual registration charge that varies with vehicle type, increasing with truck size at a decreasing rate. If an annual registration charge were to be included in the charging system, the fuel charge could be reduced so as to keep the total revenue collected at the required level.