A Policy for Sustainability of Low Volume Traffic Roads in an Australian Context

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ABSTRACT

Low Volume Traffic (LVT) roads make up the vast bulk of the Australian road network. The network ranges from tracks joining farms to sealed roads linking the major country centres. The problem for a country, which has a vast geographical area with a relatively small population, is to maintain this system of roads with the minimum practical investment, in a sustainable manner.

The unusual circumstances of the Australian environment of the driest continent on earth, a geologically old continent and a weather pattern that regularly produces prolonged drought and periods of heavy rainfall in parts of the country, all impinge on the performance of pavements, influencing their lifecycle. The deep weathering of the surface rocks has limited the availability of high quality gravels. The relative dryness of subgrades allows the use of marginal pavement materials, thinner pavements and thin non-structural seals. The depletion of the best sources of pavement materials since the First Fleet arrived from England in 1788 has caused problems for road construction. This has forced consideration of the use of lower quality materials and the incorporation of recycled materials in the construction of the elements that make up the road reserve. The outcome of the combination of circumstances is a road network that can be regarded as fragile, particularly under increasing traffic and axle load. This paper addresses the issues of pavement lifecycle management and resource conservation as approaches towards providing sustainable LVT roads, under the influence of these many factors.

INTRODUCTION

The contribution of a road network to sustainability implies consideration of externalities beyond the usual engineering considerations of maintaining a durable system of sufficient capacity. In a geologically old country, such as Australia, construction materials of high quality are scarce placing emphasis on the prudent use of non-renewable resources and the encouragement of recycling.

Construction and maintenance of Low Volume Traffic (LVT) roads (roads with less than 0.26 Million Vehicle Kilometres Travelled per Kilometre Lane Length) has an effect on the environment beyond that of providing transport and supporting the social fabric of society. There is the impact on ecosystems, agricultural cohesion and pollution. The contribution of the system to pollution and the generation of greenhouse gases must be considered.

This paper offers an outline policy for the sustainability of the LVT road system that considers factors affecting the engineering aspects of the system as well as the externalities present because of the existence of the road network

SUSTAINABILITY OF A ROAD SYSTEM

The definition of sustainable development has been stated as “Development which meets the needs of the present without compromising the ability of future generations to meet their own needs”, (Brundtland, 1987).

> **“**Sustainability is a systemic concept, relating to the continuity of economic, social, institutional and environmental aspects of human society. It is intended to be a means of configuring civilization and human activity so that society, its members and its economies are able to meet their needs and express their greatest potential in the present, while preserving biodiversity and natural ecosystems, and planning and acting for the ability to maintain these ideals in the long term. Sustainability affects every level of organization, from the local neighbourhood to the entire planet” (PIARC, 2007a)

The introduction of the “Triple Bottom Line” was an attempt to widen the basis beyond economic considerations on which company performance was judged to include the environmental and social impact of company operations. An expansion of this approach was the introduction of the concept of Corporate Social Responsibility (CSR) defined by the World Bank as “the continuing commitment by business to contribute to sustainable economic development by working with employees, their families, the local community, and society at large to improve their quality of life, in ways that are both good for business and good for development.”

The sustainability of the LVT road network requires that it supports the demand traffic flow with a minimum of disruption at the least cost to the community (cost being a measure of energy) and with the least possible pollution and it also supports the social framework in such a way that the resource consumption, in providing the asset, is kept at the lowest possible level. It also provides access to the main supply routes. In other words, the asset provides the necessary service at the least cost with the lowest resource consumption.

AUSTRALIAN ROAD NETWORK

The road network in Australia has developed in a country that is large and sparsely populated. The landmass is approximately the same size as the continental United States but contains a population of 21.3 million, which is nearly equivalent to that of the State of Texas (22.9 million). The Australian population is mainly concentrated in urban areas dotted throughout the continent, but essentially located in a strip along the Eastern seaboard.

The Australian road system has a length of almost 800,000 kms. The categorization of the system into its various components is shown in Figure 1.

The road density in terms of length of road per area of land is one of the lowest in a group of nine nations sampled (Australia, Canada, France, Indonesia, Japan, New Zealand, South Africa, UK and USA). The number of vehicles per kilometer of road is the second lowest in the same group, being just larger than that of Canada. The expenditure on the road network per kilometer of road is one of the lowest when compared with the same bundle of countries, (McManus *et al*, 2003).

INVESTMENT IN ROAD INFRASTRUCTURE IN AUSTRALIA

The expenditure on the road network in Australia is controlled at three levels; Federal, State/Territory, Local Government Authorities (LGAs).

The road networks that receive the greatest slice of budget are the State and Federal interstate highway systems that carry a high proportion of the heavy traffic between the main urban centres. This is clearly shown in the plot (Figure 2), (BITRE, 2008), which compares the investment in the various road networks for the financial year 2004-5.

The length of the road network under each level of government shows little relationship to the expenditure. The relative length of road the network for which the Local Government Authorities is responsible is considerably more than that controlled by the other two levels of government (AUSTROADS, 2005). When the travel patterns were analyzed, the highest proportion of the travel was conducted on the Urban and Rural Local network and the Rural Arterials (AUSTROADS, 2005). As a result, the LGA network has the lowest expenditure per veh-km travelled.

THE LOCAL GOVERNMENT ROAD SITUATION

The lack of funding for LGA roads has to be considered in the perspective of change to the total funding of the road network in Australia in the recent period. There has been a decline in funding of the total road network. "Road expenditure per vehicle-kilometre travelled in 1994/5 was just over 3.4 cents. This has risen from approximately 2.6 cents in 1984/5. When adjustments are made for road cost increases, the situation in the mid-1990s represents a 7.5% real decline since the early 1980s" (AUSTROADS, 1997). This global figure for all the road systems does not indicate the disproportionate effect on the LGA network.

The Australian Local Government Association presented an examination of the cost to minimize the life cycle costs for Tasmania to a Federal Government inquiry (ALGA, 1997). An analysis of the investment to minimize the life cycle costs for the 13830 km of local roads indicates that the existing fund sources could only provide 66% of the funding needed.

The expenditures on maintenance reported in the Local Roads Expenditure Project (ALGA, 1997) correspond to about 2.5% of the replacement value of the asset for Metropolitan and Regional City Councils. This implies a complete maintenance cycle of 40 years for the LGA pavements, much more than the 25-30 year cycle considered as desirable. This reveals further evidence of relative lack of funding for LGA roads in comparison with the SRA road network.

More evidence of the lack of expenditure has been revealed in an examination of the rehabilitation protocols being utilized in LGA pavements. LGA Engineers in Australia, when surveyed, felt that insufficient funding was allocated to routine maintenance and that the roads were not being resealed or reconstructed often enough (ALGA, 1997). For routine maintenance on sealed roads in urban areas, the expenditure was 65%-75% of what was needed.

All this evidence points to a road network, administered by LGAs, that is carrying a high proportion of the traffic but one that does not receive the same proportion of funding as the State and Federal road systems. The road network serving the bulk of the urban community in Australia is receiving a very small proportion of the funds, on a veh-km travelled basis, in a country where the overall investment in road construction and maintenance is already low by international standards. The majority of the LVT roads are within this system.

In summary, the LGA road network appears to be substantially underfunded in a country where the whole road network is not supported at a level enjoyed by many other countries.

ROAD FUNDING IN AUSTRALIA

On the Federation of the Australian states in 1901, one of the aims was to develop an integrated national economy which would foster economic efficiency within the federation. This overarching principle was one of promoting the optimal use of infrastructure. However, with respect to the aspect of recent road funding in practice in Australia, an analysis found that economic efficiency was not the prime motivator in allocation of funds for the supply of roads (BTE, 1993). The states were seen to have multiple objectives for the fund allocation, when the data for the period 1950-51 to 1980-81 was examined.

The major source of funding for road infrastructure was seen to be fuel taxes and these were to be applied to construction and maintenance of roads. The use of these taxes was later extended to provide general revenue raising. Then more recently, these taxes were also used to encourage substitute fuel use and to underpin regional development. (Trebeck, 2002). There has been an uncoupling over time of the assumed relationship between fuel tax and expenditure on road infrastructure.

The most recent figures summarising the relevant revenue and expenditure on roads are listed below:

1. $16.3 billion was collected from relevant taxes and charges
2. Petroleum products excise raised $9.8 billion
3. Vehicle registration fees charged by States and Territories amounted to $3.5 billion
4. Stamp duty on vehicle registration provided $1.9 billion
5. $9 billion was expended on roads by all levels of government (BITRE, 2008)

Heavy Vehicle Charges

The intention since 1992, in Australia, is for heavy vehicles to operate on a pay-as-you-go basis. In 2007, the Heavy Vehicle Charge Determination was set so that heavy vehicles pay more than $1.95 billion of the total cost for roads of $11.67 billion, being the annual average expenditure over seven years. This is paid through an annual registration fee and a net fuel charge. This covers the costs of road wear attributed to each vehicle type and a portion of the common road costs such as signage etc. It was concluded that the road use charges may not be keeping pace with the spending on roads (NTC, 2007).

The base for heavy vehicle charges is made up of the following factors, excluding other costs such as noise and air pollution, road safety costs and the costs of enforcement of associated regulations: -

- Diesel fuel excise
- Annual access charge (registration)
- Mass-distance charge
- Over–weight and over-dimension permit fees

- Fee for travel between zones where allowed by the constitution.

These charges are used to defray costs such as those listed below, (BTE, 1993): -

- Road damage costs
- Traffic congestion costs in peak traffic times
- Social costs such as noise and pollution (sometimes)
- Other costs including lighting, signage, accident and road trauma costs have also been included in some models

The heavy vehicle charges are adjusted annually, with a maximum change not to exceed the Consumer Price Index (CPI) and the minimum change not to be less than zero. The formula used takes into account the following factors (NTC, 2008): -

- Weighted change in road expenditure noting change in Rural Arterial, Urban Arterial, Rural Local and Urban Local expenditures.
- Adjustment for Fleet growth

It is worth noting that greenhouse gas emissions are not specifically taken into account when calculating these charges.

ALLOCATION OF ROAD COSTS

As an example of the attribution of expenditure of road taxes, in 2004-5, Figure 3 illustrates the way in which the road costs, in Australia, are allocated between costs due to heavy vehicles, light vehicles and other categories (NRTC, 1988).

ROAD DAMAGE

Road damage has two main causes, viz. damage due to vehicular traffic and damage due to weather. However, the costs, in an Engineering sense, associated with using a road arise from the repair of damaged roads, the strengthening of the pavement, congestion on the road and the works associated with increasing the capacity (Figure 4).

Damage is seen as mainly due to loading by heavy vehicles. The equivalent standard axle load (ESAL) is that of a standard dual-tyre axle with a load of 8.2 tonnes. As the load increases above the ESAL, the damage is seen to increase at the rate of the third to the fourth power. There is also increased cost for vehicles using the road after heavy truck traffic, due to travelling on a rougher road, to be considered.

CONGESTION COSTS

Road congestion, produced by lack of road capacity and increase in traffic flow, results in inefficiency in the use of the road system. These inefficiencies result in the following problems (BTRE, 2007):

- Increase in fuel costs
- Increase in travel time
- Business time cost
- Private time cost
- Vehicle operating costs
- Other costs, such as business relocation costs, psychological stress and irritation, etc.

Although congestion is less of an issue for LVT roads, consideration must be given to the concept when developing a sustainability policy for this road network.

THE EXTERNAL COSTS OF TRANSPORT

Major environmental impacts, which contribute to the cost of transport to the community, associated with road transport include (BTCE, 1995) :

- Air pollution, including emissions of carbon monoxide, nitrogen oxide and particulate pollution;
- Greenhouse gas emissions;
- Noise pollution;
- Habitat and wildlife destruction; and
- Water pollution.

A more extensive list of externalities (BTCE 1998) includes the following, although the costs of road accidents associated with post-accident health care have not been included: -

- Building vibration damage
- Oil spills
- Visual blight
- Barrier effect (communities separated by road)
- Accident related damage (to property)

Another consideration in a geologically old continent is that the best road construction materials have already been harvested for road-building. These are non-renewable resources. Current resources become more expensive and may be of lesser quality. In winning new materials, new quarries can be developed which can impose externalities such as habitat destruction, water and air pollution, etc. (Wilmot and Wilmot, 2003). The incorporation of existing road materials into new construction is a factor which needs to be taken into consideration.

VIEWS OF ROAD FUNDING IN AUSTRALIA

There are two major positions taken with respect the level of road funding, firstly, as denoted in the section on “Road Funding in Australia” above, revenue generated exceeds road expenditure. In the alternative view, revenue does not cover expenditure when a range of externalities are taken into account.

In a summary of the road costs and revenues, including externalities, (Laird *et al.*, (2001), it was concluded that the road deficit each year in Australia is $8 billion not counting congestion, and $19 billion including congestion. These estimates do not take into account of a number of environmental externalities, the most notable of which is greenhouse gas emissions.

This is in contrast to the position generally held by Australian motoring organizations that there is a surplus of funds on the revenue side for roads. As an example of this approach, the Royal Automobile Club of Victoria stated “The Federal Government collected approximately $13.6 billion in fuel excise in 2004/05 but spent only $2.1 billion on road construction and maintenance (about 16% of this revenue)” (RACV, 2004).

ROAD INVESTMENT APPROACH

In a strictly engineering sense, an effective road network is one which operates at the optimum level at all parts of the network with respect to durability and capacity, not including any externalities. The outward aspect of durability is seen as roads in good repair with low roughness. This can be adjusted by selection of the quality of construction materials and by variation in the thickness of the pavement.

Capacity capability is judged by having congestion kept to a minimum. Capacity can be altered by increasing lane width and providing more lanes, by increasing intersection capacity and by providing grade separation at intersections.

In addressing durability and capacity, there are several strategies to be considered when allocating funds within a road jurisdiction (BTE, 1987): -

- Preserve the physical asset: The damage due to traffic and weather only is made good. The physical state of the road remains constant.
- Preserve the operational performance: The asset is preserved. Upgrades are provided to ensure that the level of service does not deteriorate.
- Undertake all economically justified road projects: All projects with a cost-benefit ratio greater than one are undertaken in the funding year.
- Maximize economic returns for specified annual funding levels: Road projects are undertaken to the limit of the budget in decreasing order of cost-benefit ratios.

An example of the cost-benefit ratios computed by the Bureau of Transport Economics (BTE, 1999) for various road classifications in Australia is shown below in Table 1.

An Example of Allocation of Federal Funds to a State

A study was made into the process of road fund allocation to a State by the Federal Government and the subsequent disbursement of the funds by that State (BTE, 1987). The Main Roads Act in Queensland had as one of its objectives that the funds should be directed to promoting strategic economic development of the State. This objective had the potential to divert funds form roads with heavy traffic loads to roads whose construction could stimulate development and growth.

The funding allocation was tested using two hypotheses, the *Area-Population Model*: Funds for each region are distributed on the basis of the area and population for each region. The second hypothesis is the *Utility Maximization Model*: Funds are distributed to maximize the utility of the budget within constraints.

Neither model appeared to be a good fit. Previous expenditure patterns appeared to provide the best guide for preparing budgets, although there was some weight given to regions with large areas in the allocation. Internal distribution of funds within a state can always be made based on "previous expenditure patterns" or influenced by other considerations such as the area-population model or political factors such as developmental pressures.

In this process, little emphasis is given to externalities such as greenhouse gas emissions. The focus is on the asset, its preservation and development. No mention of the consumption of non-renewable resources is made. In spite of the attempt to rationalize funding sources and its distribution, the application of the funds does not necessarily follow a formula reflecting that philosophy and leaves the opportunity open to consider new guidelines for distribution of funds.

LVT Network Situation

Local Authorities have created a substantial asset base of what is essentially an LVT road network, which requires an increasing amount of rehabilitation as it ages. The substantial road network under the control of the local authorities share a lesser proportion of the funding based on system length or system use.

The approach, which suggests that "it should only be fixed if it is broke" is not seen to be acceptable in most sophisticated communities. The LGA view is that not enough is being spent on roads and that a huge liability is being accumulated for the future. "The underlying cause is that while capital programs have invariably been funded by Federal and State Governments, these spheres of government rarely make provision for ongoing maintenance. The burden for Local Government gradually increases as the infrastructure stock increases and ages" (ALGA, 1997).

As the system deteriorates, the demand for rehabilitation increases and the authorities are faced with a shortage of funds. As the pavement condition declines the cost of rehabilitation of any particular section increases, resulting in a reducing proportion of any LGA network being rehabilitated. LGAs are also faced with more complex decisions about where to apply the limited resources to the best effect so that the level of service provided by the asset is at least maintained, or preferably, improved.

From these figures, it would appear that the LVT roads generally have not been maintained so that the asset has been preserved, but it is more likely that the asset has, in generals deteriorated. Funding at a rate greater than historical levels may have to be provided to raise the level of the quality of the asset.

Deterioration of Pavements

A road, once built, begins to deteriorate and eventually reaches a stage where it ceases to fulfil its function. The plot of pavement deterioration versus time, over the lifecycle, has a theoretical shape for roads, as shown in the cumulative damage plot (Figure 5). The deterioration is displayed as the following:-

- The structural performance.
  - Potholing
  - Rutting
  - Cracking
  - Deflection under load
- The skid resistance.
  - Reduction of surface friction
- The road roughness
  - Amount of vertical travel /km for a vehicle passing over the pavement.

There are two stages in the lifecycle for maintenance and rehabilitation opportunities to conduct works on the pavement. In the early stage of the Cumulative Damage plot, before damage rates accelerate, maintenance and strengthening can take place to extend the life. Beyond this early stage, the pavement ceases to provide the required service and re-construction is the only option. If this is the case, a greater provision of non-renewable resources will be needed for re-construction.

Figure 5 shows the pavement passing through lifecycles as the traffic numbers, axle loads and congestion increase. The diagram illustrates a response to increasing congestion so that after the second lifecycle, works are carried out to increase capacity and thereby reduce congestion.

If there has been a significant underspend of funds for maintenance of the LVT road network in the past, as claimed, then the steeper part of the cumulative damage curve is more representative of the state of the pavements. To remedy this situation, extra funding, above the usual cost of damage, will be required to bring the system to an appropriate standard.

Optimal Contribution of Road Infrastructure

As well as promoting optimum use of infrastructure, the road system is seen to be such that (Engineers Australia, 2006): -

- It is cost effective
- Allocated costs are fully recovered
- Externalities are included in the cost

This approach suggests an increase in the attribution of costs above the current view which concentrates on fixing damage and reducing congestion.

Greenhouse Gas Emissions

In Australia, the transport sector contributes 14.2 % of all greenhouse gas emissions. In this sector, the greenhouse gas emissions are expected to grow at the rate of 1.7% per annum (BTRE, 2003). With the world by and large taking a view that greenhouse gas emissions are making a contribution to climate change, then the role of the LVT network in lessening emissions needs to be considered.

The Effect of Climate Change on Flexible Sealed Pavements

With the proposed phenomenon of climate warming and the acknowledged prolonged drought over the last 10 years in Australia, it has become apparent that the surface soils are drying out and the depth to stable moisture content in the soil has increased. This has the effect of increasing the strength of the upper soil layers particularly in clayey soils, making the road subgrade stronger. Thus the pavement structure is capable of supporting higher traffic loads.

On the other hand, the consequent effect of global warning raises the temperature of the thin bituminous seal, increasing the extent of the range of diurnal expansion and contraction. This will have the outcome of increasing the fatigue loading. This phenomenon, together with the loss of ductility due to evaporation of the volatiles, would cause the seal to crack and allow water to penetrate faster, causing reduction of pavement strength.

Impact of Construction and Maintenance in Low Volume Roads

Australia uses a cost-benefit assessment procedure to also measure the effect of the project, as illustrated in Table 1. On top of this, at the level of the LVT road system, there is a need to place an emphasis on environmental mitigation with the use of an Environmental Impact Assessment approach (PIARC, 2007b). This can be considered under the headings of construction, maintenance and operation of the asset. The concerns of countries were canvassed by PIARC and their responses were influenced by the status of development in each country and depended on whether the road system was fully developed or under development. Common concerns, related to construction and maintenance, were as listed below:

- Pollution of air and water including ground water
- Noise pollution
- Fragmentation of animal habitat

- Ecosystem loss
- Take up of non-renewable construction materials
- Increasing instability of soil and rock slopes

For developing countries the issues raised included: -

- Community relocation
- Creation of barriers
- Loss and breaking up of agricultural land

For countries operating mature road networks, the points of interest tended to be:

- Greenhouse gas emissions
- Energy use
- Increasing reliance on cars for passenger transport
- The impact on community life is often taken into account in terms of: -
  - Amenity access
  - Linkage to health support systems
  - Support for community cohesion and reduction of isolation
  - Access to employment opportunities

POLICY FOR LVT ROADS IN AN AUSTRALIAN ENVIRONMENT

The main issues for consideration are the apparent under-resourcing of the system causing long term deterioration with respect to durability and capacity, the lack of attention given to the externalities impinging on the service the system is providing and mitigation of the contribution of the system to greenhouse gas emissions. A proposed policy for the construction, maintenance an operation of a network of LVT roads is set out in point form below: -

- The philosophy in funding should be to at least preserve the operational performance following the work to raise all parts of the system to the required operational level.
- Maintenance needs to be carried out in a timely fashion to reduce road roughness to a minimum and in such a way that the use of non-renewable resources is minimized.
- Construction should be done in a manner that reduces pollution to minimum and disruption to community cohesion, habitat, ecosystems and agricultural holdings is kept at the lowest possible level.
- Construction should incorporate recycled materials where possible.
- Increasing traffic loads are catered for by relieving congestion in a pre-emptive manner.
- Greenhouse gas emissions associated with traffic on LVT roads require acknowledgement and the LVT road system operated to keep these at a minimum by reducing road roughness, flattening grades and eliminating congestion.
- Ecosystems damaged by construction and maintenance should be regenerated as an expense associated with road funding.

CONCLUSION

LVT road networks can make a contribution to sustainability. In Australia, previously, the performance of these roads was considered from an engineering viewpoint. The system was managed to maintain the asset and to address any shortcomings in operational performance when funding became available. Little thought was given to externalities and contribution to greenhouse gas emission.

A contribution can be made by the LVT road system to sustainability, by recognizing the impact of externalities and taking steps to mitigate the impact. In an engineering sense, a further contribution can be made by operating the system so that energy consumption is kept to a minimum by providing well-maintained smooth roads with flatter grades. The regular maintenance in the early deterioration phase of the network will reduce the consumption of non-renewable resources. Recycling of existing pavement material into new construction will also reduce demand on these resources.

An outline policy for Sustainability of Low Volume Traffic (LVT) Roads in an Australian Context has been offered. This policy differs from the existing approach of funding roads to cover damage and congestion and incorporates externalities, including the use of non-renewable resources, to be taken into account when estimating funding requirements. The capacity of the LVT road system to contribute to the reduction of greenhouse gases is also canvassed.

Acknowledgements

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APPENDIX

Table 1 Benefit-cost Ratios for Road Construction (BTE, 1999)

	Benefit-cost ratio from:		Ranking
Road group	Benefit-cost analysis, BTE	Austroads study	
Rural Roads:			
National	2.1	1.5	3
Arterial	2.0	1.4	4
Local	1.0	0.5	Equal 5 and 6
Urban Roads:			
Freeways	4.8	5.4	2
Arterial	6.0	6.3	1
Local	1.0	0.5	Equal 5 and 6

Australian Road System: Length 798450 kms

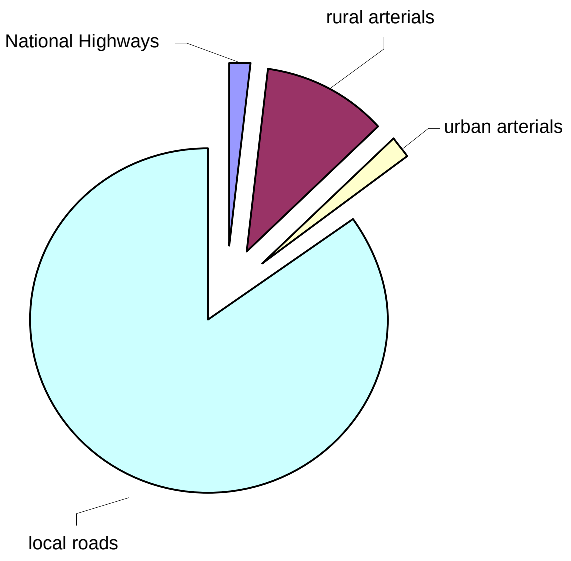


Figure 1 Australian Road System (BTE, 1987)

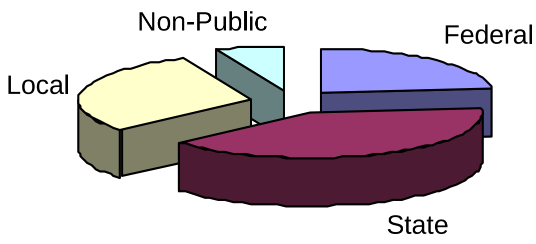


Figure 2: Road Expenditure by Level of Government 2004-5

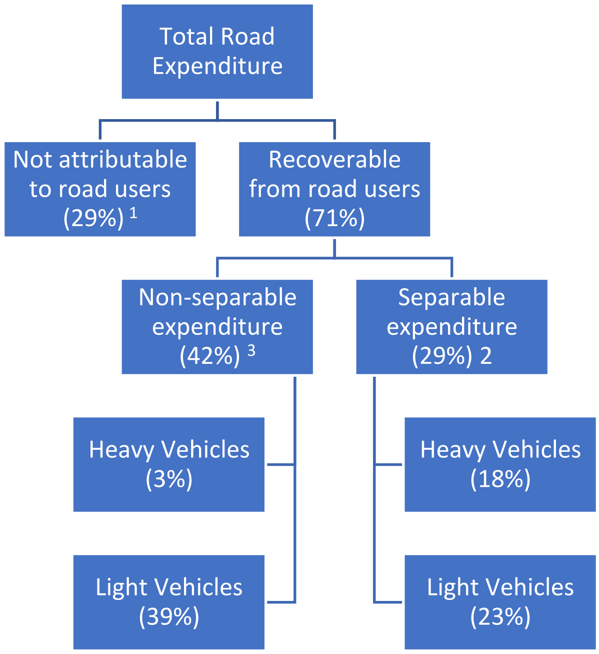


Figure 3: Road Costs Allocation (NRTC, 1988)

Legend

(1) Not attributable to road users

Vehicle registration
Driver licensing
Loan interest
Heavy Vehicle enforcement costs
50% of rural road expenditure used to provide access

(2) Separable expenditure

Based on road use, e.g., veh km travelled etc.

(3) Non-separable expenditure

Not attributed to road use, e.g., verge mowing, cost of providing a minimum standard of road, etc.

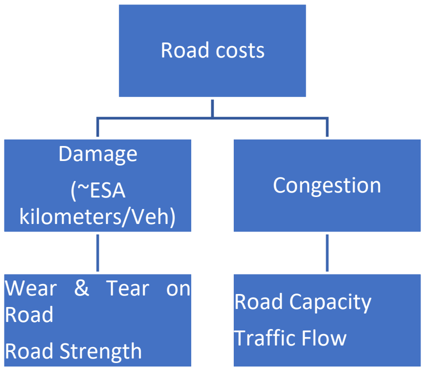
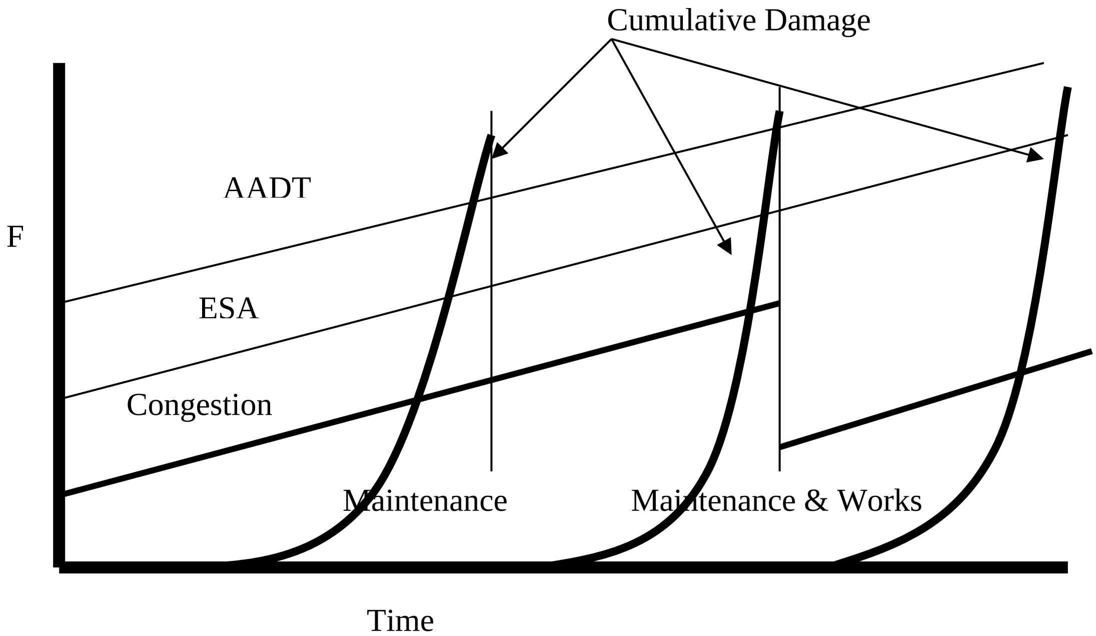


Figure 2: Engineering Costs associated with Road Use



Interaction of traffic count, congestion, axle load, maintenance and works with cumulative road damage

Figure 3: Cycle of Cumulative Damage for a Pavement