LAND TRANSPORT PRICING: DIGEST REPORT

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AN IMPORTANT NOTE FOR THE READER

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FOREWORD

Transit New Zealand, along with the Ministry of Transport and other government departments, is reviewing the pricing and regulatory framework for the land transport system in New Zealand. The main objective of the review is to determine the costs caused by users of the land transport system and the potential additional economic and social benefits that could be realised if prices and regulations were more closely aligned with these costs.

As a first step in this review, Transit New Zealand commissioned two international literature reviews. The first by Halcrow Fox and Associates in conjunction with the Institute of Transport Studies at Leeds University looked at literature on the direct costs involved in providing and maintaining land transport infrastructure, and the costs incurred related to congestion and accidents. The second review by Works Consultancy Services Ltd in association with the NZ Institute of Economic Research (Inc.) and Steer Davies Gleave (NZ) investigated the less direct costs such as environmental damage caused by transport.

These literature reviews resulted in comprehensive reports which have been summarised in this digest. The digest comprises two parts: a summary section which gives a brief overview of all the issues involved, and a more lengthy digest which covers the findings of the literature reviews in greater detail.

LAND TRANSPORT PRICING

SUMMARY

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SUMMARY

1. Introduction

The cost of transport impacts on us all, either directly as transport users or indirectly as consumers of goods and services which are transported to us. The ways in which we pay for transport is discussed in the Land Transport Pricing Digest which follows this summary.

The Digest summarises the findings of two reports (by Halcrow Fox and Associates, and Works Consultancy Services Ltd) prepared in 1992 as part of a land transport pricing study. These reviewed international literature, covering both theoretical and practical applications of pricing mechanisms for land transport, and spanning the identification and measurement of transport effects (or externalities), the financing of transport projects and the economic appraisal of road pricing schemes.

This literature has multiplied in recent years because the growth of road traffic currently being predicted in most countries seems likely to create serious problems of urban congestion and pollution if left unchecked. Road pricing, which includes various methods of making road users pay for the costs they impose on the road network, the community and the environment, can be used in combination with other measures to control this growth.

Two questions underlie the recent interest in road pricing. First, are road users as a group paying the full costs they impose on the community? If not, "too much" transport may be causing excessive provision of roads whose investment funds might be better employed elsewhere. Second, are individual road users facing the full costs of each individual trip? If not, too many trips may be being made where the value to the trip maker is less than the costs being imposed on others. In either case there may be misallocation of funds since transport business is diverted to roads from other less costly modes, such as rail or sea.

These two questions are related but not identical, since it is possible for charges to cover the full costs of the transport system as a whole yet have little impact on individual trip decisions. For instance, costs could be recovered in full from annual vehicle licensing fees, but once paid these would provide no incentive to minimise road use or avoid the creation of additional costs in future.

Transit New Zealand is charged with providing an efficient land transport system and also, under the Resource Management Act, with achieving sustainable management and avoiding adverse environmental effects. The economic efficiency of road provision is not confined to financial returns for any individual or agency, but entails maximising community "well-being" from a given set of resource inputs, and includes all effects on the community.

In principle road pricing, where users face the full costs of each individual trip, can be efficient, being more flexible than outright bans or controls, and more effective than simply exhorting drivers to change their behaviour. In practice its execution is not so simple, and few examples of true road pricing exist around the world, but recent technological advances

may mean we are on the threshold of new feasible charging methods which would lead to a radical overhaul of how we pay for roads.

2. What Are the Costs of Land Transport?

Land transport is defined as the movement of people and goods over land, embracing walking and cycling as well as other forms of public and private transport by both road and rail. The Digest reflects the pre-occupation of current research literature with roading, as distinct from other land transport modes, both because of the potential magnitude of road-use effects and the likelihood of road users' costs being out of line with the full social costs that roads impose on the community.

This is because only under limited circumstances can roads be provided like private goods, with costs fully recovered from direct user charges. Much of the road network has too many entry and exit points (e.g. onto private properties) and carries too little traffic for it to be worthwhile to observe road users and charge them directly. It is less costly to supply the network collectively through various forms of taxation on the community which benefits. In this respect roads differ from other network industries, such as telecommunications, power grids, railways and canals, whose use is more readily monitored and billed to individual users.

Motorists and vehicle fleet operators base their decisions for their use of roads - how many trips to make, which mode to use - on **private costs**. Private costs have two elements:

- the "pure" cost of vehicle operation, including financial expenditures on vehicles, fuel and vehicle maintenance, and non-financial expenditures of traveller's time and effort;
- a series of government impositions on the pure cost of transport - fuel taxes, road user charges, sales taxes and registration fees - whose revenues are often intended, implicitly or explicitly, to recover the costs of providing a transport network.

Private costs are not the only costs that roads impose on the community, since road use also creates a number of "**externalities**", effects which are borne by people other than those whose actions caused them. A truck which damages the road surface increases the discomfort of all subsequent users of that road; a car which joins a busy road and slows down the traffic stream causes delay for all other vehicles in the same stream; and any vehicle which uses urban roads creates effects like noise or vibration which are borne by residents. The externalities of road use are manifested in the costs of accidents, congestion, environmental degradation, and road repairs and upgrading.

The **full social cost** of road use therefore comprises the pure private costs plus the externality costs associated with each trip. But rather than paying directly to be on a particular road at a particular time, road pricing tends to be indirect through government impositions, such as fuel taxes, licence fees and other road use charges. A critical question for road pricing is how closely pure private cost plus government impositions approximates to the full social cost of roads.

3. Road Cost Recovery in New Zealand

Road costs have long been explicitly linked to charges levied on road users in New Zealand. When the current system was established, the sum being recovered - the annual expenditures from the National Roads Fund - related only to road repairs and improvements. Since legislative changes in 1989 created the Land Transport Fund (LTF), other components of road system operating costs have been brought into that recoverable sum, such as traffic safety administration and subsidies to public transport. However, some costs of the road system are still not included in the LTF, most notably various environmental costs and the roading expenditures by local authorities. It is debatable whether these items should also be recoverable because, if they are not, the "price" faced by road users may be less than the full social cost of the road system, and may encourage its over-use.

The existing cost recovery process allocates current annual expenditures on roading between road user groups according to the categories of expenditure which can be attributed to them. The contribution from cars is collected as a share of fuel tax, and hence the payment received from each vehicle is broadly related to distance travelled. Vehicles which run on lightly taxed fuel, such as LPG or CNG, appear to make lower contributions to the road system. Contributions from heavy commercial vehicles are collected through road user charges, which reflect distance travelled and load carried by individual commercial vehicles on the public road network. **Road repairs and maintenance** are almost wholly attributable to heavy commercial vehicles, so these expenditures are recovered through road user charges. Expenditures to expand the **space capacity** of roads, such as additional lanes or new by-pass roads, are largely attributable to cars, although a portion is also recovered in road user charges from trucks. Expenditures which **benefit all drivers** (such as lane markings and road signs) are allocated across all vehicles.

Current annual expenditure on the land transport system is $1050 million, comprising $750 million from the Land Transport Fund and $300 million from local authority rates. The $750 million revenue into the Land Transport Fund comes from fuel tax 46%, road user charges 40%, and vehicle licence fees 14%. Motorists contribute a further $600 million in fuel tax to the consolidated fund, and $100 million in accident compensation levies.

In recent years a debate has emerged over whether motorists pay too much in view of the fuel tax revenues absorbed by the consolidated fund, and whether such revenues should be dedicated to transport purposes. A less publicised question is whether the percentage share of contributions from each user group is still appropriate, since the mix of expenditure items in the Land Transport Fund has changed considerably since the cost attribution exercise was last carried out.

4. An Alternative Basis for Road Pricing

New Zealand has gone further than many countries in identifying total roading costs and recovering them through charges which vary with the type and number of trips. However, theoretical literature lends support to a different basis for charging known as marginal cost pricing.

Such an approach would view the cost of an individual truck trip **not** as some share of current maintenance spending, but rather as the contribution of that trip to "using up" the life of the road and bringing forward the date of road replacement. Similarly, the cost of an additional car trip is **not** some share of current expenditures to expand the road capacity, but rather each vehicle's contribution to congestion delays which thus brings forward the date when further space capacity is required.

The crux of the difference in approaches is that cost recovery, as currently practised, charges current users for current expenditures which have been necessitated by past use. The users creating the need for the expenditure and those paying it are not necessarily the same. Marginal cost pricing would charge current users only for their contribution to future costs, and provide in advance for foreseeable expenditures.

A problem with marginal cost pricing is that it does not guarantee revenues collected in any one year will meet the expenditures made that year. If the road system were required to operate with a balanced budget, supplementary revenue would need to be collected in a manner which did not affect individual trip decisions, for instance by annual licensing fees. The resulting charge structure could look very different from that currently in place, with a larger component of fixed charges and a smaller component of variable charges than at present. Since higher fixed charges might be expected to reduce vehicle ownership, but lower unit charges might be expected to increase the number of trips, the overall effect on traffic flows is impossible to determine without evidence of the price responsiveness of vehicle ownership and vehicle use.

The point about marginal cost pricing is that it changes the signals that users receive about making individual trips, by shifting the charges from economic "goods" (like mobility) to economic "bads" (like delay). The extent to which this is possible varies with the different categories of transport effect being priced, and it depends on being able to collect charges appropriate to individual users. For instance, congestion charges would not be levied on vehicles using uncongested roads, which is what the current recovery of space costs effectively does. Basing road charges on marginal cost pricing principles need not mean raising the overall cost of transport, for they would replace existing charges which are less tailored to individual use of the roads. Thus some users would pay more and others would pay less than they currently do.

5. Accidents

Some overseas literature suggests that accidents, if properly costed, would dwarf all other components of the social cost of roads. New Zealand motorists already pay an accident compensation levy to cover road accident costs such as ambulance, hospital and rehabilitation services. Additional charges would only be required if costs outside the existing cover offered by the Accident Rehabilitation and Compensation Insurance Act were to receive compensation, for instance the psychological suffering and trauma of accident survivors. For similar reasons, the cost of accidental property damage can be presumed to be largely met already by road users through insurance premiums, and no further charges are warranted.

Another issue is whether an accident charge should be included in the unit costs of each trip, since additional vehicles in a traffic stream increase the risk of vehicle collisions. However, none of the international research reports a consistent statistical relationship between number of vehicles and rate of accident, so there is no reliable guide to what a unit charge for accident risk should be.

6. Congestion

Although congestion is to some extent a self-imposed problem, each car which joins a traffic flow slows down all other vehicles in the flow as well. Delay costs can be cumulatively very large, until at some point they exceed the cost of road expansion and new road capacity is installed.

Congestion pricing needs to be targeted at peak-period users who cause congestion; to allow for substitution between different transport modes; and to present users with a predictable cost for travelling along different roads at different times of day. There is a trade off between having prices which accurately reflect varying conditions on the road, and too much complexity which confuses the signal being given to drivers.

The feasibility of congestion pricing depends on solving the practical problem of setting and collecting differentiated charges from vehicles without causing additional disruption to traffic flows. Various methods of electronic road pricing provide flexible means of billing vehicles for actual use of the road, but they also have high initial costs in fitting vehicles and roads with the necessary metering equipment. A simpler, cheaper alternative is to have areas within toll cordons, variants of which have been operated for some years in Singapore and Oslo, but this can be regarded as unfair to those who travel little once inside the toll area.

The level of congestion charges depends partly on circumstances. Charges need to be higher to effectively reduce congestion if there are no transport alternatives for those who must travel in congested areas and periods, for example through-traffic which has no option of by-passing urban centres. The low price and availability of off-street parking may offset the deterrent effect of congestion charges, since although it clears roads of stationary vehicles it may also attract more traffic into apparently "emptier" streets.

Because of the substantial scale of congestion costs, their very visible effects and their current exclusion from road charges, congestion pricing receives much attention in the international literature. Whether this experience of densely populated northern hemisphere countries applies to New Zealand however has yet to be demonstrated. Implementing some forms of congestion charging on New Zealand's relatively self-contained vehicle fleet may avoid some of the pitfalls identified overseas, but the aggregated costs of traffic delay here are also less acute.

7. Environmental Effects

Environmental effects of land transport can be broadly divided into various forms of community **interference** and **intrusion** caused by the transport network, and various types of **pollution** related to transport use. The network-related effects include loss of sites of special historic or cultural significance; community severance, which adds to the cost of transport and interaction between locations either side of a major transport artery; and visual intrusions which impact, among other things, on nearby property values. The treatment of such effects is to ensure they are fully accounted for in appraisals of new transport projects. Most of them are not quantified in current project appraisals, and some further refinement of measurement and valuation procedures is required to rectify this omission.

Transport use-oriented effects such as air pollution, groundwater contamination, noise and vibration, could be remedied by inclusion in unit charges. For instance, fuel tax is a reasonable proxy for an air emission charge, although to be consistent this would require introducing taxes on fuels which are currently exempt, such as LPG, CNG and diesel. It would also be desirable to distinguish between pollution which is widespread - such as the contribution of emissions to global warming - and that which is associated with localised vehicle concentrations. The latter might be more appropriately charged for through a congestion fee rather than a generalised levy which does not discriminate between the circumstances of the users.

The overseas literature suggests that environmental effects are not the largest component of social costs of transport. Some individual effects, such as air pollution and noise, are substantial enough to be regarded as national policy issues, but others such as dust and vibration are so localised as to be insignificant at national level and suited only to local remedies. Another environmental issue is the relationship between land use and transport since, if transport infrastructure is subsidised to some users such as suburban commuters, the costs that users face are less than the costs of provision. The consequence of such a subsidy could be over-use of the system, further expansion of urban areas, and consequent increases in environmental effects.

8. Road Repairs and Improvements

The costs of road repairs, rehabilitation, construction and improvements have traditionally been the principal component of roading costs subjected to charging policies, and they still comprise 80% of the recoverable sum in the Land Transport Fund. Estimates over a range of developed countries suggest they form less than half of the full social cost of transport, including accidents, pollution and the cost of time spent travelling, but they are still a significant item and often readily calculable by individual roading authorities.

Current practice in New Zealand allocates the majority of road repair and rehabilitation costs to heavy commercial vehicles. This is based on experimental results which suggest a vehicle's road wear increases with the fourth power of its axle load. This means that the wear effect of trucks exceeds that of the more numerous but lighter cars in mixed traffic streams. Some recent engineering evidence casts doubt on these earlier results or suggests only part of the wear and tear is attributable to traffic (as distinct from natural weathering),

but the reports conclude that these differences are not significant and confirm the current allocation of repair costs to heavy vehicles.

The critical question which remains to be answered in pricing of road repairs is whether to collect charges on the basis of recovery of current costs (as in the existing road user charge system) or to base use charges on marginal cost pricing. If marginal cost pricing is adopted, the unit charge faced by trucks could be less that its existing level, and the collection of any deficit on current expenditures would be redistributed across road users in a manner which could have far reaching impacts on competitive advantage between road and railfreight, and between trucks and other road users.

9. Conclusions

The idea of road pricing is that road users should pay for their use of the road according to the costs that their transport use imposes on the community at large. Such prices will be efficient if collectively road users pay the full social costs caused by transport, and individually their decisions to travel are based on a price which covers the full cost of each individual trip.

The reports covered in the Digest point to the conclusion that, for many trips, current charging procedures in New Zealand understate road transport's full social costs. Overseas literature suggests that costs of traffic delays, noise and air pollution may be substantial enough to warrant additional explicit charges. Accident costs are also substantial but in New Zealand are covered by existing accident compensation levies. Further research for New Zealand is required on:

1. How to determine the recoverable sum that should be paid by transport users;
2. How to revise contributions from different user groups;
3. Whether to change from cost recovery to marginal cost pricing for road infrastructure costs;
4. Which charge mechanisms are most cost-effective.
5. When are other mechanisms, such as regulation, more appropriate than pricing.

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ABSTRACT

This Digest summarises the findings of two reports prepared as part of Transit New Zealand's transport pricing study, excluding recommendations for further research which are the subject of another document. These reports surveyed the international literature on transport pricing, considering the justification and available mechanisms for charges to cover road wear and maintenance, congestion, accidents, and various environmental effects.

1. INTRODUCTION

The growth of road traffic currently being predicted in most countries seems likely to lead to serious problems of urban congestion, local environmental degradation and contributions to global pollution. This raises questions about the provision and funding of capacity necessary to accommodate this growth, and also about whether the growth itself is responding to the right signals about the costs of transport. If the price users pay for transport does not fully cover all the costs they create, trips will be made where the value to the trip maker is less than the total cost borne by the user and other people. This detracts from economic efficiency and has fuelled worldwide research effort into ways of ensuring prices cover the full social costs of each trip.

This Digest provides a guide to the contents of two recent Transit New Zealand research reports (No. 18 and No. 19) namely *Land Transport Pricing for New Zealand* by Halcrow Fox and Associates (HFA), London, and *Land Transport Externalities* by Works Consultancy Services Ltd (WCS), Wellington. They were undertaken during 1992 under the auspices of Transit New Zealand as part of its programme of research into land transport pricing.

The reports review the information currently available on the scale and importance of various effects caused by land transport - road wear, congestion, noise, pollution and accidents - and on some of the proposals emanating around the world for alleviating them. A principal focus is on the economic implications of these effects.

1.1 Reasons for Land Transport Pricing Study

In addition to the current worldwide interest in transport pricing research, specific New Zealand influences are reflected in the study programme.

1. Although legislation governing land transport administration in New Zealand was overhauled in 1989, the mechanisms used for charging transport users are substantially unchanged since their introduction some years before. If these mechanisms are no longer the most appropriate to be used - given recent changes in administration, technical possibilities for road charging, and evidence of the scale of transport costs - they will give incorrect price signals and stimulate a level of transport use which is not optimal for the economy.

2. Recent research effort in land transport has been directed at quantifying and valuing a range of transport effects which are external to the individual users whose travel decisions cause those effects. Many of these are outside the scope of current economic evaluation procedures used for assessing the worth of transport projects. The relative scale and importance of these various costs and benefits need to be assessed to establish whether they warrant explicit incorporation in transport prices or evaluation procedures.

3. The passage of the Resource Management Act 1991 created a set of new duties, particularly on local government, to consider the effects of various resource uses with a view to achieving sustainable management. This applies to transport systems as well as the more traditional resources of land, water and air.

1.2 Objectives of Research Study Programme

The overall objective of the Land Transport Pricing Research Programme is to establish a comprehensive pricing and regulatory framework for the land transport system. This requires identifying the means to ensure that users base their transport decisions on the full costs their transport use imposes, reflecting all relevant effects, costs and benefits caused by the system. A further aim is to assist in applying to land transport the principle of sustainable management as established in the Resource Management Act.

The objectives of the HFA report were to provide an understanding of current structure and pricing of land transport in New Zealand, and to review international literature relevant to pricing of land transport, with particular emphasis on road pricing. Its focus is those transport-related effects which are external to the individual user, but internal to the community of transport users - costs of road maintenance, congestion and accidents. HFA's findings are reported primarily in sections 2-5 of this Digest.

The objectives of the WCS report were to review international literature on the quantification and valuation of transport-related effects which are external to both individuals and the transport system - effects such as air pollution, noise, loss of amenity which can be felt by those who are not transport users themselves - and to determine the efficiency and

effectiveness of various mechanisms intended to bring such external costs into transport users' decisions. WCS's findings are reported in sections 6 and 7 of this Digest.

1.3 Brief Explanation of Some Terms Used

Land transport is defined as the movement of people and goods over land, embracing walking and cycling as well as other forms of public and private transport by both road and rail. In the current research literature road transport predominates, both because of the magnitude of effects of road use and the likelihood of costs faced by users being out of line with the costs their use imposes on the community.

The focus of **economic analysis** is **economic efficiency**, the maximising of outputs from a given set of available inputs. The viewpoint of **economic analysis** is wider than a financial analysis, being concerned with all the ways in which land transport affects the outputs obtained from resource inputs: proposed solutions are evaluated not just in terms of their monetary cost, but also in terms of non-monetary costs (e.g. time delays) imposed on transport users. Similarly the analysis is not concerned primarily with impacts on a single agency or transport authority, but rather with the impact on the well-being of the entire community, residents as well as transport users.

The usual mechanism for deciding on resource use and allocation is the process of **market exchange** in which the **price mechanism** signals the relative scarcity of input resources and the relative strength of demand for the products derived from them. Sometimes the market fails to provide sufficient goods or services because it is not feasible for a private supplier to recover costs from users and exclude non-paying "free-riders", or because the nature of some goods or services is such that, once supplied to one person, they are available to all so that charging is inefficient in deterring use which could be accommodated at no additional cost. Such goods and services are commonly provided as **public goods**, funded out of taxes levied on the community which benefits. They are not necessarily provided free to users, but use charges can not effectively recover the full costs of use.

"**Externalities**" are those effects of one person's actions which are wholly or primarily borne by other parties. Externalities in transport include road wear, traffic congestion, accidents, noise and pollution, and they are potentially important because individuals are likely to use transport more and make greater impositions on the community if they are shielded from the full costs of their transport use.

Transport pricing refers to all the ways in which transport users are faced with the costs created by their transport use, including:

- **Private costs** which impact directly on vehicle users' transport choices, such as the acquisition and depreciation of vehicles, tyres or fuel, and driver time;

- **Social costs** which are felt only indirectly by individual users:
  repair and maintenance borne by highway authorities,
  delays borne by other transport users,
  accident risks,
  pollution.

Full social costs are the sum of private costs and social costs. A function of economic policy is to reduce the difference between private costs and full social costs, supplementing market prices with taxes if need be so that users face the full costs they create by using transport. The extent to which various levies and taxes (such as road user charges, licensing fees) presently cover social costs is open to question.

2. PRINCIPLES AND PRACTICE OF TRANSPORT PRICING

2.1 Current Practice in the New Zealand Land Transport System

The HFA report provides a comprehensive summary of the current structure and funding arrangements of New Zealand's land transport system. It does not describe how the current structure evolved from what existed before, or what were the critical motives for recent changes.

New Zealand's land transport system underwent substantial legislative reform in 1989, with the passage that year of the Transit New Zealand Act, the Transport Services Licensing Act and the Local Government Amendment Act (No. 4). The stated aims of the reformed system established by these acts are to provide a fully integrated planning, funding and operational structure for land transport, within which a coherent unified system is provided that reflects community interests, improves road safety, encourages innovation to meet particular local needs, clearly identifies social costs and benefits, provides cost-effective facilities, and develops an appropriate partnership between local and national government.

2.1.1 Structure of the System

At its simplest, New Zealand's land transport system can be characterised by the following points.

State highways and motorways are the main arterial roads carrying inter-district traffic, whose construction and maintenance is the responsibility of a national Crown agency, Transit New Zealand.

Networks of local roads within districts are the responsibility of local territorial authorities (city and district councils), whose approved maintenance and upgrading programmes attract a subsidy from Transit New Zealand.

Urban passenger (road) transport services are provided in the cities by various operators, subject to licensing and subsidy of some routes determined by the regional councils. Both private sector and local government owned operators currently exist, but the latter are being divested to avoid conflicts of interest between local government's regulatory and operations roles.

New Zealand Rail is a state-owned enterprise with a network linking the main cities in both islands, used primarily for freight but with suburban passenger services in the metropolitan centres and some inter-city passenger routes. It is fully responsible for upkeep of its network and rolling stock, and operates under commercial objectives, but receives subsidy from regional councils on some suburban passenger services.

Local territorial authorities are each required to prepare a land transport programme for their respective districts, setting out the roading works that can be eligible for subsidy. Each **regional council** also prepares a land transport programme setting out its planned passenger transport services and the degree of subsidy required to support them. Both territorial and regional authorities are charged under the Resource Management Act with land use planning and control of adverse effects caused by transport.

Transit New Zealand's functions are to prepare annually a National Land Transport Programme; to provide advice, research and information on land transport; to manage the state highway system; and to administer the Land Transport Fund, disbursements from which are made to local road projects, traffic safety programmes and support of public transport services.

The **Ministry of Transport's Land Transport Division** has responsibility for developing safety policy and standards for drivers and vehicles, and administering collection of road user charges. Enforcement of traffic safety regulations is undertaken by the Police.

The **National Land Transport Programme** is a package of recommendations to the Minister of Transport for revenue collection and expenditures on a range of activities, including construction and maintenance of state highways, subsidies to local roads and public passenger transport, safety programmes, research, administration and enforcement. Construction and maintenance proposals for both state highways and local roads are subjected to a cost-benefit analysis, and available funds allocated to this purpose are rationed between projects according to their benefit/cost ratios (tempered by other considerations). These ratios measure benefits of roading proposals as principally savings in time, vehicle running costs and accidents avoided; and costs are primarily concerned with construction and maintenance expenditures. Most of the environmental and social effects considered in the WCS report are not currently valued in monetary terms and included in benefit/cost ratios but they are taken into account in the overall project appraisals.

2.1.2 Funding of the Land Transport System

In New Zealand, revenues for roading expenditures have long been collected from road users, but not in a manner which necessarily bears a close relation to the costs created by a particular user's trip patterns. The introduction of Road User Charges for heavy vehicles provided a mechanism for aligning charges and costs more closely for those vehicles.

The main source of funding of the land transport system is the Land Transport Fund (LTF), expenditures from which are directed to three purposes:

- Funding the National Land Transport Programme, principally construction and maintenance of state highways and subsidy of local road infrastructure and public transport;
- Funding safety administration activities administered by the Ministry of Transport and the Police Department;
- Enforcement of vehicle revenue collections by the Ministry of Transport.

Contributions to the LTF come from three principal sources:

- a proportion of motor spirits excise duty paid by light vehicle users which is dedicated to the Fund;
- road user charges collected from heavy vehicle operators; and
- licence fees from all vehicle registrations.

Government collects additional money from transport users (chiefly through tax on petrol) which goes to the Consolidated Fund for general revenue purposes, but it may also transfer money from those revenues into the LTF when necessary.

Currently annual revenue from transport taxes, road user charges and licence fees is about $1,350 million, whereas expenditures from the LTF total $750 million. The local government share of local roading expenditures contributes an additional $300 million per year. This local share comes principally from local property tax (rates) revenue, although territorial authorities receive 0.66 cents per litre of petrol tax collected in their districts, and regional councils can levy a regional tax of up to 2 cents per litre for funding public transport systems.

Even though road users currently appear to pay more than is spent on the land transport system, current expenditures do not cover total transport system costs since these expenditures exclude indirect costs such as those stemming from congestion, pollution and accidents. These indirect costs are largely felt by road users as non-monetary burdens, such as time loss, discomfort, pain and health damage. With the inclusion of safety and administration expenditures the LTF has internalised more of the total systems costs than its predecessor, the National Roads Fund, but the extent to which further indirect costs should also be charged is open to question.

2.1.3 Charging for Land Transport

The basic system for transport charging set out in the National Land Transport Programme aims to recover annual costs incurred, allocating them across transport users according to the effects they create. The present procedure for recommending levels of excise duty, road user charges and vehicle registration fees has been little changed since its introduction in 1978.

Once the annual roading budget is determined and approved, detailed cost estimates are examined to categorise the work into three subtotals. These subtotals are:

- **Strength-imposed costs**, i.e. all works entailing the strengthening of the road pavement or repair of road wear;
- **Space-imposed costs**, encompassing all works designed to increase the capacity of the road network (e.g. new roads, additional lanes);
- **Driver-imposed costs**, which provide resources for road users irrespective of the demands of different vehicle types (e.g. roadmarkings, signs and other costs not elsewhere classified).

The **strength-imposed costs** are allocated almost entirely to collection from heavy commercial vehicles (HCV) through road user charges, since a vehicle's road wear appears related to the fourth power of its transmitted axle load, and the wear effect of light vehicles is negligible. The charge rate is set to distribute the total cost according to each vehicle's load rating (expressed as equivalent design axles): so that, broadly, the more axles a truck has for a given load, the lower is its load rating. Road user charge administration requires operators of vehicles of over 3.5 tonnes to estimate their expected annual use and purchase in advance road use licences in units of 1000 km. Licence costs vary with each vehicle's nominated maximum weight. Distances travelled on public roads are recorded by the operator and cumulatively use up the pre-purchased licences. Periodically the Ministry of Transport verifies records against the vehicle's hubodometer reading and checks for loading in excess of the licensed weight. Refunds are available for vehicle use off the public road system.

For administrative simplicity the road user charge system assumes that vehicles travel empty for half the distance travelled, i.e. the rate at which the licensed distance is used up is adjusted for a loading factor of less than 100%. This may advantage long distance hauliers, who are more likely to back-load, and disadvantage local delivery hauliers whose loading may be less than the assumption used for charge setting.

Space-imposed costs are allocated across vehicle categories according to their occupancy of road space: light vehicles are given a value of unity, while heavy vehicles are given a mean value of 3.[1] A proportion of total space costs is allocated to heavy vehicles in proportion to their share of space in the traffic stream, and added to the amount to be recovered from individual vehicles through road user charges. Because of the large number of light vehicles in the traffic stream, most of the space costs are allocated to them and collected through a contribution of fuel tax.

Driver-imposed costs are allocated between light and heavy vehicles in proportion to the estimated vehicle-kilometres attributable to each group. Unpowered vehicles and trailers are excluded. The total allocated to each type is then collected through their respective charge mechanism: by an addition to road user charges for HCVs, or a share of fuel tax from light vehicles.

Each of the three cost categories comprises approximately a third of total roading expenditures, space costs being slightly larger, driver costs slightly less. The distribution of these costs is almost evenly split between light vehicles and heavy commercial vehicles.

Since fuel taxes paid by light vehicles reflect distance travelled, and road user charges reflect the wear effect of tonne-kilometres carried, the current system appears to allocate costs approximately in proportion to individuals' use of the road network. However, the total costs being recovered in these charges are based on an estimate of cost shares derived in

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[1] There is some literature questioning the appropriateness of this figure: trucks are not only larger than cars, but also slower and less manoeuvrable in urban settings, detracting from the efficiency of traffic flows.

1987 when the only items being funded were road construction and maintenance. The range of costs now being funded includes central government's administration and safety expenditures, subsidies to public transport (which are arguably equivalent to some level of space expenditure since they reduce traffic on the roads). So although the Land Transport Fund has been extended to cover a wider range of transport system costs, the transport charging systems are still based on construction and maintenance costs.[2]

The HFA report acknowledges the existing road funding system as a good start for developing an economic pricing system for road transport, but suggests it is deficient in that its current allocation of charges to user groups may be neither efficient nor fair. A more efficient pricing system would include external costs in the sums to be charged to road users, and refine allocations to individual users so that the price they pay for each trip more closely approximates the full social costs incurred by that trip.

2.2 Pricing Principles for Transport

The essence of most road pricing research has been to replace established road charges, which do not discriminate by time, location, damage caused or amount of vehicle use, with charging structures directly related to these factors. Research interest worldwide has been on pricing for road congestion, a time- and location-specific problem which is not readily treated by traditional measures such as fuel taxes or vehicle licence fees.

One counter-argument to implementing more efficient pricing regards congestion as a self-imposed cost because motorists voluntarily enter a traffic stream and suffer the consequent delays. This fails to recognise that every vehicle added to a congested traffic stream not only suffers congestion itself but also slows down the progress of every other vehicle, creating a genuine externality. A second counter-argument suggests that externalities can be ignored because prices in most other sectors ignore them as well. This would be correct if external effects were equally important and uncharged in all sectors but, as the transport sector is exceptionally prone to the external effects of congestion and environmental damage, they cannot be ignored. Overseas literature suggests transport is exceptional, but the scale and significance of these external effects may be less in New Zealand.

The critical distinction is between the components of the private direct costs paid by road users and the social costs borne by the community. Private costs include the "pure" cost of vehicle use, comprising operating expenses and driver's time, plus a range of government impositions for recovering public expenditures - licence fees, fuel taxes, road user charges and a range of other payments (such as fines). The full social cost includes the pure cost of the national vehicle fleet but excludes the government impositions which are simply transfer payments within the community. The additional components of full social cost include the

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[2] Although the mix of total land transport expenditures has shifted since 1989 to include safety administration and public transport subsidy, the allocation of recoverable expenditures is still based on an estimate of cost shares derived in 1987, when only road construction and maintenance costs entered the calculation. Vehicle licence fees are now collected into the LTF, but there has as yet been no explicit matching of fund contributions with the new expenditure categories.

expenditures of all roading authorities (including local government) on repairs and maintenance, administration and enforcement; costs that vehicles impose on each other, such as congestion delays and enhanced risk of accident; and a wide range of environmental effects whose presence hinders other economic activities.

2.2.1 Objectives for Transport Pricing

Pricing policies may serve a number of different objectives, the requirements of which do not necessarily coincide. HFA lists these as economic efficiency; environmental protection; urban planning; equity; and revenue generation.

Economic efficiency requires removing the difference between the private costs perceived and acted upon by individual users and the full social costs imposed by their actions. When road charges are inefficient, it is possible in principle to improve them so as to make some users better off without making anyone worse off. More commonly some redistribution of payments will occur - for instance peak-time travellers pay more - although the total cost of achieving a given level of transport movements will decline.

When moving to a new set of efficient prices it is necessary to ensure that the cost of implementing the system is less than the benefit estimated to flow from it. Also, where the new system covers a discrete area, some provision is needed to allow for diversion of use beyond the systems boundaries, for instance upgrading by-passes or ring roads when city centre access for through traffic is controlled.

Concern over **environmental protection** has traditionally centred on local transport impacts such as noise and vibration, severance and accident risks, but recent emergence of global issues, such as ozone depletion and greenhouse gas emissions, has given environmental protection a more general significance.

Transport pricing may also help achievement of **urban planning** goals by improving accessibility, assisting inner city renewal and relieving pressures for encroachment of built-up areas over adjoining countryside. In principle, if transport prices include all social costs, both environmental and urban planning objectives would coincide with the economic efficiency aim.

The **equity** or fairness of transport pricing depends heavily on individual viewpoints. Road pricing may benefit well-off motorists at the expense of poorer ones who are displaced by the new charges, but the overall effect depends on the use to which the new revenues are put: for example, if used to improve public transport they may benefit the less well-off who may use these services more. If income redistribution is a policy aim, it is more effectively achieved through direct assistance targeted at specific groups (for example, discounts to the elderly), rather than by general improvements to an open access road network which benefits rich and poor alike.

Revenue generation to cover costs of the transport system is a major motive behind transport pricing, and one whose requirements do not necessarily coincide with the requirements of efficient pricing. Efficient prices for reducing environmental pollution need to change polluters' behaviour and encourage less polluting activity, whereas for revenue raising

purposes prices should minimise behaviour changes in order to avoid driving polluters away from the taxable activity and undermining the revenue base.

Evidence of road pricing schemes overseas reveals considerable variation in the objectives they are intended to meet: systems in Singapore and Hong Kong sought reductions in congestion, Holland and Stockholm sought environmental benefits, and toll ring cordons in Norway are primarily for revenue raising. Only Norway and Singapore have fully implemented such systems to date. The definition of what prices would be if economic efficiency were the only criterion is a useful starting point for assessing the costs of pursuing other objectives. Thus HFA examines at some length the pricing principles indicated by economic theory, and their application to the components of transport costs.

2.2.2 First-Best and Second-Best Pricing Principles

An ideal pricing structure would levy on all vehicles a charge which raised the marginal private cost of each trip to its marginal social cost (in other words the costs faced by a user for each additional trip would equal the additional cost imposed on society by each trip). This would be infinitely variable with time and location, reflecting traffic flows, vehicle mix, congestion and other social effects, which would leave each user with no prior knowledge of the actual costs they are going to face. Too much price variation would confuse users and would be costly to implement, so it is preferable to standardise charges according to some average effect for particular locations and times of day.

HFA describe some of the theoretical economic principles for efficient pricing. **First-best rules** for pricing efficiency require that a product's price be set equal to its marginal cost of production (i.e. the incremental cost of the last unit produced). In the presence of market distortions such as unpriced external effects or public goods, the marginal social cost should be used. But first-best rules ensure efficiency only if they are applied to all parts of the economy, a situation which presumes that full social costs can always be determined.

Where this is not the case, **second-best rules** allow prices to vary from marginal costs, with the difference between price and marginal cost least on those items whose consumption is most price sensitive, and greatest on those items whose consumption is least price sensitive. With levies structured in this way, revenues are collected with the least distortion to consumption, relative to what would occur in the absence of levies.

Setting prices for competing transport modes needs to take account of the private and social costs that each mode creates and the substitutability of demand for the different modes. Rail transport does not create as many external social costs as road transport, since the price of a ticket implicitly includes a contribution to maintaining the rail system and provision for managing network congestion. Where rail services compete directly with congested roads, it can be efficient to discount rail trips below marginal cost by means of a subsidy. The greater the price sensitivity of rail use, the substitutability of car and rail trips, and the incremental social cost of car use, the greater that discount can be.

2.2.3 Difference between Accounting and Economic Pricing

HFA characterise the current structure of land transport charges in New Zealand as **an accounting approach**, which aims to recover from each user some share of the costs already incurred in constructing and maintaining the road network. This differs from **the economic approach** to pricing, which regards past expenditures as "sunk" costs whose recovery is irrelevant to achievement of efficiency in future. Economic prices would attempt to collect from each user the contribution their trip makes to incurring further costs.

Since roads are built as "fatigue" structures, with a design life which is used up with the cumulative passage of loads, additional traffic brings forward the date when repair or replacement is required. This is the marginal cost of additional traffic which can be allocated to individual vehicles on the basis of their standard load rating. For congestion, the marginal cost is each additional vehicle's contribution to bringing forward the date when new capacity is required - a new road, or an additional lane. This in turn is determined by the point at which the cumulative costs of delay exceed the cost of constructing the additional capacity.

Considering which components of road transport system costs could enter into the marginal social costs of an economic pricing structure, HFA suggest:

a. Fixed costs of track construction, land purchase and road building: all allocation procedures for their cost recovery are arbitrary and irrelevant in defining the marginal cost caused by a trip;

b. System maintenance costs do enter marginal cost-based prices to the extent that repair work, policing, etc. vary with the amount of traffic;

c. "Fixed" maintenance costs (such as those attributable to weather) are not traffic-related, and are irrelevant to defining marginal costs of a trip;

d. Direct user costs of a journey do enter marginal cost of a trip;

e. Social and environmental costs such as congestion, pollution and accident costs do enter marginal cost of a trip.

Current road charging in New Zealand's accounting structure approximates to recovery of items a - d inclusive, whereas economically efficient marginal cost pricing would cover items b, d and e.

If prices are based on marginal costs, there is no reason to expect revenues collected to cover the costs incurred today. Whether such revenues exceed or fall short of current expenditures is a matter for empirical determination, depending on the scale of effect being covered by the price. In some overseas contexts, charging road users an efficient price for congestion, or for accidents, could yield revenues far in excess of current roading expenditures, assuming such charges are politically and practically implementable.

Since pricing for economic efficiency does not ensure financial viability, the ideal price structure for road systems operating under a break-even requirement is likely to include both first-best and second-best principles. One component would set prices per trip to reflect

marginal social costs as far as possible, so that users are given the appropriate incentive to consider the full effects of their trip decisions. If the revenue fails to meet current expenditures, the shortfall can be collected from the community of road users in the least distorting manner possible, for instance through flat charges for access to the road network (licensing fees) or supplementary charges on the less price-sensitive users.

Where the private sector is involved in transport infrastructure, pricing should not aim at economic efficiency but rather be based on what the market will bear, to generate a return. This applies to private toll roads and rail operators whose services represent only a small part of the total transport system.

2.2.4 Infrastructure Investment

A characteristic of the provision of roading is the uneven pattern of investments over time: large expenditures are required to establish the network, against which variable costs associated with subsequent use are relatively small. HFA discusses how to provide for this in a transport price structure, concluding that whether prices should be based on long run marginal costs (which allow for future expansion), or short run marginal costs (which do not), is an empirical issue which varies from case to case. Given the difficulty of specifying either of these costs correctly, basing investment policy on cost-benefit evaluations (as is current Transit New Zealand practice) is an appropriate second-best procedure.

A question of competitive neutrality arises where transport modes operate under different circumstances, as between rail (which unambiguously maintains its own network) and road freight (which may receive or pay a subsidy from/to other road users). Requiring a given rate of return from public road investments is made difficult by the need to place an asset value on the road stock, yet treating capital as a sunk cost leads to road users being charged nothing for increasing the capacity of the road stock.

If road use is constant and requires no capacity increase, the costs of road use would be correctly reflected in short run marginal costs covering maintenance, congestion delays and other environmental effects. Growth in vehicle use requires additional road capacity if the marginal cost is not to rise with increasing congestion. By adding the annual cost of capacity expansion needed to hold road conditions constant to other short run marginal costs in a road levy, capital costs (including return) can be incorporated into the price of roading. Such an approach is also consistent with the economic prescription of sustainable management of the road network, since it results in each generation passing on to its successors a constant capital stock of roading.

2.2.5 Some Proposals for Road Pricing

HFA review some current proposals for road pricing systems, with emphasis on congestion charges. Extensions of existing charge arrangements (vehicle taxes and licensing fees, fuel taxes, etc.) do not discriminate by time and location, which are critical determinants of congestion. Alternatives considered include supplementary licensing for access to specific congested areas; cordon tolls, which act as pay-as-you-go supplementary licences; time, distance and congestion-based charging; and electronic metering and road pricing, charged either by invoice or smart card.

Criteria for assessing road pricing systems include:

- Charges should relate closely to actual road use;
- Charges should be variable by area, time and vehicle class;
- Prices should be stable and readily understood by users;
- Any equipment should be reliable and immune from fraud or evasion;
- Payment to be in advance or with credit facilities;
- The system should seem fair and accommodate occasional users and visitors;
- Charge records should protect users' privacy yet allow them to verify charges on their accounts.

None of the charge mechanisms satisfy all these criteria and there are trade-offs between the flexibility of pricing and the cost of implementation (e.g. of fitting electronic meters). Singapore has supplementary licensing and Norway has cordon tolls, but neither system relates charges closely to use of the road. More complex systems come closer to charging for actual use, but are less easily understood by users or accommodating for visitors. Enforcement is the principal challenge in road pricing design, particularly for the more complex systems dependent on technology.

HFA survey other traffic management measures which might be used in conjunction with explicit pricing. Parking controls are the most widely applied, but they appear to have some ambiguous effects: provision of off-street parking as a condition for redevelopment may encourage traffic into congested areas; local authorities have little control over parking fees where much of the parking capacity is in private hands; and poorer casual users are more likely to be affected than regular, better-off users with access to company-sponsored parking.

Physical controls over access have limited effectiveness and cause wasted resources by imposing queuing delays indiscriminately on travellers. Voluntary measures such as car pooling and staggering work hours are unlikely to lead to large scale reductions in road traffic demand. Various regulatory measures (specific vehicle-class bans, access by lottery, access on alternate days by odd/even registration number, etc.) are arbitrary, unpopular and subject to non-compliance. None of these traffic management mechanisms can match the efficiency of the pricing mechanism in simultaneously reducing the number of trips and ensuring that the value of remaining trips at least matches the costs imposed by them.

Choice of charging instrument depends on the feasibility of application. Fuel taxes might be reasonable proxies for the damage caused by emissions, but they provide no incentive to avoid causing congestion (other than a general discouragement of motoring by adding to its cost). Charging instruments need to be specific to the problem they are addressing.

Types of charging instrument include:

- **Direct unit charges or taxes** are intended to raise the variable costs faced by transport users, and hence provide a continuous spur to reduce the level of use. They include direct road user charges (based on distance and axle loadings), taxes on transport inputs (such as fuel), access tickets, road tolls and electronic pricing.

- **Periodic charges** add to the standing charges (fixed costs) of using transport facilities, and include such items as driver licensing, vehicle excise duty and vehicle registration fees. They may discourage vehicle ownership but provide little disincentive to vehicle use. In some circumstances they may be counter-productive: e.g. owners may seek to reduce the average cost of such charges by using vehicles more; and sales taxes on new vehicles may retard scrapping older, less fuel-efficient vehicles.

- **Untargeted taxes** are those whose principal function is revenue earning, and include general indirect taxes (GST), direct (income) taxes and local authority rates. Their collection pays little regard to variations in use of particular transport facilities, and their role in pricing is negligible.

2.2.6 Responses to Road Pricing

The effect of road pricing on overall traffic levels depends on the price sensitivity of traffic demand, and also the extent to which explicit road pricing supplements, or is offset by reductions in traditional fuel and vehicle taxes. International evidence suggests that increasing the price of transport results in modest reductions in car use or switching to other modes (particularly with respect to commuting), and the price required to achieve a reduction in any location needs to be determined empirically. The immediate effect of reducing trips or diverting them around the road-priced area is likely to decline in the long term.

Road pricing which shortened journey times would benefit roving commercial vehicles and public transport more than single-destination cars. Areas where the price of access rises will favour high value-added activities (specialist retailing, hotels and offices) and businesses which generate heavy traffic for relatively low value turnover (e.g. mass retailing) would be encouraged to relocate.

New charges appear more acceptable to road users if they are raised for roading or environmental purposes, but not if they are specifically for congestion. It is not necessary for road charge revenue to be earmarked for spending on transport or environmental activities, or for spending in the areas where it is collected, or to be additional to current taxes, since transport spending by government can be inefficient if "driven" by available revenues. The whole point of explicit road pricing is to replace less well-designed road charging schemes, such as fuel taxes and licence fees. This raises the efficiency of tax collection across the country's economy as a whole, since other distortionary taxes can be reduced: the national tax burden is shifted from economic "goods" (such as income) to undesirable economic "bads" (such as pollution, or delays).

2.2.7 Road Pricing and the Resource Management Act

The Resource Management Act 1991 has a stated purpose of promoting sustainable management of natural and physical resources, defined as management of the natural environment to safeguard its life-supporting capacity and retain its potential for meeting foreseeable needs of future generations. It emphasises avoiding or mitigating adverse effects on the environment.

The HFA report examines one approach to defining sustainability which would require a constant capital stock to be passed from each generation to the next. Rather than depleting a natural resource for current consumption, each generation would divert some of the proceeds to investments which would bequeath an equivalent capital to its successors. Further refinements of this idea are the avoidance of irreversible losses of environmental assets, and maintenance of the stock of environmental assets. A practical example of this approach would be a presumption against transport developments which threaten unique wildlife habitats, unless an equivalent habitat can be reproduced elsewhere.

This approach would regard some environmental limits as binding constraints, which is consistent with the Resource Management Act. Pricing in transport still has a role in achieving efficient use of resources within those constraints, although the limits themselves are likely to be set through political processes.

The WCS report makes a distinction between the "effects" defined in the Resource Management Act and the "externalities" which might justify adjustments to prices. Externalities which enter into the social cost component of prices are a sub-set of the effects listed in the Act. Its broad definition could be interpreted to include self-inflicted effects, for which individuals can be expected to have adequate incentive to avoid through private cost components. The legal interpretation of effects, sustainable management and the powers of the Act have yet to be determined through the courts, but explicit transport pricing appears to have a role in fulfilling at least part of its purpose.

3. DIRECT SYSTEM COSTS OF LAND TRANSPORT

The direct system costs of land transport comprise primarily the construction and maintenance costs which, in New Zealand, have traditionally been recovered by road use charges. Other costs of operating the system which could come under this heading include costs of policing the network, traffic flow controls and street lighting.

3.1 Scale and Significance

Current annual expenditures from the Land Transport Fund are approximately $750 million, of which $600 million go to road maintenance and improvement on state highways and local road subsidy. The balance of spending comprises $100 million on road safety and enforcement and $50 million in supporting public transport.

In addition, local authorities contribute about $300 million on road maintenance and construction. HFA suggest there is a convincing case on traffic efficiency grounds for including public hospital and medical costs caused by road accidents as part of the overall system costs to be recovered from road users. However, it is difficult to estimate the full costs involved given the co-existence of both publicly and privately funded medical treatments, and largely hidden costs associated with lost output, pain, grief and suffering.

3.2 Pricing and Regulatory Measures

Current revenues from road user charges, vehicle licence fees and a proportion of fuel taxes are intended to cover the entire expenditures from the LTF. The distribution of these charges between the collection mechanisms (and hence between road users) is quite likely out of step, being based on an outdated calculation of user group shares of national construction and maintenance expenditures. If current cost allocation procedures are retained, some revision appears necessary in light of the expanded coverage of the LTF: for instance, would public transport subsidy be viewed as alleviating congestion and allocated as a space cost, or would it be spread in some other way? It may also be necessary to include local authority contributions in the total to be recovered if the "price" faced by road users is to approximate to the full social cost of improvements and maintenance.

More radical changes to the current charge structure include:

- Current traffic expenditures could be re-categorised into variable (traffic-related) and fixed (non-traffic related) components. The variable portion could then be allocated between user groups and collected on a similar basis to the current procedure, while the fixed portion would be covered by a flat charge across all users for "access" to the road network, such as the vehicle registration fee, or local authority rates.

- Move to marginal cost pricing, in which each vehicle's charges for "strength" and "space" are based on its contribution to future expected costs for the network, and any shortfall of annual revenue against expenditures would be collected through a flat charge.

These and other options are only briefly hinted at by HFA, and further research is required to determine what each might entail in terms of cost allocations and chosen charge mechanisms. But the HFA report devotes substantial space to some issues of contention about the basis of the current charging structure.

3.2.1 The Fourth Power Rule

The widely used relationship linking a truck's road wear (or road pavement damage) to the fourth power of the axle load is derived from one extensive, controlled experiment carried out in the USA in the early 1960s. Recent revisions and re-estimates of the same data have suggested that the relationship between axle weight and road pavement damage may be closer to a third power than a fourth power law, which raises questions about the appropriateness of cost allocations based on such a fourth power relationship.

HFA conclude there is likely to be only a slight overcharge if any, as a result of approximating by the fourth power rule. HFA firmly believe the evidence shows that the thin surface flexible pavements typical of New Zealand roads have a higher exponent than the thicker rigid pavements commonly encountered overseas.

Since any exponent greater than 2 results in road wear being attributed almost entirely to trucks, varying the exponent for cost allocation between 3 and 4 mainly redistributes costs between trucks of different types. A lower exponent would shift attribution of wear from heavier trucks to lighter trucks. This would shift the allocation from long distance trucks to short haul vehicles, and might confer a cost advantage in the long haul sector which competes directly with rail freight. HFA also suggest the incidence of overloading and excess wear is likely to be greater amongst the heavier trucks than the lighter ones, which would offset any overcharging of heavier vehicles caused by the exponent. They conclude that for those damage costs attributable to axle loads, the best exponent currently available for New Zealand is 4.

3.2.2 Treatment of Non-traffic Related Costs

Some recent studies suggest that a substantial fraction of total maintenance costs are attributable to the age of road stock and weather and are not attributable to traffic flows. If so, this might invalidate current charging procedures of allocating according to axle loads. But HFA cite more studies which suggest that weather damage is worsened by passage of vehicles. On balance almost all weather damage, except that perhaps occurring on lightly trafficked roads, is appropriately chargeable to vehicle use.

3.2.3 Economies of Scale in Road Maintenance

Road construction and maintenance commonly exhibits economies of scale: a road's load-bearing capability can be doubled for less than double the cost. Basing charges on total costs averaged across current axle loads carried therefore overstates the marginal costs of road strength and over-collects revenue from trucks. HFA acknowledge this is correct with respect to a single road but suggest that networks may exhibit decreasing returns to scale because of the increasing number of intersections. In urban areas, the high cost of land can more than offset economies of scale in road capacity expansion. The evidence is inconclusive, so it may be reasonable to assume that returns to scale are constant, which is consistent with current charging procedures.

4. CONGESTION

4.1 Scale and Significance

Much of the discussion of pricing principles in the HFA report is implicitly or explicitly focused on pricing for congestion. The inference from the overseas literature is that road damage costs are a small proportion of total road system costs, as also are environmental costs. The largest potential components are accident costs and congestion delays, so that passenger vehicle charges, including congestion charges, might be expected to contribute a major part of roading revenue. New Zealand's attenuated road network might attribute a larger share to road damage and a smaller share to congestion, but this exercise has yet to be done.

4.2 Valuation of Effects

The costs of congestion can be estimated through the additional time required to make specified journeys under different traffic levels, aggregated across all vehicles suffering congestion at particular times of day. Since these values depend on the density of traffic and the value of time lost (which depends on prevailing income levels), such estimates are not readily compared across countries exhibiting different conditions.

4.3 Pricing and Regulatory Measures

The distinctive characteristic of congestion is that the demand for expansion of road capacity depends on the traffic levels at peak periods. If congestion charges are to be effective they must differentiate between peak and off-peak traffic.

The critical issue in designing a congestion charge is to find a mechanism which is both capable of being tailored to particular traffic conditions at specific locations and times of day, and cost effective to implement. Electronic road pricing appears the most flexible charging mechanism but it requires substantial implementation costs in retrofitting vehicles. Most examples of congestion pricing in practice are simple systems of cordons and zones. Turnpikes and other entry controls create bottlenecks and delays for traffic passing through, which militates against a large number of zone boundary points. But when zones are large, charging may discriminate unfairly against those who travel short distances across the zones compared with those who travel extensively within them.

5. ACCIDENTS AND SAFETY

5.1 Scale and Significance

Some overseas estimates of the total cost of medical treatment and recovery of road accident casualties dwarf all other components of the road system. These results depend on the treatment of items such as insurance payouts and lost output caused by hospitalisation, and can not be generalised across countries. HFA suggest there is a strong case for including accident costs in the system costs recovered from road users. Since a major cause of road death is drunk driving which can only be controlled through regulation, enforcement and social intolerance of such behaviour, the costs of publicity, educational campaigns and policing for improved safety can also be added to the recoverable system cost.

However, this is not the appropriate figure to use in pricing individual trips. Rather the figure is each individual vehicle's contribution to the increased risk of collision. Total accident costs would need to be recovered as part of the fixed costs of the system and the total would need to exclude private costs already paid by drivers, such as contributions to Accident Compensation levy and private health insurance. Marginal cost pricing for efficiency purposes would be limited to charging each vehicle for its addition to the expected cost of collision faced by all other vehicles.

Neither the HFA nor the WCS devote much attention to transport accidents, an omission related largely to the lack of conclusive empirical evidence. Some relationship between traffic volumes and accidents can be expected: at the extreme, if there was no traffic there would be no traffic-related accidents. But there is a major problem in determining a link between accident numbers and traffic volumes. Most evidence indicates accidents per passenger-kilometre travelled have declined over time for all forms of transport: road, rail, air and sea. The rate of road accidents has fallen as traffic has increased, reflecting factors such as improved road design, vehicle standards or driver behaviour whose interactions cloud the contribution of any other single factor.

Since additional cars do not increase the risk of accident in any predictable sense, there is no definable externality between vehicles suited to treatment through road pricing. But the risk of vehicles colliding with pedestrians or cyclists may rise with increases in kilometres driven, suggesting that vehicles do impose an accident externality on non-motorised traffic, which could be incorporated in unit charges in situations of mixed traffic flows (e.g. urban streets other than motorways).

5.2 Valuation of Effects

The main thrust of recent transport safety research has been on valuing casualties, to ensure that an appropriate level of safety features is built into the transport infrastructure. In New Zealand, an attempt to harmonise public expenditure guidelines with private willingness to pay for avoiding risk led to the value per life saved used in road project appraisals being increased almost 10-fold. Further research is in progress worldwide to refine valuations for fatal and non-fatal casualties, and between casualties in different forms of transport (e.g. public and private, road and air, etc.).

5.3 Pricing and Regulatory Measures

The lack of clear empirical evidence of the contribution of individual vehicles to accident risk does not prevent safety features being provided in transport infrastructure. But the cost of such safety features cannot be attributed to individual transport users so they must be funded as public goods rather than through unit charges. This is current practice in New Zealand.

6. ENVIRONMENTAL EFFECTS AND POLLUTION

The environmental effects of land transport can be categorised in various ways. The WCS report initially identifies three levels of effect resulting from land transport:

1. All direct impacts of construction, maintenance and operation of land transport, including most forms of pollution;

2. Indirect effects on urban and regional systems, induced responses to the presence of land transport, including such things as transport's influence on urban form and land use, accessibility to facilities and effects on personal safety;

3. Indirect effects on dependent and related activities, including upstream supply industries (e.g. energy extraction), downstream servicing industries (e.g. mechanical engineering), and proximate activities which bear risks from transport movements (e.g. transport of hazardous materials).

Alternatively, if environmental effects are grouped according to their dominant characteristics, they fall into four broad categories. One is discharges into a common medium, of which the various forms of air pollution and water contamination are the most obvious. Most of these accumulate with potential to cause problems later on, such as the long-term risks to health caused by ingested lead, the thinning of stratospheric ozone, and the enhancement of the greenhouse effect. Such pollution can be local or global in effect.

Another category is "nuisance" effects, usually contained to particular locations or time periods. These include noise, vibration, dust and the disposal of transport wastes, such as car bodies, batteries and tyres.

A third category of effect comprises physical changes in the environment which lead to a resource loss: for instance irreversible changes to sites important for wildlife, recreation, cultural or historic reasons. These effects are primarily local, but may be of national significance if occurring on unique sites.

The last category is intrusion or interference with pre-existing activities. For example, new motorways or rail routes may have a severance effect, increasing the perceived and actual cost of interactions between communities on either side of them. They can cause visual intrusion, and temporary diversions and disruption of other activities during construction. Infrastructure determines urban form, affecting urban vitality and security by encouraging or discouraging pedestrians and residents in different parts of the urban area, and contributing to psychological effects such as isolation, suburban neuroses, and intimidation of pedestrians by vehicles.

Environmental effects can be distinguished according to whether they are local or global; continuous or intermittent; permanent or temporary; associated with trade-offs against other effects; involve real costs or merely cost transfers within the community. These distinctions influence whether it is worthwhile attempting to treat effects through price or some other mechanism.

It is convenient to separate consideration of the various forms of pollution and nuisance from the intrusion, interference and land use effects. The former appear suited to some form of user charge or pricing, but the latter are more suited to being factored into roading project appraisals, adding to the cost of the road system but not differentiating between different users. Within the pollution category three broad causes of the effects may need remedying: emissions into the atmosphere, contamination of water systems, and sundry other issues in disposal of transport wastes.

6.1 Scale and Significance

6.1.1 Atmospheric Emissions

Transport is associated with a wide variety of atmospheric emissions, manifested at various levels. Local emission effects (e.g. lead and particulates) impact mostly on human productivity, health and mortality. They can also contribute to reduced visibility and psychological distress, and may be expressed through changes in property values. To the extent that they coincide with traffic concentrations, they might be appropriately priced through a congestion charge.

Regional emission effects include acid rain, which damages forest habitats and corrodes buildings, and tropospheric ozone (low-altitude accumulations) which may harm human and animal health. Prevailing wind patterns may spread these effects from generators in one country to recipients in another (e.g. USA/Canada, Europe/Scandinavia), but this trans-boundary aspect is not as important for New Zealand.

Global effects include climate change (carbon emissions) and depletion of stratospheric (high altitude) ozone. Their implications are not currently visible, their effects are unclear and will not be felt until far into the future, but potentially they are very large. Transport appears to be a significant contributor to carbon emissions and to the possibility of climate change, rising sea levels and the resultant upheavals in land use, ecology and hazardous event frequency. Policies to remedy these effects, whether through price or other means, need to be applied uniformly rather than with local variations. The fact that these effects transcend national boundaries also means that unilateral remedies by any one country are unlikely to be effective.

With the exception of ozone-depleting chlorofluorocarbons in air-conditioned vehicles, air pollution from the transport sector is almost entirely related to fuel use. Land transport overshadows marine and air transport as the chief contributor to transport emissions in developed countries; and cars dominate other vehicles used in land transport. Thus encouragement of energy efficiency and more benign fuels receives prominence in literature about tackling pollution.

Cost estimates from studies of transport air pollution concentrate on local rather than global effects. Such local pollutions are commonly estimated as equivalent to 0.3-0.4% of GDP in OECD countries. The total cost of transport in OECD countries has been estimated as equivalent to 23% of GDP, 18.3% attributable to road transport alone. Road use expenditures, encompassing the cost of road network administration and the direct user costs, amount to 9%, the balance comprising (in decreasing order of significance) the estimated cost of time delays, accidents, pollution and noise. The relative magnitude of the figures may vary from country to country and reflect the method of estimation, but the implication that environmental effects of transport are of less significance than costs of time and casualties is one commonly encountered in the literature.

6.1.2 Water Contamination

Land transport has been linked to various forms of water contamination, including rust, rubber, lead and other heavy metals, dirt, oil and petrol products. These can be washed off road pavements into stormwater drains, surface waters, or percolated through the soil into subsurface aquifers, increasing the cost of restoring water quality for subsequent uses. Water also acts as a transporting agent, so that land transport residues collected in one place may be moved and deposited in concentrations elsewhere. For instance land transport sources have been implicated in contaminated dredgings in some harbours and inland waterways.

6.1.3 Waste Products

Awareness has increased in recent years about the final disposal of transport waste products, including lubricating oil, tyres, lead acid batteries and vehicle hulks. Some reduction in volumes of these wastes can be effected through charging mechanisms and deposit-refund schemes, but little evidence suggests that the scale of these wastes constitutes a major problem.

6.1.4 Noise

Noise is the most frequent of nuisance effects considered in the literature. One study suggests that the proportion of population exposed to road traffic levels over 65 decibels ranges between 5% and 31% in a selection of OECD countries. The range for exposure to equivalent rail noise lies between 0.4% and 4%. But road noise is continuous whereas rail noise is intermittent, and on average transporting a given load by rail is 5-10 decibels quieter than by road.

There is no reliable estimate of the number of people adversely affected by transport noise in New Zealand, but adapting overseas estimates to New Zealand's standards of residential amenity suggests some 160,000-300,000 may be exposed to a level potentially deleterious to health. This would imply a value of noise effects between $44-$150 million.

6.1.5 Vibration

Vibration from transport has been linked to psychological and physiological effects on health, as well as to deterioration in the physical condition of buildings. It is particularly associated with heavy commercial traffic in close proximity to residences and workplaces, but there is no evidence of its importance in New Zealand and it is not a high priority for mitigation.

6.1.6 Dust

Dust may arise from construction activities or traffic travelling on unsealed roads. It is most critical in the vicinity of cropping and horticultural land, and may also add to running costs for land transport operations through clogging of air filters. However, the scale of impact does not warrant high priority.

6.2 Valuation of Effects

WCS present a literature search of studies of magnitude and value of the various effects, which reveals little consistency between the approaches adopted or the results obtained. Many studies adopt the viewpoint of a highway authority or other agency involved with particular road schemes, and focus on the financial implications for the agency rather than on the aggregated costs and benefits felt in the community at large. There are some marked variations in the methods chosen and items included in analyses, and severe problems in separating effects which often occur together (e.g. noise and air pollution).

An important distinction between "real effects" and "transfer effects" receives little attention in the literature. Real gains are made when transport unleashes an area's productive potential - for instance a road which opens an area for farming or forestry and makes export production viable. But other gains and losses are more ambiguous: property value changes along a new route, reflecting either the benefit of improved access or the cost of nuisances such as noise, will be partly offset by changes in values of other properties beyond the ambit of the road. This is clearly illustrated in urban settings, where new arterial routes facilitate outward shift of residential areas and a run-down of inner city areas: part of the appeal reflected in property values is transferred from inner city areas to peripheral suburbs. There can be real gains from urban road developments but they need to be disentangled from transfer effects before observed value changes can be used as measures of a transport project's worth.

Two implications are important to this study. First, if transport systems shield urban road users from the full social cost of their trips, urban road use will appear cheap and encourage residential decentralisation, resulting in increases in trip length and associated environmental effects. This can be corrected with explicit transport prices, which will encourage cities to adopt more sustainable layout and form. Second, land use relocations encouraged by transport infrastructure have financial implications for a whole range of local services, since they lead to separation of residential areas with high rateable values from the more densely built-up areas where many of the services are concentrated.

The WCS report considers the methods available for valuing environmental effects. Since environmental quality is rarely explicitly exchanged in a market setting, changes in quality often require some form of "non-market valuation" technique. Where a valuation is obtained for a non-market effect, e.g. loss of wildlife habitat from transport infrastructure construction, it can be incorporated explicitly in a cost-benefit analysis to remove any bias against non-market effects which would otherwise colour the analysis result. But because these techniques usually provide estimates for discrete, rather than continuous, changes in environmental quality, they rarely indicate what rate of "corrective charge" to incorporate into a unit price for transport.

Noise in urban settings has been the most commonly studied transport effect. Studies in the US suggest that house values fall between 0.08% and 0.88% per unit increase of an "equivalent continuous sound level". Unfortunately, it is hard to draw consistency from these studies because the "effect" being measured is so hard to specify.

Studies of air pollution in the US suggest a 1% rise in air pollution is associated with a 0.01-0.22% fall in property values. This variation is plausibly explained by the dominant characteristic of the pollution, for example health effects, loss of visibility and so on. However the difficulty of deriving reliable figures for economic appraisals is illustrated by contrasting treatments in Swedish and Danish project appraisals of people affected by carbon monoxide levels which exceed World Health Organisation guidelines. The WCS report notes that, given rough parity between the Danish and Swedish kroner, the reason why Denmark uses a value of DKr165 per person, whereas Sweden uses SKr 15,500, is unclear from the available literature.

6.3 Pricing and Regulatory Measures

WCS summarise the range of separate remedies for environmental effects, which can be broadly described as:

a. Education and encouragement of environmentally benign practices;

b. "Command and control" regulation, noise and emission standards, etc.;

c. Penalties and compliance fees, for infringement of regulations;

d. Subsidies to encourage change to more benign behaviour or equipment;

e. Taxes and charges designed to reduce the rate of pollution;

f. Market creation and property rights realignment, as in the cases of tradeable discharge permits.

The term "economic instruments" usually applies only to c - f, since these allow the polluter more choice and flexibility (than regulations) to choose the most cost-effective response for their specific circumstances. That is, those for whom pollution reduction is very costly may opt to pay the appropriate charge, fine or quota cost, while those who can reduce pollution relatively cheaply have an incentive to do this and so avoid these costs.

One difficulty with treating environmental effects is that a single transport characteristic can lead to several different effects, whose remedies are not the same. For instance, the treatment of global emissions (e.g. greenhouse gases) could impose unnecessary costs on travellers if also applied to an apparently similar, but strictly localised, emission effect (e.g. urban smog).

Fuel taxes are relatively good proxy charges for effects related to vehicle running time or distance, but they are better suited to global effects than to local pollution. If congestion charges are introduced, they may be a better proxy for local pollution effects which appear related to concentration of vehicles.

7. INTRUSION, INTERFERENCE, URBAN FORM AND LAND USE

7.1 Scale and Significance of Intrusion Effects

7.1.1 Visual Intrusion

This includes those temporary effects arising during road construction and revegetation stages, and also residual effects on private views and public amenity once the road is completed. As part of transport system costs, visual effects are consistently addressed in project investigations and environmental impact assessments, but they are difficult to quantify and hence to value how much remedial activity is warranted. Visual intrusions can be managed and minimised, and effects appear to reduce over time. They occur similarly with road and rail.

7.1.2 Habitat Modification

This includes changes in vegetation, topsoil, natural drainage, spread of exotic species along transport corridors, barriers to wildlife migration and increased wildlife fatalities due to collisions with vehicles. Habitat impacts are handled primarily on case-by-case assessment of project proposals in environmental impact assessments.

7.1.3 Land Stability

Where transport routes require cuttings and embankments, periodic slips or continuous erosion and deposition may cause loss of productivity on adjoining property. There is little evidence that this is significant and, where it is, it can be resolved through common law liability.

7.1.4 Sites of Special Significance

Transport can impact on recreation when developments encroach on public open space or interfere with access to such sites, and also the possibility of loss of archaeological or culturally significant sites. There is little evidence of the scale of such effects. They are most appropriately handled at the development appraisal stage, and should be minimised with consultation.

7.2 Scale and Significance of Interference Effects

7.2.1 Community Disruption

This occurs during construction, and imposes costs in relocation of houses, businesses and diversion of existing traffic flows around the new facilities. It can be regarded as a temporary manifestation of other nuisance effects (such as noise and vibration).

7.2.2 Community Severance

Although transport routes aim to increase the accessibility between points along them, they may also provide a partial barrier which divides the communities on either side and increases the costs of interaction between them. Severance encompasses both the psychological impact of increased "perceived distance" which reduces propensity to travel, and the actual cost of physical diversion and added travel time to pass over or under the new facility. It most commonly applies to restricted access facilities, e.g. railways and motorways.

7.2.3 Urban Blight

This is inertia in urban land development caused by anticipation of future transport projects which would negate the benefits of development. The remedy is to expedite the planning process for transport projects to minimise uncertainty for other investors. In some instances there may also be calls for compensation.

7.2.4 Hazards

Movement of hazardous materials results in incremental increase in risk of accident. This can be factored into project appraisals as an "expected value of damage" from accidents involving hazardous materials. This expected value is itself a product of multiplying the cost of damage if an accident occurs (sometimes substantial) by the probability of an accident occurring (usually very small). In principle, movements of hazardous materials could be subjected to a charge to cover the cost of precautions incurred to minimise risks, but this encourages transporters to conceal the nature of what they are carrying.

7.3 Valuation Techniques for Intrusion and Interference

The WCS report surveys the values required for a road project appraisal to represent the loss of community well-being which results from intrusion or interference effects. These include:

- **Current Use Values** from both production (such as agricultural outputs) and consumption (informal recreation, landscapes and so on);
- **Option Values**, corresponding to a "premium" that the community may be prepared to pay to retain resources for a future use option;
- **Existence Values**, or expressions of community preference for retaining resources irrespective of any expectation of future use.

Various techniques of non-market valuation are available to impute values of a community's willingness to pay, or willingness to accept compensation, for changes in environmental quality. The non-market valuation methods most commonly encountered are:

- **Travel-cost analysis:** a revealed preference technique which analyses travel costs of current recreational patterns to derive a demand curve for particular sites; of limited use for transport effects.

- **Hedonic pricing of amenity attributes:** a revealed preference technique which employs multiple regression of house sales data to isolate the extent to which prices for similar houses vary with differences in neighbourhood amenity, such as pollution, noise and risk.

- **Contingent valuation:** a stated preference technique which entails surveying respondents to record their willingness to pay for environmental quality if a hypothetical "market" existed for it.

All these techniques are relatively data-intensive and have not been widely applied in New Zealand. Each has well documented limitations and as yet unresolved problems in application and in validating results. However, their main drawback for applying to transport issues is that they are inherently case-specific and do not yield general valuations.

Where non-market valuation techniques are not feasible, more direct estimates of costs of transport-related environmental changes can be used as a partial indicator of the scale of effect. Broad categories identifiable are:

- **Lost Output Values** ("opportunity costs"), usually derived from market prices adjusted for transfer items like taxes and subsidies.

- **Indirect Expenditures**, such as costs incurred on installing insulation against traffic noise.

- **"Shadow Estimates"** of the cost of replacing, removing or recreating a threatened resource elsewhere.

All these direct approaches are based on observed prices, and hence reflect only current use components of value. Stated preference techniques are the only means of estimating option and existence values.

7.4 Pricing and Regulatory Measures

Intrusion and interference effects occur because of changes in the transport infrastructure which detract from some aspect of environmental quality enjoyed by the community. "Pricing" for these effects therefore requires ensuring they are explicitly considered in appraisals of projects for new infrastructure.

7.5 Conclusions on Environmental Externalities

On the basis of the literature identifying scale and significance of environmental effects, WCS identify priorities for application to New Zealand.

Grouped in the highest priority are:

- ensuring that transport prices give correct signals for a sustainable urban form;
- tackling air pollution, with emphasis to local effects rather than global effects, whose policy treatment depends on international agreements;
- effects on water systems; and
- noise.

Of secondary priority are:

- loss of natural habitat;
- severance; and
- disposal of transport wastes.

The remaining environmental effects, such as

- dust,
- vibration,
- visual effects,

do not appear to warrant different treatments than those they currently receive.

8. CONCLUSIONS

The purpose of the reports summarised in this Digest was to review the current state of knowledge (and identify further research needs) on the reasons for, and means of, pricing the use of land transport. They form part of the Land Transport Pricing Study which aims to assist in establishing a comprehensive pricing and regulatory framework for the land transport system in New Zealand, consistent with sustainable management principles required by the Resource Management Act.

While the reports point to the conclusion that road transport's social costs may be understated by current charging, they are less conclusive on the manner of individual charging. Their recommendations for further research are summarised in Transit New Zealand Research Reports No. 18 (Halcrow Fox and Associates 1993) and No. 19 (Works Consultancy Services Ltd 1993).

9. REFERENCES

Halcrow Fox and Associates. 1993. Land Transport Pricing for New Zealand. *Transit New Zealand Research Report No. 18.*

Works Consultancy Services Ltd. 1993. Land Transport Externalities. *Transit New Zealand Research Report No. 19.*