Unsealed roads are sustainable

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Strategies for low volume rural roads are assessed to find out how sustainability can best be implemented. The basic options reduce to deciding whether the roads which are currently unsealed can continue to serve New Zealand's needs in the future, either by continuing current operating and maintenance procedures, adapting to alternative procedures, or if seal extension is finally necessary.

Factors likely to be relevant to sustainability are examined. Resources typically used in maintaining both sealed and unsealed roads are compared. The author concludes that, principally for reasons related to intergenerational equity, low volume unsealed pavements are the better choice, providing that specific 'good practice' techniques are applied. At the same time the need to conserve non-renewable resources used for resealing existing more heavily trafficked roads, became apparent.

Dust remains an on-going problem on unsealed roads. More research is needed into methods of quantifying the amount, effects and abatement of dust.

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1. Introduction

As the low volume rural road network forms a major proportion of the length of the New Zealand public road system it is appropriate to consider how the Resource Management Act of 1991 coupled with current efforts leading towards a less carbon and energy intensive future, applies.

The current public perception is that gravel roads are to be avoided(1). Seal extension is frequently seen by the public as the way to satisfy future needs(2). Nevertheless available and proven technology does exist which, when applied to the question "Should we seal that road?", would result in a reduced demand for seal extension and a more defensible use of finite resources.

Good unsealed road design was developed by New Zealand engineers (3) in the 1930s, in the days before seal extension became established and affordable. It was for nearly twenty years the accepted method of constructing a pavement. This paper includes an attempt to illustrate this largely forgotten but still very effective 'good practice', and suggest that it can again be useful. It argues that such good and proven unsealed road technology must be preserved for the future. The time will come when restraints will be applied to non-renewable resources, such as premium quality aggregates and fossil fuel products, and the use of these for sealing low volume roads will need increasingly strong justification.

2. Defining sustainable management

2.1 The IPENZ version

The IPENZ *Code of Ethics*(4) Clause 4 defines sustainable management to mean:

- Be committed to the efficient use of resources.
- Minimise the generation of waste and encourage environmentally sound reuse, recycling and disposal.
- Recognise adverse impacts of your work on the environment and seek to mitigate or avoid them.
- Recognise the long-term imperative of sustainable management throughout your work.

Sustainability is frequently defined as ‘meeting the needs of the present without compromising the ability of future generations to meet their own needs’.

Other definitions include one by Dr John Peet of the University of Canterbury stating that we should be ‘minimising unsustainable actions’(5).

The question then is: How do we interpret these concepts in practice as applied to low-volume roads?

2.2 Application of sustainable management to low volume roads

Applied to roads, particularly low volume roads, sustainable management for today can be suitably defined as conserving and minimising, over its life-cycle, the utilisation of the non -renewable resources of high quality aggregates, asphalt, fossil fuels and the associated roading equipment.

Roads, too, must be capable of adjusting to the traffic requirements of the future.

3. Basis of choice of sealed versus unsealed

One method, presented by Farmar-Bowers (6) of the Australian Road Research Board uses a sequential three step analyses. The components are:

1. development analysis (Do we really need the road and if so what are the options?);
2. resource use analysis (itemises and quantifies the resources to be consumed during the life of the proposed work);
3. payment analysis (itemises who, what, how, when and where payments will be made).

Guidance for using this analysis technique has also been provided by Tideman and Todd (7) of the Dept. of Transport, South Australia, when they applied it to comparing the energy requirements needed for alternative pavement designs proposed for use in that state.

Roads in this paper are assumed to have been in existence for some years, hence ‘development analysis’ will not be considered further. ‘Resource use analysis’ (RUA) and ‘payments analysis’ (PA) appear relevant and should provide a guide in determining the best option.

Table 1 lists the factors typically involved and postulates commonly used ingredients for two hypothetical pavements carrying similar traffic, except that one is sealed and one is unsealed. Quantification did not always seem needed, but in marginal and specific cases, this may be required.

TABLE 1. Analyses of resources and payment

Chip sealed pavement	***Unsealed pavement***
<u>Construction (Resources used)</u> granular pavement production(280 mm say) produce sealing chips produce bitumen at refinery transport materials to site place aggregates heat bitumen and spray operate rollers and graders on site place sight rails and signage	 produce basecourse (100 mm say) produce wearing course (50 mm say) transport materials to site place aggregates operate rollers and graders on site
<u>Maintenance (Resources used)</u> patch, clean drains and repair each year; paint road markings. reseal with chips at 12 years	 replace wearing course and patch at rate of application of 15 mm each year; clean drains. blading (grader) for shape and smoothness; four bladings per year.
<u>Environment (Payments by community)</u> air pollution (sulphur, diesel particulates and nitrous oxides) noise operation of road user vehicles (rolling resistance)	 air pollution (sulphur, diesel particulates and nitrous oxides plus airborne dust particulates). noise operation of road user vehicles (rolling resistance)
<u>Safety (Payments by community)</u> accidents	 accidents dust
<u>Equity (Payments by future generations)</u> non renewable resources used up (quality aggregates, fuel and bitumen)	 non renewable resources used up (fuel and aggregates)

This summarises some of the typical resources used and payments made for rural roads carrying about 100 vehicles per day.

Items which are expected to have an impact upon the options proposed are now discussed in more detail.

4. Considerations

4.1 Availability of bitumen and non-renewable fuels

During the next 15 to 20 years the supplies of oil from traditional sources are likely to become increasingly restricted. Bitumen as a product of the oil industry is included in this category. Various estimates have been published as to the future of conventional global oil supplies. All agree that globally a finite resource is being used up at an ever-increasing rate. The US Department of Energy(8) predicts that as the supply of light crude oil decreases, the quality of the replacement crude oils will present increasing challenges to the refining industry. The production of light sweet crudes is expected to peak around the turn of the century, then start to drop off and be gradually replaced with high sulphur content heavier crude oil. Refining will become more complicated and thus more expensive. Canada, for example, anticipating a slowdown from conventional sources, has started, in June 1996, with the development of oil sands projects in the Athabasca, Cold Lake, Wabasca, and Peace River regions of Alberta, deciding to spend C$5 billion on opening them up(9). These regions are estimated to contain more oil than Saudi Arabia, but it is questionable what proportion of it will be economically recoverable. The point may be reached where the energy required to recover a barrel of oil equates to the quantity of oil obtained.

The rapid economic development in some areas, particularly in non-OECD Asian countries such as China, plus the political instability of the Middle East where most of the conventional global oil supplies exist, are two of the factors contributing to future uncertainty.

4.2 Greenhouse gases

Concern about carbon dioxide and other greenhouse gas emissions is intensifying. Most developed nations now agree that doing nothing is not an option. Future curbs are certain to be applied to the use of fossil fuel - currently as a product creating the emission of greenhouse gases and secondly as a non-renewable resource needing to be wisely and not wastefully used.

The transport industry in New Zealand will surely be targeted because it is the largest sector emitting greenhouse gases. This sector produced 10.7 million tonnes of emissions per annum in 1990 and this is predicted to increase to 13.3 Mt p.a. in 2000 and 16.1 Mt p.a. in 2010 (these figures include all forms of transport in New Zealand) (10).

The effect of this upon road pavement options is unclear but it seems likely that ways of reducing greenhouse emissions may include a carbon tax. Restraints in some form will doubtless be placed to discourage use of fossil fuels.

4.3 Road properties required

Trends in the design of motor vehicles are towards a lighter stronger chassis combined with greatly reduced energy consumption. Current fuel-efficient cars weigh about 1000 kg and use 10 litres of fuel to travel 100 km. Cars of the future have been predicted to weigh 300 kg, and use about three percent of the energy requirements of today's vehicles(11).

Comparisons between sealed and unsealed surfaces must include comparative tyre wear, fuel consumption, and rolling resistance (both from deflections and surface texture). At this stage little is known about these factors as applied to a well designed unsealed surface. A smooth non-skid riding surface, although not currently typical of unsealed roads, will be required in the future and, as will be explained later, is both practical and economically achievable.

Unsealed roads usually allow thinner pavements and higher pavement deflections, but this can be modified should it prove to be justified economically in specific cases.

4.4 Safety, welfare and health

Unsealed roads fall well behind sealed roads when it comes to dust control. This has an adverse effect on road safety, the growth of crops and the health of humans and farm animals. At present no cure for dust is as cost effective as sealing. A range of dust suppressants are reviewed in a recently published ARRB publication (12). Chemical suppressants are frequently shortlived, expensive or environmentally unacceptable. More research is necessary to try and overcome or reduce the dust problem. A practical, robust and standardised method of quantifying dust is required.

After studies in Kenya in 1984, Jones of the Transport and Road Research Laboratory, UK(13), concluded that a well bound tight mosaic surface course was the most effective for reducing dust in developing countries. It is clear that a well designed 'good practice' wearing course suited to the local conditions and using local materials should be constructed as the first step, towards reducing dust. This at the same time usually provides an improved skid-resistant riding surface.

When considering accident statistics we need to look at accident frequency for identical alignments and facilities. In practice, when a road is sealed, the travel speeds of vehicles increase and added safety factors, like sight rails and guard fences, are substituted for the increased risk.

Loose surface material which is really a defect in maintenance techniques is a common cause of accidents on unsealed roads. This is not consistent with 'good practice' maintenance as will be explained later. Current accident statistics, while indicating that rural roads are accident-prone, make no clear distinction between loose and well bound unsealed surfaces.

4.5 Intergenerational equity

All maintenance and construction activities generate costs. In broad terms payment analysis as defined by Farmar-Bowers includes how,when and where the payment is made. Good practice implies that finite resources, whatever they are, should be conserved and used carefully when no other viable option is clearly available.

The key issues, as applied to local roading, are that bitumen and premium aggregates are finite resources and are currently essential for sealed roads, whereas gravel roads are much better constructed from local secondary quality materials containing some plasticity.

5. General perceptions versus technical reality

5.1 Sealed roads

Maintenance of sealed roads in the public sector involves a resealing programme estimated (based on Transit New Zealand annual reports of area resealed and an application rate of 1.5 litres per square metre) to use between 35 000 and 40 000 tonnes of bitumen annually. Premium quality aggregate is basic for the chips for the resealing, even for low volume roads, as weathering and wear both have to be considered. On low volume sealed roads where wear is not appreciable the aim is to extend the period between reseals as long as possible so that the weathering of chips becomes the dominant factor in that situation. The annual usage of bitumen and high quality sealing chips combining all public and private roads in New Zealand is therefore substantial.

This scenario implies a commitment in the long term to a regular and continuing reseal programme, at say ten year intervals, after taking second coat seals into account.

Roads which are sealed are perceived by adjoining residents and road users as being:

- technically ordinary;
- not often needing total coverage maintenance (such as grading) and hence not costly to maintain;
- comparatively safe to drive upon;
- relatively dust-free and environmentally friendly.

At the same time the technical reality is that sealed roads require:

- a sufficiently rigid pavement structure requiring adequate engineering design input to ensure that the seal coat will survive the anticipated traffic loading;
- use of high quality aggregates of such calibre that they perform until at least the next major rehabilitation (almost certainly in excess of 25 years);
- regular resealing about every ten years and rehabilitation at longer intervals;
- close policing against damage by overloaded vehicles;

- relatively longer hauls and hence higher energy input for processed materials, e.g. bitumen and premium quality aggregates used in construction and maintenance;
- significantly greater energy resources during construction;
- safety fences, guard rails, markers and more adequate sign posting to offset the higher operating speeds that a sealed surface induces.

5.2 Unsealed roads

Approximately forty percent of the public road system is unsealed and currently costs close to $50 M annually to maintain (14). Traffic on these roads is generally less than 100 vehicles per day and consists mostly of light vehicles (about 10% are heavy vehicles). Rural roads mainly service the agricultural, pastoral and forestry sections of the community which, despite the low traffic volume, originates a substantial percentage (about 50%) of our export earnings.

Maintenance consists primarily of regular grader blading and regravelling to replace wear. Due to combined climatic erosion and vehicle attrition most gravel roads not carrying a high percentage of heavy vehicles lose between 8 to 15 mm with an average of say 12 mm from their surface each year (15). This equates nationally to an annual requirement of between one and two million cubic metres of replacement aggregate. About half the wear loss is climate-related so that, even without any traffic, regular regravelling is required if the road is to last. The road material used is preferably not premium quality aggregate. Slightly weathered quarry overburden (often currently cast aside or used as fill material) makes a superior type of wearing course.

Unsealed roads are perceived by adjoining residents and road users to:

- require relatively frequent maintenance;
- have low safety values, including poor skid resistance (often due to loose material on the surface);
- limit driving speeds;
- be dusty in dry weather, creating both environmental and traffic safety problems;
- be unsuited to use by inexperienced drivers and tourists (16);
- involve increased vehicle operating costs, i.e. fuel consumption, tyre wear, and vehicle damage;
- cost more than sealed roads to maintain.

At the same time in actual practice they:

- are forgiving of occasional heavy vehicle overloading;
- are constructed with a thinner (more flexible) pavement structure;
- need less input of high technology, i.e. less special-purpose plant and workmen;
- use lower quality, less cost, less durable aggregates with a lower life expectancy;
- use local materials thus generally incurring shorter haul distances;
- can be put back into service more quickly after damage (by flooding, slips or washouts);
- can suffer considerable overloading abuse and neglect over a period of time without incurring undue extra cost increases to restore;
- require minimal road safety signs and guard rails due to their lower speeds capability;
- can be nearly as efficient as sealed surfaces regarding vehicle operating costs, if ‘good practice’ techniques are implemented.

6. Design and good practice

6.1 Pavement design

In general terms the unsealed pavement requires less total thickness compared to its equivalent when sealed (17). The sealed pavement needs the extra thickness to limit flexure induced cracking of the sealed surface under commercial vehicle loading and to limit the rate at which permanent traffic-induced surface deformation develops. Materials used must be of higher quality than for unsealed pavements to provide strength and durability until first reshaping (rehabilitation).

Unsealed roads are constructed from local materials which may be of lesser quality and shorter life span. Regravelling to replace wear on unsealed roads means that, in terms of life cycle quantities of material used, an unsealed road may require more material, but the lower quality requirements for unsealed will usually result in lower tonne/km haulage requirements.

6.2 Fuel consumption

Under current usage of non-renewable fuels, vehicle speeds and rolling resistance have an effect on fuel consumption which in turn affects the rate of emission of greenhouse gases. Road design can alter these factors. Recent research in Australia(18) shows that three separate factors contribute to the fuel consumption of vehicles. First there is the fuel required to idle the engine (transmission not included), then the amount to overcome rolling resistance, and thirdly what is needed to overcome windage. Surface unevenness, commonly measured as NAASRA counts/km, is the second factor in the equation which can be modified by appropriate design and maintenance of the wearing surface of both sealed and unsealed roads. This is further discussed in the next section. The third aerodynamic factor starts to become consequential at speeds above 60 km/hour.

6.3 What is 'good practice' for unsealed roads?

The past can provide an answer to this question. There was a time in New Zealand history when practitioners did not know much about sealed roads but had used their skills to develop a good unsealed road using local materials. This pavement had a tightly bound stone mosaic surface with a prescribed particle size distribution and plasticity so designed as to produce maximum density. Involved were simple laboratory tests to control the clay binder fraction, shrinkage and strength.

That design, after it had been developed and used for some years, was adopted in 1938 by the then Main Highways Board as a standard specification for pavements which were to be tar primed and then sealed (19). Although it made a good unsealed road it did not function well under the dual effects of an impervious seal coat and with increased traffic loading and changed axle configurations imposed on it after World War II. The problem was that moisture could accumulate on the underside of the seal coat, and allow development of pore water pressure in the upper basecourse. Sealed pavements were subsequently designed with a free draining basecourse. The continued use of the impervious 'topcourse' for unsealed surfaces fell into disrepute and was then largely forgotten. That design is still capable of producing a firm, skid resistant and relatively dustless surface for unsealed roads. What is required is that specifications be updated to utilise modern test methods, and the control measures converted into modern technical terms.

During a twelve month monitoring period in 1987/1988 Southland County was experimenting with steeper crossfalls on two test sections of McIvor Road, with an ADT of 70, near Invercargill on a research project (20) for the Road Research Unit of the then National Roads Board. Roughness (NAASRA counts/km) measurements made then on both sections averaged 100, with a maximum value of 120 and a minimum of 73. No special efforts were then being made to smooth the sections, which were routinely graded four times during the year because wear is accepted on an unsealed road between gradings and crossfalls must be maintained sufficiently to minimise standing water.

New Zealand 'good practice' unsealed wearing courses have been found to possess grading characteristics closely matching the design of a modern asphalt concrete mix (Figure 1).

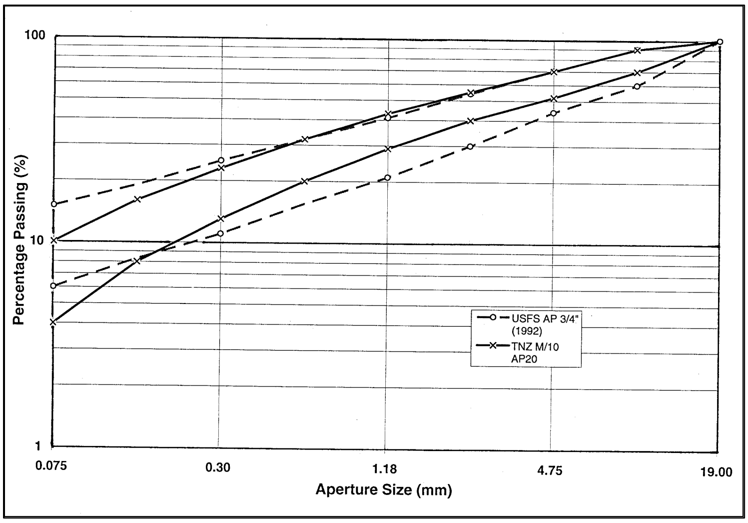

FIGURE 1. Compares the grading envelopes of an asphalt concrete and a 'good practice' design for an unsealed surface wearing course.

6.4 Road maintenance

Both sealed and unsealed roads require appreciable energy inputs for maintenance, but generally for light traffic the unsealed road appears to minimise overall energy usage. Maintenance of unsealed roads uses energy in processing and trucking in aggregates and grading the surface; sealed roads use energy when resealing, and periodic rehabilitation occurs. The balance varies considerably from site to site. Clearly though, when higher levels of traffic intensity (possibly in the range of several hundred light vehicle equivalents per day) are reached and increasing vehicle operating costs clearly dominate, the sealed road becomes the more appropriate.

Maintenance requirements for the future will include more rigorous safety standards. One particular need will be to maintain an agreed standard of skid resistance which is not attainable if loose gravel surfaces continue to be condoned.

Roads carrying logging trucks are generally left unsealed despite the visibly higher wear rates on both vehicles and road surface resulting in extra maintenance. A reason for this is that logging traffic is often short lived during harvesting and between long growing periods, and damage occurring during the period of heavy loading is more easily repaired afterwards than if the road was sealed. In the one case reshaping with a grader may be all that is required but if a seal coat is ruptured a complete rehabilitation treatment may be required.

7. Discussion

There are a number of reasons why unsealed roads currently have a poor public image:

1. Contractors, often inexperienced in good unsealed maintenance practice, obtain contracts on the basis of competitive tender prices and non-exclusive specification clauses for the surfacing maintenance aggregate.

2. Some practitioners are persuaded that, if a road has any prospect of being sealed in the future, the possibility is reduced if a correctly designed unsealed pavement containing clay binder is put in place. There is a philosophical difference between the two types of pavement design. Sealed roads are designed to let water out while unsealed roads keep water out (21).

3. Comparisons are often made between an indifferently maintained unsealed road and an adjacent recently constructed sealed surface.

The cited example of an unsealed road in Southland suggests that, with a modest technical input which did occur in that case, a reasonably smooth and relatively dustless road surface can be maintained and can provide a satisfactory level of service. It may be more difficult to achieve in some other areas outside Southland but it is still an economically viable approach for most parts of New Zealand.

Sealed surfaces in rural areas generally have higher roughness counts than is acceptable for major highways, and roughness counts around 100 NAASRA c/km and similar to those obtained on McIvor Rd. are typical. Thus, in the moderate to low traffic range, whether sealed or not, pavements can be made comparable in terms of smoothness.

Table 2 summarises the overall findings.

TABLE 2. Comparison of sealed and unsealed pavements for low volume roads

Energy	Unsealed probably uses less energy overall as lower quality materials are often more suitable involving less cartage and less processing energy.
Materials	Bitumen is a non-renewable resource used in sealing and resealing. Premium quality basecourse and sealing chips are non-renewable aggregates, unless recycled.
Environment	In the absence of better information noise and greenhouse gas emissions are judged approximately the same.
Health and welfare	Dust is often a serious problem for unsealed roads but is capable of mitigation to tolerable levels with good wearing course design.
Intergenerational equity	We should consider not just today’s needs, but future needs in the use of finite resources.

Table 2 indicates that despite the more obvious and immediate concerns with global warming, intergenerational equity may ultimately be the controlling factor in deciding which option is best. At this stage we cannot be sure which way the balance lies between sealed and unsealed in so far as greenhouse gas emissions and energy usage are concerned but prudence would still require that unsealed surfaces be chosen on the basis that it was the more sustainable.

8. Conclusions

This paper deals with rural and local New Zealand roads in general terms. Due to wide variations in climate, terrain and distance from material resources a detailed analysis will frequently be required for a factually based choice.

1. In rural areas with low traffic volumes, unsealed roads, given the correct treatment, generally represent the better option when compared with seal extension.
2. To be sustainable for future safety and traffic needs unsealed roads, will require a more thoroughgoing implementation of some specific technical inputs and quality control.
3. For the use of bitumen and premium aggregates a conservative approach is necessary so that some is obtainable in the future, for the currently sealed roads.
4. Research is needed for quantifying dust, rolling resistance, rate of loss of shape, performance of alternative wearing courses, skid resistance and development of specifications.

9. Acknowledgement

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