

Gravel roads: Do they make economic sense?

Introduction

This document is based on a paper *South African road surfacing policy, international oil price changes, and the shadow pricing of costs and benefits* by Ross and Field which examines in some detail the economic consequences of providing gravel roads for low traffic volume as compared to upgrading these roads to a surfacing standard.

The main thrust of the paper is to demonstrate that, while rising global petroleum prices will drive up the cost of bituminous layer construction, their effect on the cost of provision and, especially, the maintenance of gravel roads is more severe and will swing the balance in favour of providing low volume roads with a bituminous surfacing.

The paper identifies a range of negative externalities on both vehicle operators and the community at large that gravel roads impose on society. However, the (shadow) costs associated with these externalities are not analysed. A number of negative externalities that are associated with gravel roads are described and the authors note that each must shift their conservative figures in the direction of favouring the sealing of a higher proportion of SA's roads.

The prime purpose of the revision of the original paper is to shorten it and to render it more readily digestible to a wider readership. In doing so, more up-to-date was incorporated where feasible.

Government investment in infrastructure

Since the launching of ASGISA and other elements of the Government's infrastructure push in 2004, it has become evident that the public sector administrative structures would face challenges to optimise public investments in infrastructure.

Roads constitute the single largest component of infrastructure allocation, constituting roughly one-quarter of the budgeted expenditure up to 2009. Expenditure on provincial and national roads has increased substantially from R9,1 billion in 2003 to R33.1 billion in 2010. The nine metro municipalities expend annually R12 billion on road provision and maintenance. . Finally, SANRAL raises funds from tolling and Build-Operate-and-Transfer (BOT) schemes that are reinvested in roads. (BOT revenues alone are forecast to reach an eventual steady state of R20 billion.)

NATIONAL CAPITAL EXPENDITURE ON KEY INFRASTRUCTURE (R million)

Year ending	MTEF							Total MTEF	% Total MTEF
	03	04	05	06	07	08	09		
Water	4,966	5,038	4,531	6,039	7,422	6,176	5,706	19,304	7.7
Sanitation	782	1,565	1,368	2,297	2,422	2,494	2,606	7,522	3.0
Electricity	6,427	7,294	8,981	13,233	18,018	18,719	21,310	58,047	23.0
Housing	5,828	5,206	5,185	8,398	9,594	11,075	11,746	32,415	12.9
Education)	1,046	1,610	2,277	2,481	3,022	3,351	3,894	10,267	4.1
Health	4,501	4,901	5,030	6,381	6,744	7,425	8,087	22,256	8.8
Roads)	9,097	11,175	10,810	13,851	16,310	22,079	24,791	63,180	25.1
Rail	1,891	2,245	2,147	4,465	5,090	6,321	6,380	17,791	7.1
Ports	1,659	1,589	2,221	2,843	5,244	5,172	4,268	14,684	5.8
Courts	271	244	245	253	980	851	831	2,662	1.1
Police	257	314	368	447	498	708	1,188	2,394	1.0

Prisons	164	204	100	235	398	451	570	1,419	0.6
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The total annual investment as of 2010 will be about seven times the comparable figure for 2000 (before adjusting for inflation).

Notwithstanding these increases and scale of investment in road infrastructure, we face a backlog in expenditure on roads, estimated by the Minister of Transport in 2007 at R50 billion. There is no reason to believe that this backlog has shrunk; on the contrary, it may have widened.

Low volume roads

The paper focuses attention on *one* major source of inefficiency in the application of current road budgets, namely sub-optimal proportional investment in low volume bitumen sealed roads compared with gravel roads.

Table 1 shows the South African Road Network in terms of road type and responsible authority. It is evident that a huge proportion of public roads (approximately three quarters) are indeed gravel or even dirt, the latter type being generally applicable to the unproclaimed roads.

Table 1

Authority	Paved	Gravel	Total
SANRAL	16,170	0	16,170
Provinces - 9	48,176	136,640	184,816
Metros - 9	51,682	14,461	66,143
Municipalities	37,691	302,158	339,849
Total	153,719	453,259	606,978
Un-Proclaimed (Estimate)		140,000	140,000
Estimated Total	153,719	593,259	746,978

While this proportion of unsurfaced roads is not high by African standards, it is more than other countries with per capita GDPs similar to SA's. There are compelling economic reasons for thinking that many of these roads, at least among those engineered with gravel rather than dirt, should be upgraded to bituminous surfacing. The authors suggest that other gravel roads, and most dirt roads, should not currently be maintained at all except where a community is crucially dependent on them for basic mobility, or where a road can be entirely maintained by local labour with no public contribution beyond workers' salaries

This recommendation stands, notwithstanding significant increases in the price of bitumen, driven by the general spike in the world cost of petroleum products since early 2005.

The situation is brought into sharp focus when the condition of rural gravel roads throughout SA is taken into account. The condition, shown in Figure 1 below can be summarised by stating that while only 20 - 30% of rural gravel roads can be classified as good or better, no less than 30 – 50% are classified as poor or worse. A sorry state of affairs indeed.

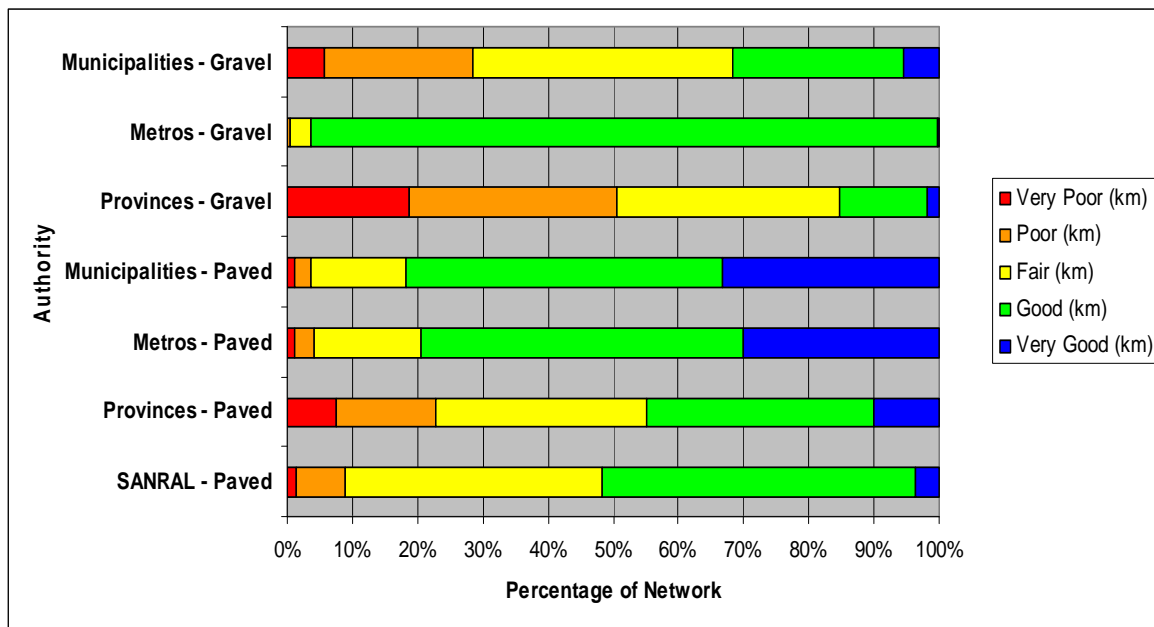


Figure 1 Road Condition RSA

Source: SANRAL

The point that surfaced roads are becoming more costly, and will go on becoming more costly over the near term, should not be misinterpreted that their provision and maintenance has become significantly more expensive *relative to* properly maintained gravel roads. This reasoning tends naturally to lead to the conclusion that the *proportion* of unsurfaced roads to be upgraded and the *proportion* of new surfaced roads should both be reduced from what they otherwise would be. This reasoning is mistaken, and indeed has the case backwards

Comparative evaluation of road investments

In the case of public infrastructure, benefits accruing over some period determine the life cycle cost of public infrastructure. Future costs or benefits are discounted by the difference between having the benefits and paying the costs now, or deferring them. A common approach is to set the discount rate to the difference between the interest rate earned by a safe financial asset and the expected medium-term rate of inflation. In SA it is currently customary to benchmark this at 8%.

The key to proper economic analysis of any investment decision is finding a way to account for all consequences that benefit people or impose costs on them, even where the values and costs in question don't have prices assigned to them directly by markets. Such non-traded cost and benefit streams must be assigned so-called 'shadow prices' - monetary amounts people would apparently be willing to pay to avoid the costs and acquire the benefits if a market for them existed.

The National Department of Transport's Road Infrastructure Strategic Framework for South Africa (RISFSA) cites World Bank research into comparative economic rates of return from infrastructure investment in Bank-funded projects around the world over the period 1974 to 1992.

gives average rates of return on types of investments. The average return on infrastructure projects in general was 16%. Road infrastructure returns were highest among all categories, earning an average over the total period of 24.5%.

Table 2: Average economic rates of return on World Bank-supported projects, 1974-92

SECTOR	1974 to 1982	1983 to 1992
	Percentage	
Irrigation and drainage	17	13
Telecommunications	20	19
Transport	18	21
Airports	17	13
Roads	20	29
Ports	19	20
Railways	16	12
Power	12	11
Urban Development	-	23
Water and sanitation	7	9
Water supply	8	6
Sewerage	12	8
Infrastructure	18	16
All Bank operations	17	15

In the past there existed a general rule of thumb that only roads carrying more than 400, or sometimes 700 vehicles per day would qualify for an upgrade from gravel to a surfaced standard. These rules were based on an economic analysis of agency costs only, i.e. the cost to the road authority. It ignored the benefits accruing to society, for which they would be prepared to pay. As this concept of societal benefits through improved safety and reduced vehicle operating costs became entrenched, the threshold traffic volumes decreased significantly.

Now, the SADC Guideline on Low-Volume Sealed Roads (SADC 2003) introduces a new approach of customised road design to correspond to:

- local climates;
- particular natural materials located in project vicinities; and
- particular transport needs specific to Southern Africa.

The Guideline document identifies cases from the region where providing gravel roads with bituminous surfaces is economically justified at average annual daily traffic (AADT) threshold of less than 100.

Similarly, RISFSA does not attempt to specify a rigid surfacing algorithm, but instead simply specifies factors relevant to judging best surfaces. It prescribes attention to key performance indicators listed and described in

Table 3.

While it would be impracticable to represent these indicators in a single comprehensive economic decision making model they can be put to good use as will be demonstrated in a later section..

Table 3: South African Strategic Framework performance indicators

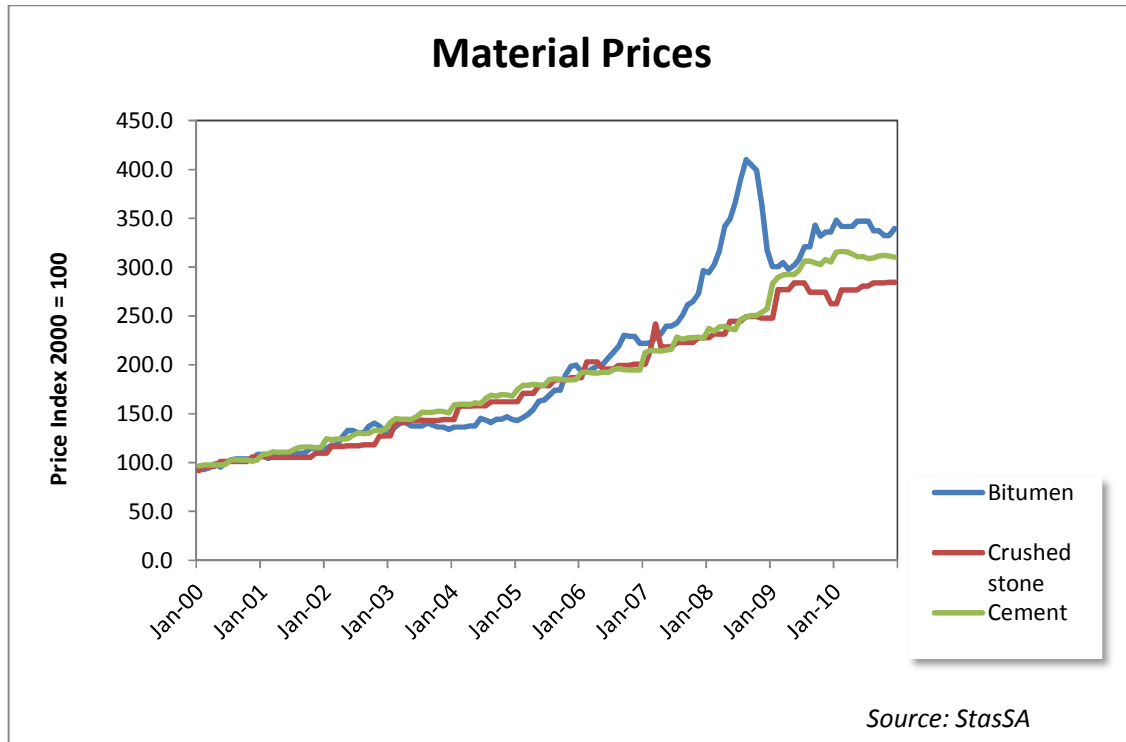
Performance Indicator	Description
Serious casualty crashes	The number of crashes, involving hospitalisation or death per year (normalised per 100 000 head of population).
Road fatalities	Crash fatalities per year (normalised per 100 000 head of population).
Persons hospitalised	Persons hospitalised per year as a result of crashes (normalised per 100 000 head of population).
Road maintenance effectiveness	A cost index reflecting the proportion of the road network that is being maintained to target conditions and the expenditure per km required.
Smooth travel exposure	The proportion of travel undertaken each year on roads with roughness conditions less than the specified levels.
Greenhouse gas emissions	Gross emissions of CO ₂ calculated from fuel sold for road use and appropriate emission factors.
Traffic noise exposure	Arithmetic average of sound levels exceeded for 10% of each of the eighteen hours between 6.00am and midnight on a normal working day.
Return on construction expenditure	The percentage distribution of programmed expenditure by benefit cost ratio (BCR) range.
Actual travel time	The aggregation of travel times actually achieved per km on a representative sample of arterial roads and freeways.
Congestion indicator (urban)	The aggregation of delay per km on a representative sample of arterial roads and freeways in the urban metropolitan area.
User cost distance (passenger car)	The operating costs per km of a standard passenger sedan.
User satisfaction index.	Index of users' qualitative evaluation of satisfaction with road system outcomes. Also measured for freight and courier users.
Consumption of vehicle fuel [CVF].	Average rate of fuel consumption over time.

Source: NDoT 2002

Influence of the costs of petroleum products

The rise in the relative price of bitumen corresponds closely to the most recent period of sharply rising global oil prices. Superficially, this might appear to validate the notion that as oil becomes dearer, surfacing proportions on new roads should shift away from bitumen in favour of gravel, and fewer gravel roads should be re-surfaced. Figure 2 below shows the price movements of bitumen, crushed stone and cement from 2000 through 2010. The effect of crude oil spikes, especially during 2008, on the price index of bitumen is clearly visible.

Figure 2: Relative bitumen and construction material prices, 2000-2010



However, it can be demonstrated that the relative costs of bitumen and gravel roads are not simply, or even mainly, functions of the relative costs of the two basic materials. It is the costs of fuel associated with the haulage and construction of the road layers that is the dominant factor.

Savings in future maintenance costs for a road with a bituminous surfacing, relative to an unsealed one, principally arise through the fact that the seal prevents gravel from being lost through the action of traffic, wind and rain requiring replacement with freshly mined and hauled material. The bituminous surface also eliminates the need for periodic grading of the gravel road to render it passable and safe.

In their paper Ross and Field consider the undiscounted comparative costs of a bituminous surface road and a gravel road, including the costs of oil-related products i.e. diesel for haulage and construction of road layers, bitumen surfacing chips and gravel, based on information supplied by industry, the Department of Minerals and Energy and Sabita for the period January 2003 to July 2007, for the following conditions:

1. A gravel road
2. A surfaced road utilising the existing pavement layers
3. A surfaced road requiring the construction of a suitable granular base layer.

In the first instance a hypothetical haul distance of 100 km is adopted, simply for ease of calculation.

Using the above set of conditions for generating simulations, Figure 3 compares undiscounted cost ratios per km of haulage distance between a gravel source and a construction or maintenance point over a 10-year period, given ratios between real oil prices as they varied during the period analysed.

It is clearly illustrated that, when gravel road construction and maintenance are compared with the construction and maintenance of a bitumen surfaced road, the diesel cost component of the total

undiscounted cost of an unsurfaced road outweighs the combined undiscounted bitumen and diesel costs associated with constructing and maintaining a low-volume bitumen-sealed road.

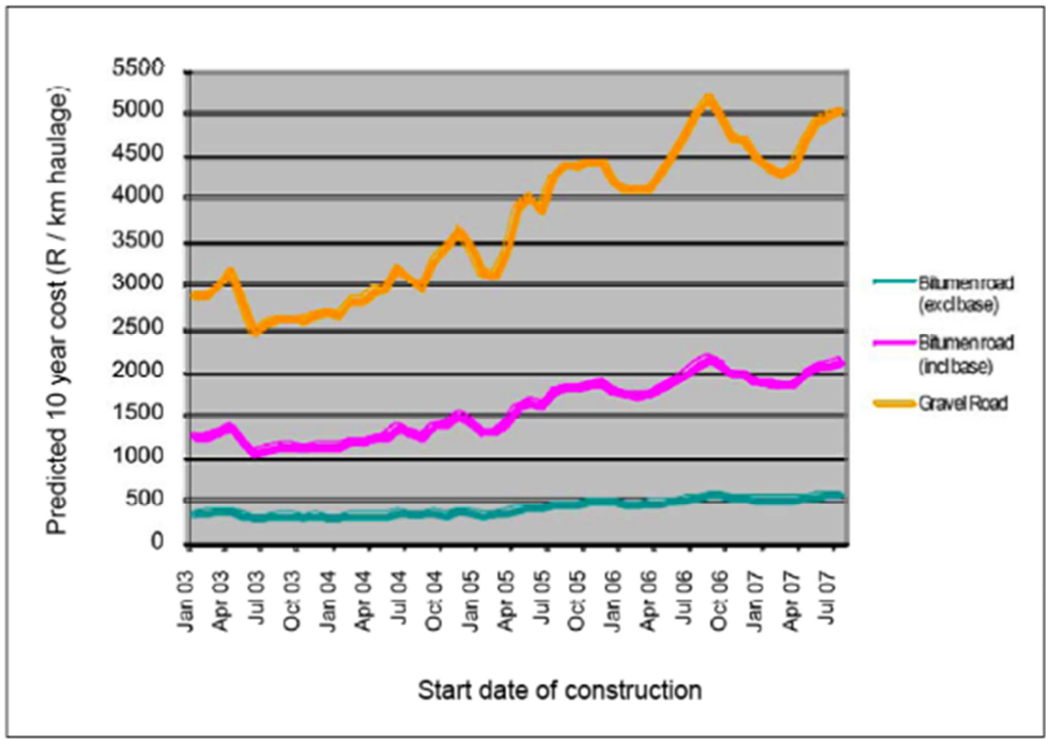


Figure 3_Petroleum price impacts on maintenance costs per km of haulage for three different types of road

The comparison will of course be still more favourable for sealing an already constructed gravel road.

Figure 4 Relative costs of oil-price linked inputs shows real values of the above ratios as at July 2007 for plausible haulage distances in SA, calculated over a 20-year period.

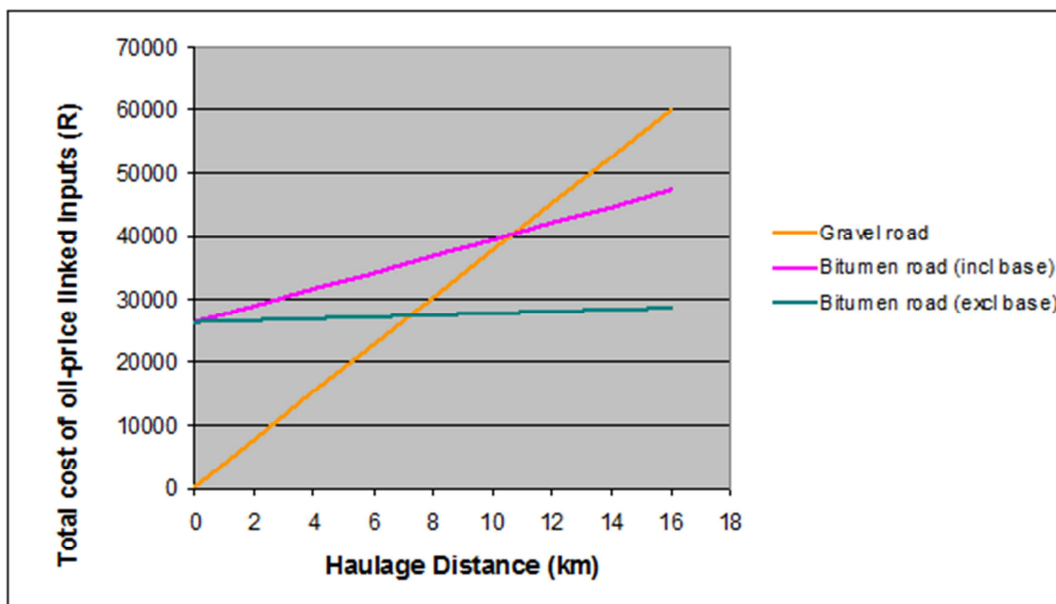


Figure 4 Relative costs of oil-price linked inputs

Haulage distances used is the average viable transport distance between each point on the road and the nearest source of adequate aggregate material.

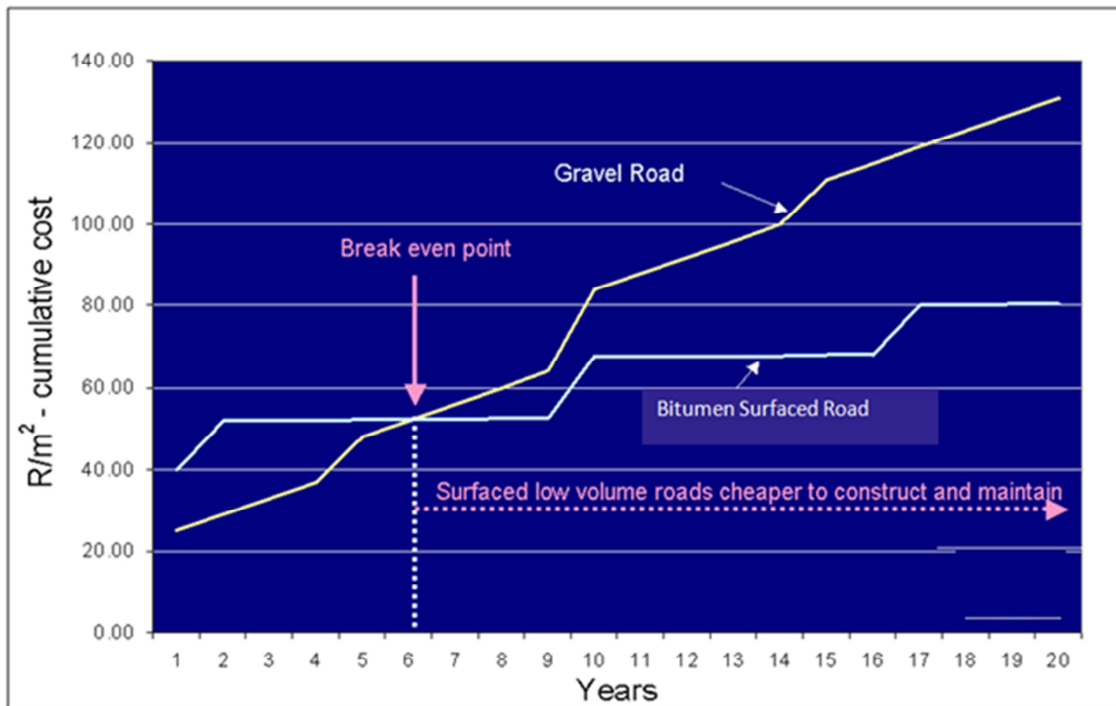
It will be seen that building and maintaining a bitumen road utilising existing base materials consumes fewer oil-based inputs over 20 years than building and constructing an unsurfaced road, measured by Rand cost, at an average haulage distance of just over 7 km. Where base course material is imported for a sealed road the break-even occurs at an average haulage distance of 11 km. This corresponds to findings from South-East Asia as reported in Jähren *et al* (2005).

Given that the oil-based cost of bitumen is included in this model, it illustrates the extent to which bitumen, despite being a petroleum-derived product, does not represent an intensive allocation of this ever-costlier commodity to roads relative to its main alternative.

The authors draw a provisional conclusion that should SA wish to minimize oil consumption by its expanded road works programme:

- either new borrow pits should be dug so as to match oil-price increases with reduced haulage distances, *or*
- at present oil prices – but given expectations of rising oil prices – any gravel road that averages more than 10 km in haulage distance from nearest sources of adequate aggregate material should either be allowed to deteriorate and then be abandoned or, if it is deemed to be worth maintaining, sealed with a bitumen surface at its soonest scheduled maintenance point.

Based on data collected in Tshwane an economic analysis presented in 2007 by Henning shows that the cumulative costs of a gravel road and a bitumen surfaced roads reach a breakeven at just over 6 years. These findings are shown in Figure 5.



Source: Henning, 2007

Figure 5 Break-even point for a low-volume surfaced road relative to an unsurfaced road

One could therefore conclude that if an unsurfaced road is worth maintaining, *then* if it is sealed the investment should be expected to pay positive returns in saved opportunity costs after a maximum of 5 - 6 years

Social costs of unsurfaced roads

Gravel roads impose a range of negative costs on both vehicle owners and the community at large. A true estimation of the societal cost of constructing and maintaining a gravel road, rather than a sealed road, would incorporate shadow prices for these externalities. If unsurfaced roads carry a range of shadow costs that bitumen-surfaced low-volume roads avoid, then this must affect the break-even point in time. For a given rate of inflation it must occur sooner. Because the negative externalities also reduce the supply of gravel, and hence increase haulage distances, they also reduce the threshold for gravel use at which expenditure on oil is minimised

Accepting that assigning shadow costs to these external factors is extremely difficult, the authors describe negative externalities associated with gravel roads, noting, again, that each must to some unknown extent shift their conservative numbers in the direction of implying the sealing of a higher proportion of SA's roads.

Negative externality #1: health and environment impacts. Each year, more than 30 million cubic metres of gravel blows or washes off SA's roads and must be replaced (NDoT 2002). Because of this dust that they spread onto crops, wildlife and people, gravel roads impose heavier environmental costs than surfaced ones. Dust causes allergies and respiratory illness, especially in

small children. People must clean their homes, businesses and vehicles more often, which must reduce either their leisure time or their productivity. This cost may appear insignificant to a particular person, but seemingly trivial expenses can produce high collective costs. In addition, borrow pits are generally regarded as insults to natural landscapes, both aesthetically and because they impact vegetation through disruption to water tables and absorption patterns.

Legislation requires that any level of government must carry out costly, complicated and time-consuming procedures for approval whenever it intends to open new quarry or borrow-pit facilities. These procedures comprise:

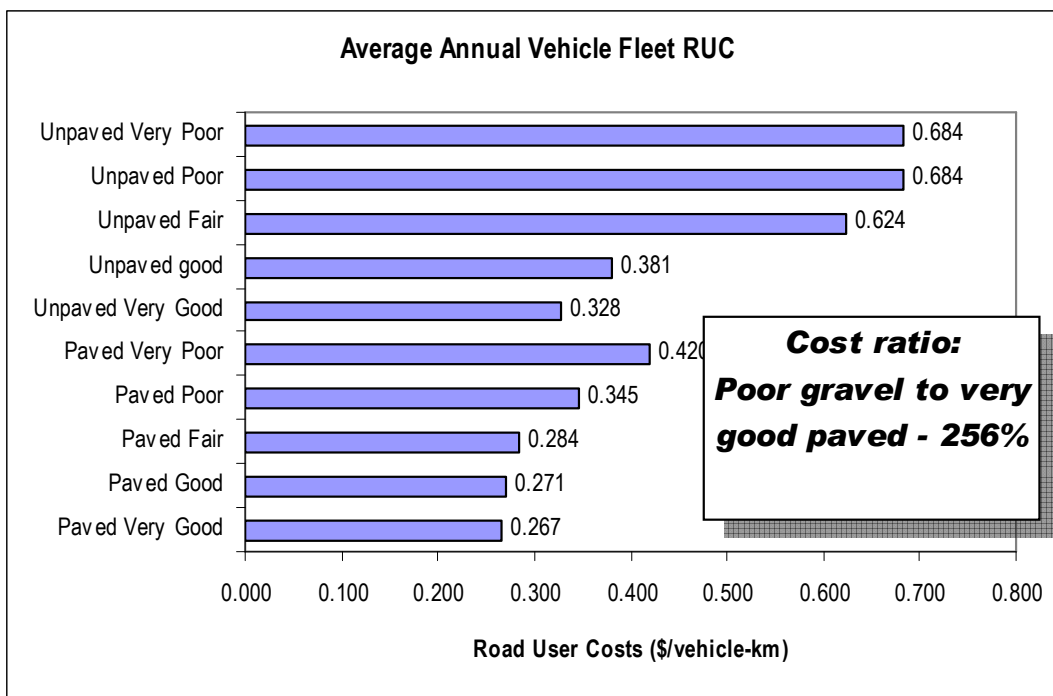
- The formulation of an environmental management programme;
- Environmental Impact Assessments (EIA); and
- A proposed sustainable environmental management programmes.

SANRAL, for example, have experienced setbacks and added costs associated with the timely approval of EIAs and mining permits for the establishment of new quarries and borrow pits.

Negative externality #2: impacts on vehicle operating costs. Rougher road surfaces increase vehicle operating costs, especially petrol use and tyre wear. Fuel consumption premiums on gravel roads are especially noteworthy if one of the considerations leading to concern about bitumen use is its upward influence on national consumption of petroleum products. Based on research carried out in SA and neighbouring states, fuel consumption is 6% to 7% higher on gravel roads than on paved ones and could be as high as 20%.

Overall vehicle operating costs, which typically include fuel consumption, maintenance and repairs, depreciation and tyre costs increase significantly when travelling on gravel roads compared to travelling on surfaced roads. According to studies carried out by the World Bank and taking all these components of road user costs into account it could cost up to 2½ more to travel on gravel than on a surfaced road, as illustrated in Figure 6.

Figure 6 Road user costs and road condition



Studies based on a mix of Namibian and South African data show that merely factoring vehicle operating costs into the comparative economic evaluation of road types reduces the threshold average daily traffic volume for justification of resurfacing a gravel road with a single surface dressing to 120. If the threshold of 120, were adopted in, for instance, Gauteng, this would result in 50% of present gravel road kilometres being regarded as warranting upgrade based on consideration of vehicle operating cost savings only.

Negative externality #3: safety. Surfaced roads are safer than gravel roads because on paved surfaces vehicles can brake to faster stops from equivalent speeds and are less disposed to skid. According to Caterpillar Inc. (2004), the coefficient of traction for rubber tyres on a paved road is 0.90, as opposed to 0.36 on unsealed gravel. This is offset somewhat by the fact that vehicles tend to travel faster on surfaced roads. However, accident data considered by Labuschagne and Schermers (1998) lead them to conclude that road surface conditions contribute to about 8.6% of all accidents in SA, and that surface improvements would prevent 10% of these altogether.

The accident rate per million vehicle kilometres on gravel roads is more than double that for two-lane paved roads, and the proportion of fatalities among accidents on gravel (10.9%) is *higher* than on 2-lane paved roads (7.8%), and much higher than on full-speed freeways (3.2%). Thus effects of differences in vehicle control appear to swamp differences in driving speed where accident harm is concerned.

Labour-intensive road maintenance

Policies to construct and maintain gravel roads fail to take account of SA's abundance of underutilised labour and are less effective at developing human capital in small contractors than projects to construct and maintain sealed surfaced roads.

Gravel roads, due to their dependence on long-distance haulage of large volumes of gravel material and large machines for grading and finishing, cannot practically be constructed and maintained using small equipment that can be operated by unskilled people. Bituminous surfaces on the other hand, can be constructed and maintained with light equipment that requires little training to master (Pinard and Overby 2006).

This capacity of bituminous surfaces was demonstrated by a documented project which used manually operated chip spreaders to construct low-volume sealed roads near Siyabuswa in Mpumalanga in early 2005. The project resulted in the employment of more than *60 mainly unskilled workers for a month*, whereas conventional, machine based methods would have employed *5 to 6 people for a few days*. A major advantage for small, emerging contractors was the reduced capital investment made possible by the employment of manual stone chip spreaders and as alternatives to more expensive heavy chip spreading equipment (Pagel, Distin and Stonemann 2005).

National Government's Extended Public Works Programme (EPWP) mandates that wherever labour-intensive methods can be deployed for the same budget outlay as capital-intensive methods, the former should be favoured. *In fact this is too conservative, using a financial measure of value where an economic measure would be more appropriate.*

Use of small contractors in road construction and maintenance builds human capital in the form of competency in management, tendering and investment in addition to operational skills required to carry out the work efficiently and profitably.. Since such capital is an economic asset with future multipliers.

The economic basis of the EPWP as it is currently formulated is therefore open to criticism in mandating that labour-intensive production methods should be used wherever they have an accounting cost no higher than alternative capital-intensive methods,.

If newly employed people learn skills from working – for example, in the case of road construction and maintenance, if groups of them develop capacities to manage projects as small contractors – then this increases the national human capital stock.

The surfacing of gravel roads with graded stone seals has created over 100 km of economically stimulating access roads in the eThekweni District Municipality (KZN's largest) since 1999 and has made use of labour-enhanced construction methods (Naidoo, Purchase and Distin 2004). Local contractors have observed that use of labour made good financial sense, particularly on areas of the road network where terrain and weather conditions limited the suitability of heavy construction machinery.

On the Gundu Lashu Programme for Labour Intensive Rural Roads Maintenance project in Limpopo province labour-based contractors used low-volume sealed road construction techniques which have resulted in both employment benefits for the area, as well as savings in construction costs and future maintenance bills (Paige-Green *et al* 2004). Part of the explicit motivation for this project was the growing local scarcity of good quality gravel to maintain the road network, which had been sharply driving up its cost.

Conclusions

The main conclusions drawn by the Ross and Field are:

1. Compared to bitumen-surfaced roads a substantially higher proportion of the price of gravel roads is driven by the petroleum price. Therefore, as the petroleum price rises, the relative economic costs of gravel and surfaced roads should be expected to shift in favour of surfaced roads.
2. At present oil prices – but given expectations of rising oil prices – any gravel road that averages more than 10 km in haulage distance from nearest sources of adequate aggregate material should either be allowed to deteriorate and then be abandoned or, if it is deemed to be worth maintaining, sealed with a bitumen surface at its soonest scheduled maintenance point.
3. The specific haul distance cited in (2) above will decrease, at an accelerating rate, as the price of oil rises.
4. Barring a persistent surge in inflation beyond the official target of the Reserve Bank, an investment in a bitumen surface seal on any road that is worth maintaining at all for the sake of traffic volumes recoups its value in 5 to 6 years.
5. Significant negative social effects associated with gravel roads make it likely that the supply of gravel will continue to contract, the viable haulage distance threshold for gravel roads will shrink (over and above shrinkage caused by rising oil prices), and the duration between a decision to surface and the break-even point will shorten.
6. Rural bitumen-surfaced roads that are constructed and maintained using labour-intensive methods bring two positive externalities:
 - potential augmentation of human capital, and

- exploitation of SA's large gap between shadow wages of underemployed workers and formal-sector market wages.

Finally the authors state that, when all of the aforementioned considerations are taken into account, SA should maintain gravel roads only where daily traffic volumes are too low to normally justify expenditure on *any* road, but a community's access to a minimally acceptable quality of life is crucially dependent on it. They suggest that, if maintenance of a low-volume road is justified by traffic volumes, then sealing of that road's surface with bitumen is also justified. In the absence of quantified shadow costs of the negative externalities associated with gravel roads there are good reasons to believe that the unknown magnitudes are significantly large. Given that the estimated conservative numbers already suggest an aggressive surfacing policy for low-volume roads, the end of the gravel road in SA may be at hand.