Developing Heavy Vehicle Road User Charges

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Abstract:

Recent ARRB research has shown that the heavy vehicle attributable portion of road track costs (road agency expenditure) varies significantly with both road use (heavy vehicle road use effect) and road agency expenditure strategies (expenditure allocation effect) A parametric heavy vehicle charging study was undertaken using various refinements to uniform national charging to examine the relative influence of the rural/urban expenditure allocation effect, the rural/urban cost attribution process and heavy vehicle road use effects The results of this study have demonstrated that heavy vehicle road user charges are mainly influenced by the rural/urban expenditure allocation effect. The study's findings suggest that more direct scrutiny should be placed on the soundness of road agency urban and rural expenditure allocation and pavement intervention maintenance strategies without the need to refine the uniform national heavy vehicle charging scheme at this stage

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1. INTRODUCTION

Recent ARRB studies into heavy vehicle road track cost (road agency expenditure) attribution by Martin (1992) and Australian arterial road use by Taylor and Botterill (1992), provide an objective basis for developing heavy vehicle road user charges under an Australian pay-as-you-go (PAYGO) system. The cost attribution research used relatively limited arterial road sampling. This sampling is now being extended to provide further cost attribution refinements within the next year or so. Similarly, the arterial road use research used current road agency vehicle usage data bases which will be hopefully refined by the wider use of continuous and accurate vehicle monitoring equipment.

Specifically the above studies provide a basis for calculating heavy vehicle road user charges which recover road track costs. The following cases are used as a basis for three possible heavy vehicle road user charge schemes:

Case (a) A uniform national heavy vehicle charging scheme based on combined national urban and rural heavy vehicle road use and expenditure data;

Case (b) A national charging scheme separated into rural and urban areas based on national rural and urban heavy vehicle road use and national rural and urban expenditure data respectively;

Case (c) Two state charging schemes (NSW and Victoria) separated into rural and urban areas based on state rural and urban heavy vehicle road use and state rural and urban expenditure data respectively.

The National Road Transport Commission (NRTC) proposes to introduce by 1995 a uniform heavy vehicle charging scheme along the lines of case (a) above. Heavy vehicle charging cases (b) and (c) are progressive refinements of case (a). Cases (b) and (c) are compared with case (a) by estimating the heavy vehicle charges for three classes of rigid trucks and three classes of articulated trucks. Assuming the average variable costing approach that normally applies to the PAYGO, the following component variables are considered to significantly influence heavy vehicle charges:

Component (i) Road track expenditure (assumed equal to cost) allocation by the road agencies to rural and urban roads (rural/urban expenditure allocation effect);

Component (ii) The variation of heavy vehicle cost attribution characteristics, such as GVM[a] and ESA[b], with respect to rural and urban roads (rural/urban cost attribution process effect);

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a GVM, Gross vehicle mass

b ESA, Equivalent standard axle

Component (iii) Heavy vehicle road use variations with respect to rural and urban roads (rural/urban heavy vehicle road use effect)

The independent influence of these component variables on the heavy vehicle charging cases (a) to (c) is examined. A review of the effects of these variables together with the comparisons of the overall charging outcomes of cases (a) to (c) allows formulation of recommendations concerning the future direction of heavy vehicle charging in Australia.

2. HEAVY VEHICLE COST ATTRIBUTION PROCESS CHARACTERISTICS

ARRB study: general

The attributable road track expenditure was assumed to be the variable portion of the annual maintenance and capital expenditure as the residual component of road track expenditure, operations expenditure, is generally regarded as non-attributable. The attribution characteristics of maintenance and capital expenditure were examined separately. The attribution study's results show that both the attributable portions of maintenance and capital expenditure are highly dependent on the road use variables and road design parameters.

ARRB study: routine maintenance expenditure

ARRB initially studied the statistical relationship between pavement related average annual routine maintenance expenditure (minor patching, shoulder grading, side drain clearing) and road use for a sample of arterial roads in NSW, Victoria and Queensland. This approach has been widely applied to road maintenance expenditure elsewhere, Al-Suleiman et al (1991). The statistical study showed that generally pavement related routine maintenance is non-attributable to heavy vehicles because it is not statistically related to heavy vehicle road use. Pavement related routine maintenance expenditure generally appears to be resource driven. One exception to this was the routine maintenance expenditure relationship with road use for several road samples from remote sites in Queensland. For these sites the routine maintenance expenditure was 95% attributable to heavy vehicles

ARRB study: periodic maintenance expenditure

A statistical relationship between road wear cost, assumed equal to the average annual periodic maintenance (resealing, major patching, surface corrections, thin overlays), and road use was developed from a sample of arterial roads in NSW, Victoria and Queensland. The function below was derived for the general relationship between the attributable (or separable) portion of periodic maintenance expenditure and road use:

$$\text{Attributable periodic maintenance expenditure portion} = \%\ \text{attributable maintenance expenditure} = \frac{b_3 \,.\, \text{road use variable}}{b_1 + b_3 \,.\, \text{road use variable}} \times 100 \qquad (1)$$

where,

b_1 = constant (from linear regression)

b_3 = independent road use variable coefficient from linear regression

road use variable = one of the following:

- cumulative equivalent standard axles(CESA)/lane/year,
- cumulative gross vehicle mass(CGVM)/lane/year,
- cumulative passenger car units(CPCU)/lane/year,
- annual average daily traffic (AADT)/lane

Only one road use variable was used in equation (1) due to multicolinearity between the variables. The road use variable that provided the highest statistical significance (as given by t test and overall F) was accepted for equation (1). Table 1 gives the values of b_1, b_3 and the statistical significance of equation (1) for the jurisdictions considered.

As noted earlier, the statistical sampling was relatively limited, particularly for NSW, although the overall result appears to be statistically significant. There is also some concern about the accuracy of the periodic expenditure data provided as only three consecutive financial years were considered in estimating the average annual periodic expenditure. Periodic maintenance expenditure by its nature is lumpy with respect to time as activities such as resealing and resheeting are carried out on average every 8 to 12 years. The three financial year sampling period may not have captured the average annual expenditure over the longer periodic maintenance cycle. However, the statistical results for attributable periodic maintenance (load related road wear) were on average confirmed by the direct measurement of load related road wear, Martin (1992).

Table 1 Percentage attributable periodic maintenance expenditure relationship parameters

Jurisdiction	Road use variable	b_1	b_3	No. samples	R^2	F_{val}
National (NSW/VIC/QLD)	CGVM/lane/yr.	14994.9	0.00087	32	0.51	31.3 ($p<0.01$)
Victoria	CGVM/lane/yr.	714.6	0.00074	18	0.77	52.6 ($p<0.01$)
NSW	CESA/lane/yr.	590.8	0.024	8	0.39	3.82 ($p<0.1$)

ARRB study: factors influencing periodic maintenance expenditure attribution

The results of the statistically derived equation (1) indicate the influence of road agency intervention strategy on attributable periodic maintenance. Victorian attributable periodic maintenance expenditure is largely influenced by the road use variable, CGVM/lane/year (equivalent to a GVM.km[c] periodic maintenance expenditure allocator under average variable costing), while NSW attributable periodic maintenance expenditure is influenced by the road use variable, CESA/lane/year (equivalent to a ESA.km[d] periodic maintenance expenditure allocator under average variable costing). The Victorian sample arterials also showed lower rates of pavement deterioration (0.086-0.015 IRI[e] /year) relative to the NSW sample arterials rates of pavement deterioration (0.157-0.029 IRI/year).

In summary, the road use variable in equation (1) tends to reflect road agency pavement maintenance intervention strategy. This finding confirms current pavement damage theory which predicts that for fatigue cracking and surface distress wear (relatively low levels of pavement deterioration), the exponent in the axle load equivalency (ESA) power relationship, Kinder and Lay (1988), is approximately equal to one, which is nearly equivalent to the GVM term in the CGVM/lane/year road use variable. Higher levels of pavement deterioration have a higher value exponent, which is approximately equivalent to the ESA (to the fourth power) term in the CESA/lane/year road use variable.

Apart from the influence of the pavement maintenance intervention strategy on the road use variable in equation (1), the actual level of road use is the other major variable in determining the attributable portion of periodic maintenance expenditure. According to equation (1) if there is no road use there is no attributable periodic maintenance, while at high levels of road use, such as the Hume Freeway at Beveridge in Victoria (CGVM/lane/year=20.6 x 10^6), the attributable periodic maintenance is around 92%.

ARRB study: capital expenditure

The ARRB study examined the relationship between capital expenditure and road infrastructure design parameters for bridges and pavements using a statistical approach as applied to transport cost elsewhere, Brown et al, Talley (1988), and a two step incremental cost method, Wong and Markow (1983).

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c GVM.km, Gross vehicle mass multiplied by annual vehicle kilometres travelled (AVKT).

d ESA.km, Equivalent standard axles multiplied by annual vehicle kilometres travelled (AVKT).

e IRI, International road roughness index (m/km) a dimensionless number representing the surface condition of a road pavement

ARRB study: bridge capital expenditure - its attribution and the factors influencing it

The function below was derived from a study of the general statistical relationship between the attributable portion of bridge expenditure and one bridge design parameter:

$$\text{Attributable bridge expenditure (capital) portion} = \%\ \text{attributable bridge expenditure} = \frac{b_4 \cdot \text{bridge design parameter}}{b_1 + b_4 \cdot \text{bridge design parameter}} \times 100 \quad (2)$$

where,

b_1 = constant from linear regression

b_4 = independent bridge design parameter coefficient from linear regression

bridge design parameters (over whole life) = one of the following;

- cumulative equivalent standard axles (CESA)/lane,
- cumulative gross vehicle mass (CGVM)/lane,
- cumulative passenger car units (PCU)/lane,
- annual average daily traffic (AADT)/lane.

The bridge design parameter that provided the highest statistical significance (as given by t test and overall F) was accepted for equation (2). Table 2 gives the values of b_1, b_4 and the statistical significance of equation (2) for the jurisdictions considered.

Again it should be noted that the statistical sampling is relatively limited for both Victoria and NSW. The correlation coefficients (R^2) for any of the above relationships for each jurisdiction are low, but the overall F values for the relationships are significant at the 95% level (except for NSW).

The statistically significant bridge design parameter, is the whole of life bridge design value, CPCU/lane/day, which is based on the AADT/lane value modified for the influence of heavy vehicles in the traffic stream and traffic growth over bridge design life. The CPCU/lane/day parameter becomes a PCU.km bridge expenditure allocator under the average variable costing approach. This is contrary to the conventionally accepted allocator of GVM.km, but the design live load (or GVM), in terms of total live load per lane, in the Australian design process NAASRA (1976) is related to bridge width (a PCU effect) rather than variations in bridge span length and variations in heavy vehicle class (GVM effects).

Equation (2) is dependent on an assessed value of CPCU/lane/day to estimate the attributable bridge expenditure. According to equation (2) if there is no road use (CPCU/lane/day=0) there is no attributable bridge expenditure, but at high levels of road use, such as the Hume Freeway at Beveridge in Victoria (CPCU/lane/day=30,700, assuming 4% annual traffic growth over 40 years), the attributable bridge expenditure is around 55%.

Table 2 Percentage attributable bridge expenditure relationship parameters

Jurisdiction	Bridge design parameter	b_1	b_4	No samples	R^2	F_{val}
National (NSW/VIC/ WA/QLD)	CPCU/lane	5525	0.217	35	0.1	5.4 ($p<0.05$)
Victoria	CPCU/lane	5388	0.231	8	0.61	9.3 ($p<0.05$)
NSW	CPCU/lane	6819	0.215	11	0.07	0.7 ($p>0.1$)

ARRB study: pavement capital expenditure - its attribution and the factors influencing it

The function below was derived from a study of the general statistical relationship between the attributable portion of pavement expenditure and one pavement design parameter:

$$\text{Attributable pavement expenditure (capital)} = \text{\% attributable pavement expenditure} = \frac{B\,.\,(1-e^{-a\,.\,\text{pavement design parameter}})}{A + B\ (1-e^{-a\,.\,\text{pavement design parameter}})} \times 100 \quad (3)$$

where,

A = constant from non-linear regression

a & B = independent pavement design parameter coefficients from non-linear regression

pavement design parameters (over whole life) = as defined for bridge design parameters in equation (2)

The pavement design parameter that provided the highest statistical significance (as given by t test and overall F) was accepted for equation (3). Table 3 gives the values of A, B, a, and the statistical significance of equation (3) for the jurisdictions considered.

Non-linear regression analysis was used for the attributable pavement expenditure relationships in Victoria, NSW and nationally as it produced improved correlation coefficients relative to linear regression. This result is not unexpected as increasing pavement thickness (and therefore cost) is considered to provide disproportionately higher levels of pavement design capacity (economies of scale effect).

The statistical sampling is relatively low in Victoria. The larger number of pavement samples from NSW influenced the national attributable pavement expenditure relationship more than any of the other state's samples. The correlation coefficients are low for all the jurisdictions' relationships, however, the overall F values are significant at 95% level (except for Victoria).

The statistically significant pavement design parameter is the whole of life pavement design value, CESA/lane, as expected. This parameter becomes the conventionally accepted pavement expenditure allocator of ESA.km under the average variable costing approach.

Table 3 Percentage attributable pavement expenditure relationship parameters

Jurisdiction	Pavement design parameter	A	B	a	No samples	R^2	F_{val}
National (NSW/VIC/ WA/QLD)	CESA/lane	197598	603000	3.188 E-9	47	0.1	5.1 ($p<0.05$)
Victoria	CESA/lane	137026	130408	4.55 E-7	8	0.34	3.0 ($p>0.1$)
NSW	CESA/lane	226947	590523	3.926 E-9	19	0.25	5.7 ($p<0.05$)

Estimation of the attributable pavement expenditure is dependent on an assumed value of CESA/lane in equation (3). From equation (3) if there is no design capacity there is no attributable pavement expenditure, while at high levels of road use, such as the Hume Freeway at Beveridge in Victoria (CESA/lane=120 x 10^6, assuming 4% annual traffic growth over 40 years), the attributable pavement expenditure is about 49%.

3. HEAVY VEHICLE ROAD USER CHARGES

The separate influence of rural and urban expenditure allocations (component (i)) on charging cases (a) (b) and (c)

The heavy vehicle road user charges developed for cases (a) to (c) are based on the estimated 1989/90-91/92 average annual road track expenditure (in 1992/93 values) from Table A.3 of NRTC (1992) distributed as follows:

- National expenditure. All urban and rural area expenditures are combined (case (a));
- National expenditure for urban and rural areas treated separately (case (b));
- NSW and Victorian state expenditures for urban and rural areas treated separately, based on details supplied by the NRTC (1993) (case (c)).

These different rural and urban road track expenditures, at both national and state levels, allow the separate influence of rural and urban road track expenditure allocations within the network (rural/urban expenditure allocation effect) to be assessed on heavy vehicle road user charges. The appropriate allocation of expenditure to rural and urban roads is an issue that PAYGO and uniform charging does not directly address. The appropriate allocation of road track expenditure at a broader level, that is, its optimality of investment, is also not addressed by either PAYGO or uniform charging as noted by Meyrick (1992) and Access Economics (1992).

The separate influence of rural and urban cost attribution processes (component (ii)) on charging cases (a) (b) and (c)

As noted earlier, attributable maintenance expenditure depends on level of road use, which varies from rural to urban roads, and pavement maintenance intervention strategy, which varies between road agencies. Attributable bridge and pavement expenditure depends on the magnitude of the relevant design variable which varies from rural to urban roads. There are also differences in the attributable portions of bridge and pavement expenditure at state and national levels, and differences between states (see Tables 2 and 3). Consequently the results of the ARRB cost attribution study enable construction of a national cost attribution process and separate rural and urban cost attribution processes at national and state levels.

Heavy vehicle road user charges for cases (a) to (c) can be based on building up the relevant cost attribution process from the relationships derived in Tables 1 to 3. The representative road use variable and road design parameter, from Tables 1 to 3, used in constructing a national cost attribution process and separate national and state level rural and urban cost attribution processes were derived as follows:

Road use variable, CGVM/lane/year = GVM/HV x AADT/lane x %HV x 365 (4a)

Bridge design parameter, CPCU/lane/day = PCU/HV x AADT/lane x %HV + (1 - %HV/100) x AADT/lane (4b)

Pavement design parameter, CESA/lane = ESA/HV x AADT/lane x %HV x 365 x GF (4c)

where,

GVM/HV = average GVM/heavy vehicle
PCU/HV = average PCU/heavy vehicle

ESA/HV	=	average ESA/heavy vehicle
AADT/lane	=	annual average daily traffic/lane
%HV	=	percentage heavy vehicles in traffic stream
GF	=	annual traffic growth factor over a 30 year pavement design life.

Average national and state values of the heavy vehicle cost attribution characteristics (GVM/HV, ESA/HV, and PCU/HV) were taken from Table 3.10 of Taylor and Botterill (1992). Heavy vehicle cost attribution characteristics for urban and rural roads are expected to be different rather than using the above average values, but they were not available for a more accurate analysis. Greater apparent accuracy could have been obtained if urban and rural estimates of the cost attribution characteristics were known, although the ARRB cost attribution study should not be ascribed a high level of precision due to its limited sampling base.

The road use variables, AADT/lane and %HV for urban and rural roads on a state and national basis, were extracted from Tables 3.4 and 3.5 respectively of Taylor and Botterill (1992).

Cost attribution processes built from equations (1) to (3), using the variables and parameters derived from equations (4a) to (4c), vary with each of the heavy vehicle charging cases (a) to (c). This variation of heavy vehicle cost attribution process with respect to the heavy vehicle charging cases allows the separate influence of heavy vehicle cost attribution characteristics (rural/urban cost attribution process effect) to be assessed.

The separate influence of heavy vehicle rural and urban road use variables (component (iii)) on charging cases (a) (b) and (c).

Heavy vehicle charging case (a) used the average national values of the road use variable, AVKT[f], for six representative classes of heavy vehicles (rigid and articulated) from Tables 3.8 and 3.9 of Taylor and Botterill (1992). Charging cases (b) and (c) used the AVKT for these heavy vehicle classes on urban and rural roads at national and state levels, respectively which was estimated as follows:

- Rigid heavy vehicles' AVKT is 50% more in rural areas than in urban areas;
- Articulated heavy vehicles' AVKT is 100% more in rural areas than in urban areas;
- The urban and rural heavy vehicle AVKT estimates when added together give the national and state totals for each vehicle class in Tables 3.8 and 3.9 of Taylor and Botterill (1988).

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f AVKT, Annual vehicle kilometres travelled

The road use variables, GVM and ESA, representing each heavy vehicle class were estimated as follows:

- The average GVM of each heavy vehicle class was taken as the weighted average (by number of vehicles) of the relevant ranges in Tables 21 and 22 of ABS (1989);

- The average ESA value of each heavy vehicle class was derived from its average GVM value as follows:

$$ESA = C \cdot GVM \tag{5}$$

where,

C = 0.094 for rigid heavy vehicles and 0.097 for articulated heavy vehicles

The relationship between ESA and GVM in equation (5) was based on that found for samples of rural arterials from Table B.2 in Martin (1992). The ESA estimates from equation (5) are generally similar to those given by the ISC (1990) method.

Heavy vehicle road use variables, GVM and ESA, are likely to vary for each vehicle class on urban and rural roads, however, urban and rural estimates of GVM and ESA were not available for a more accurate analysis.

The variation of individual heavy vehicle class road use with respect to urban and rural areas at a national and state level allows assessment of the influence of heavy vehicle road use (rural/urban heavy vehicle road use effect) on heavy vehicle road user charges.

Heavy vehicle charge calculation

The individual heavy vehicle class charges for cases (a) to (c) were based on the usual average variable costing calculation defined below:

Annual charge/
vehicle (j)

$$= \left[\sum_i \frac{\%\,\text{Attrib.}\,\$(i) \times \text{Road var.}\,(i,j)}{\sum_k \text{Road var.}\,(i,j)} + \left(100 - \sum_i \%\,\text{Attrib.}\,\$(i)\right) \times \frac{\text{AVKT}\,(j)}{\sum_k \text{AVKT}\,(j)}\right] \times \frac{\text{Total}\,\$}{\text{No. vehicles}\,(j)} \tag{6}$$

where,

% Attrib. \$(i) = percentage attributable expenditure for expenditure category "i" *(component (ii))*;

Road var.(i,j) = Road use variable or design parameter for expenditure category "i"

		for vehicle class "j" *(component (iii))*;
AVKT(j)	=	Annual vehicle kilometres travelled by vehicle class "j" *(component (iii))* ;
Total $	=	Total annual road track expenditure for either cases (a), (b) and (c) *(component (i))*;
No. vehicles (j)	=	number of vehicles in class "j".
k	=	number of vehicle classes.
i	=	number of expenditure categories (maximum considered = 3)

Equation (6) is widely used for heavy vehicle charging under average variable costing as shown in Fwa et al (1990). Equation (6) assigns non-attributable expenditure to each vehicle class on the basis of its share of road use as measured by AVKT. There many other possible means of assigning non-attributable expenditure, but this method is the most common.

The number of heavy vehicles in each individual class and state was based on Tables 10, 12, 21 and 22 of ABS (1989), assuming that the state of registration represented the state of operation. The number of heavy vehicles within urban and rural areas at a national and state level were estimated using the same assumptions stated under "The separate influence of heavy vehicle road use variables (component (iii)) on charging cases (a), (b) and (c)".

4. VARIATIONS FROM UNIFORM NATIONAL HEAVY VEHICLE ROAD USER CHARGING (CASE (A))

Overall percentage variation of cases (b) and (c) from case (a) uniform national charging

Figure 1(a) shows the overall percentage variation in charging case (b), national rural and urban charging, from case (a), uniform national charging. The negative percentage variation of national urban heavy vehicle class charging from case (a) charging indicates that national urban vehicle charges could be reduced from a uniform national charge. Conversely there is a positive percentage variation of national rural heavy vehicle charging from case (a) charging, indicating that national rural vehicle charges could be increased from a uniform national charge.

Figures 1(b) and 1(c) respectively show the overall percentage variation in charging when case (c), state rural and urban charging, is applied to Victoria and NSW, relative to case (a), uniform national charging. Figure 1(b) shows a negative percentage variation from case (a) charging for most Victorian rural and urban heavy vehicles, indicating that generally Victorian urban and rural charges could be reduced from a uniform national charge, although the reduction in urban charges would be greater than the reduction in rural charges.

Figure 1(c) shows that all the NSW rural heavy vehicles have a large positive percentage variation from case (a) charging, while all the NSW urban heavy vehicles have a much lower negative percentage variation from case (a) charging. These percentage variations indicate that NSW urban and rural vehicle charges respectively could be reduced and increased significantly above a uniform national charge.

In summary, cases (b) and (c) heavy vehicle charging options show significant percentage variations from case (a) uniform national charging when individual heavy vehicle classes are examined. There generally appears to be scope for reductions in the urban heavy vehicle charges (more in Victoria relative to NSW), while conversely there is scope for increasing rural heavy vehicle charges, with the exception of rural Victoria. In the case (c) charging option it is interesting to note the resulting percentage variations from case (a) uniform national charging between the urban and rural areas of Victoria and NSW.

These percentage variations in charges from uniform national charging (-62% to +208% see Figs. 1(b) and 1(c), respectively) for urban and rural areas supports Stanley's (1993) contention that charging tools are fairly blunt instruments. Individual vehicle charging variations within the each of the heavy vehicle classes has not been considered in this analysis; these variations are probably greater than those found for charging cases (b) and (c).

Component variables influence on overall variations of cases (b) and (c) from case (a).

As noted in Section 1, heavy vehicle charges are assumed to be influenced by a rural/urban expenditure allocation effect (component (i)), a rural/urban cost attribution process effect (component (ii)), and a rural/urban heavy vehicle road use effect (component (iii)).

For the purposes of this study, the sum of the above three components account for all of the overall percentage variation in charging of cases (b) and (c) from case (a). Component (i) was examined by separating out rural and urban differences in expenditure allocation effects between cases (b) and (c) and case (a). Components (ii) and (iii) are interdependent because they both depend on the variations of road use in the network. Component (ii) generally reflects the road use characteristics that effect cost attribution, while component (iii) generally reflects the individual heavy vehicle class road use effects. Components (ii) and (iii) were treated by separately examining the relevant road use effect on each of the components.

Figure 2(a) shows the percentages of various component influences on case (b), national rural and urban charging, relative to case (a), uniform national charging. Component (i) is the major influence for the overall percentage charging variation of national rural and urban charging from case (a) The influence of components (ii) and (iii) tends to vary between vehicle classes across rural and urban areas. Component (ii) is responsible for positive variations (increases in charges) from case (a) in urban areas and for negative variations (decreases in charges) from case (a) in rural areas. The converse is true for component (iii) variations in rural and urban areas, as expected.

Figures 2(b) and 2(c) show percentages of various component influences, relative to case (a), when case (c), state rural and urban charging, is applied to Victoria and NSW respectively.

Figure 2(b) shows that component (i) is responsible for the vast majority of the overall percentage charging variation from case (a) in urban Victoria, while component (iii) is responsible for around 50% of the overall percentage charging variation from case (a) in rural Victoria. Component (i) has the next most influence on percentage charging variation in rural Victoria. The influence of component (ii) on percentage charging variation varies across all vehicle classes in urban Victoria. Component (ii) is also responsible for negative percentage variations from case (a) for all heavy vehicle classes in rural Victoria.

Figure 2(c) shows that component (i) has by far the most influence on the overall percentage charging variation in urban and rural NSW, in a similar manner to its' influence on case (b) charging across national urban and rural areas. Components (ii) and (iii) have only marginal impact on overall percentage charging variations in NSW. Component (ii) is responsible for slightly positive percentage charging variations from case (a) in urban and rural NSW, with the exception of two heavy vehicle classes in rural NSW.

In general component (i), the rural/urban expenditure allocation effect, is the most significant factor influencing the percentage variation of charging cases (b) and (c) from case (a), with the exception of the heavy vehicles in rural Victoria. Component (ii), the rural/urban cost attribution process effect, tends to be responsible for positive percentage charging variations in urban areas and negative percentage charging variations in rural areas. There are some vehicle class exceptions to this in urban Victoria and rural NSW, however. These exceptions for component (ii) more or less reflect the cost attribution road use variations within the heavy vehicle classes across the road network. The rural/urban cost attribution effect in rural and urban areas is generally the reverse of the rural/urban expenditure allocation effect nationally, but this is not always the case at a state level.

This study has highlighted a strategic economic concern with road agency expenditure allocation because of an apparent cross-subsidy from urban to rural areas. This is because of the rural and urban area variations from uniform national charging, indicating current over investment in rural road track expenditure relative to that in urban areas. In the context of long term elaborately transformed manufacturing and high technology industries located in urban areas, a cross-subsidy effect could have serious cost implications on industries competing internationally. On the other hand, primary industries in certain rural areas would almost certainly suffer significant cost increases with heavy vehicle charges based on national or state rural areas, if the recent BTCE (1992) analysis of heavy vehicle charging on remote and rural areas is any guide.

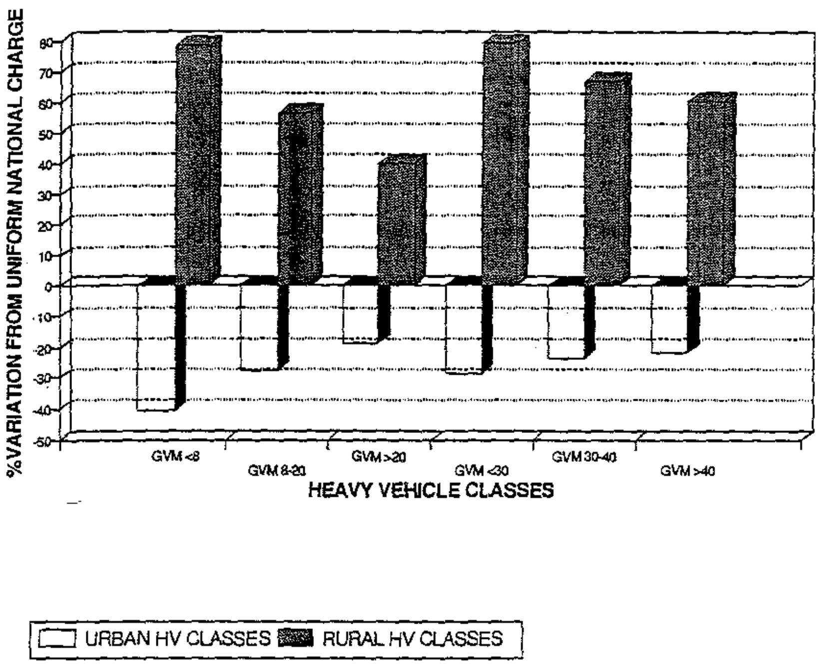


Figure 1(a) Case (b) charges variation from Case (a)

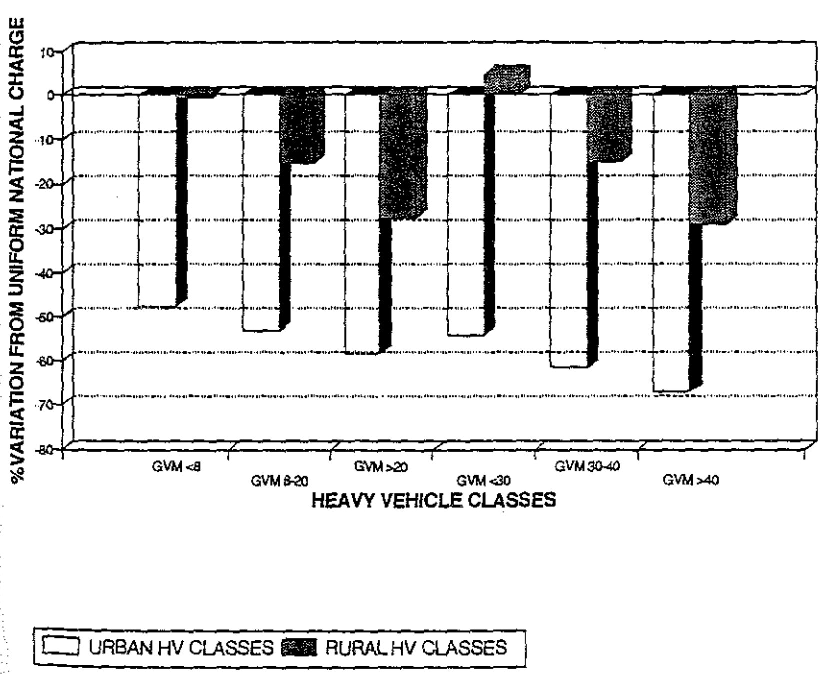


Figure 1(b) Victorian Case (c) charges variation from Case (a)

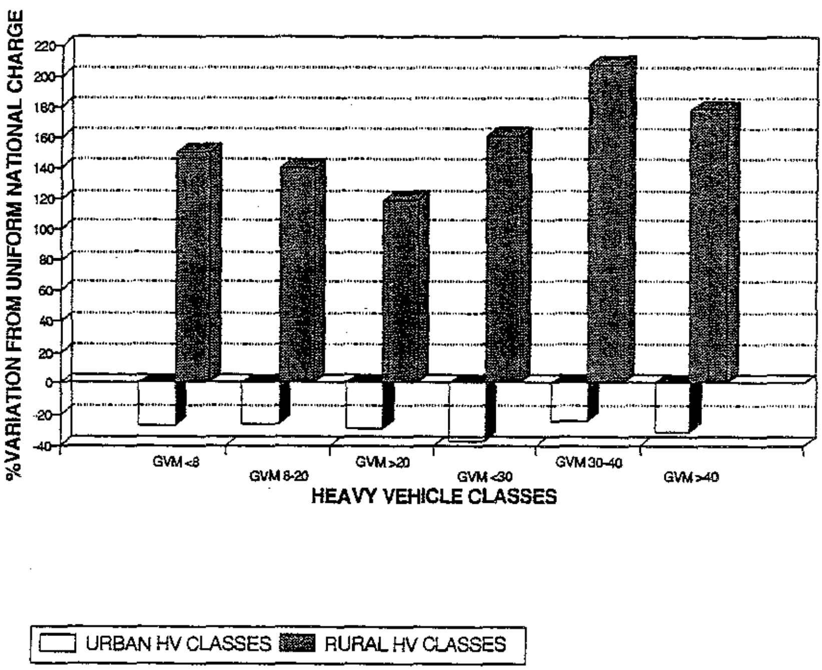


Figure 1(c) NSW Case (c) charges variation from Case (a)

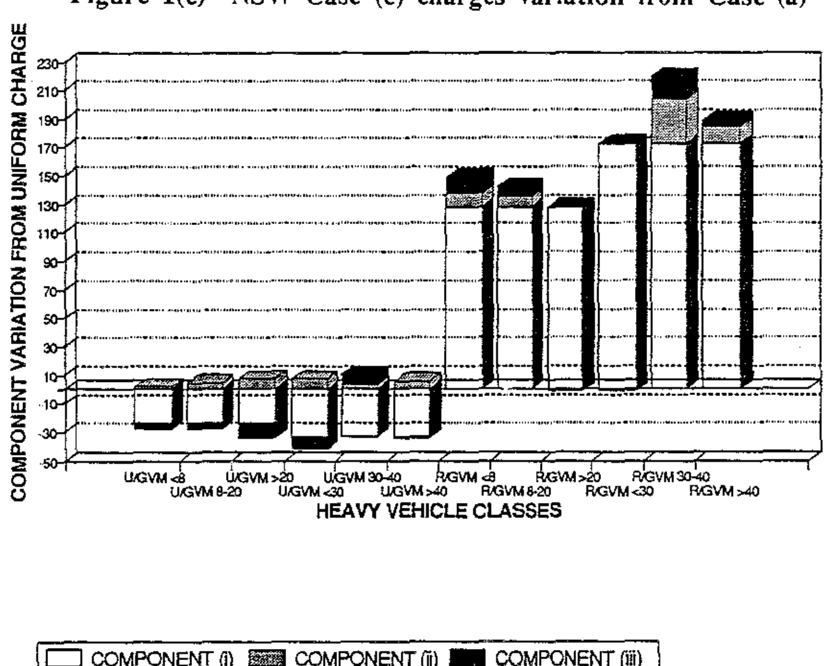
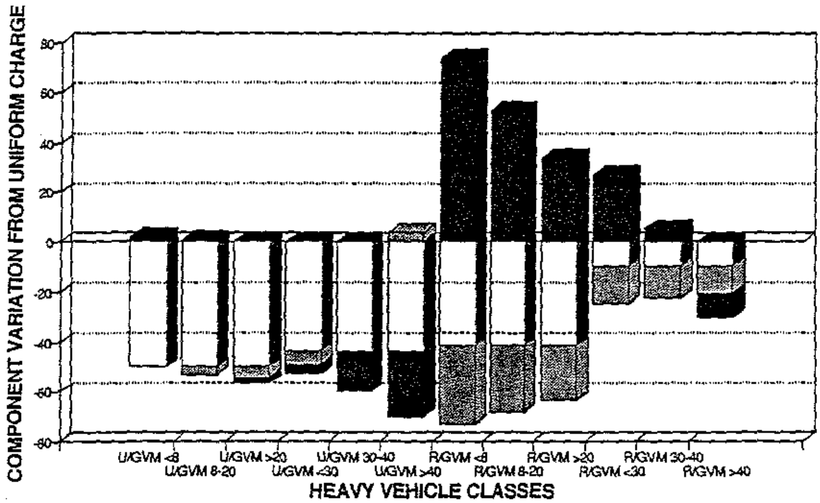
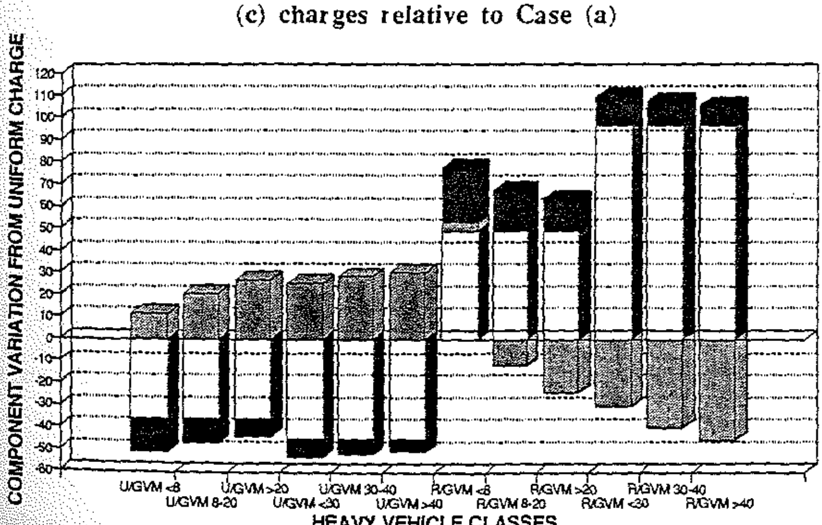


Figure 2(a) Influence of components (i) (ii) and (iii) on Case (b) charges relative to Case (a)



COMPONENT (i) COMPONENT (ii) COMPONENT (iii)

Figure 2(b) Influence of components (i) (ii) and (iii) on Victorian Case (c) charges relative to Case (a)



COMPONENT (i) COMPONENT (ii) COMPONENT (iii)

Figure 2(c) Influence of components (i) (ii) and (iii) on NSW Case (c) charges relative to Case (a)

5. CONCLUSIONS

The parametric study undertaken in section 4 shows that quite significant percentage variations (-62% to +208% in individual vehicle classes) from the uniform national charging case (a) occur when using charging cases (b) and (c). These variations from uniform national charging are mainly influenced by national urban and rural and state urban and rural variations in road agency expenditure allocation and road use. Generally the rural/urban expenditure allocation effect is the single most important factor influencing the level of the heavy vehicle charges under charging cases (b) and (c).

The above rural and urban variations from uniform charging case (a) generally indicate a current over expenditure on rural roads relative to that on urban roads. This apparent mis-match in expenditure relative to road use has quite serious long term economic implications, as Williams and Mullen (1992) have demonstrated with the link between road capital investment and regional economic performance.

Although the rural/urban cost attribution effect from this study is not normally the major component influencing the heavy vehicle percentage charging variations from case (a), it should be noted (under section 2) that the road agency pavement intervention strategy influences the type of heavy vehicle road use variable used to attribute maintenance expenditure. Ideally the heavy vehicle cost attribution process should reflect both the reality of road agency practice and the how and where of the costs caused by the users.

If the refined heavy vehicle charging options were implemented there would be presumably increased road user scrutiny of the cost attribution process and of road agency capital and maintenance intervention strategies due to their influence on individual heavy vehicle charges and industry costs However, the single most important factor, the rural/urban expenditure allocation effect, may not receive from this approach the individual attention it richly deserves.

In addition, there are a number of practical limitations in adopting refined charging options, such as how the charging options can be cost effectively applied to individual vehicles that travel in both rural and urban areas and through different states. The electronic hardware exists now to actually implement these charging options, LTT (1993), but it has only been applied in relatively limited areas such as major cities and not to countries as vast and thinly populated as Australia.

6. RECOMMENDATIONS

As a result of this parametric study it is recommended that more direct scrutiny be placed on the soundness of road agency rural and urban expenditure allocation and road agency pavement intervention maintenance strategies. The refinement of a uniform national heavy vehicle charging scheme is of secondary importance at this stage, particularly when the apparent cross-subsidies of expenditure between urban and rural areas are considered. This more direct approach also needs closer monitoring of road use variations across rural and urban areas in each state to support the economic evaluations that may be required to improve the soundness of expenditure allocation and pavement intervention practices.

In adopting this approach road agencies need to be able to demonstrate the following:

- That road agency pavement maintenance intervention strategies are appropriate in terms of both their timing and the nature of the intervention;
- The level and distribution of road agency maintenance and capital expenditure in rural and urban areas is economically appropriate in relation to road use and its associated benefits.

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