VEHICLE OPERATING COSTS ON UNSEALED ROADS

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AN IMPORTANT NOTE FOR THE READER

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EXECUTIVE SUMMARY

The study undertaken in 1992 identified the factors that contribute to the costs of operating vehicles on unsealed roads compared to those costs on sealed roads in New Zealand. These factors were derived from a review of international literature and a Workshop of representatives of the transport industry in New Zealand.

The literature review identified road surface roughness as a major determining factor for vehicle operating costs. However, little in the literature suggested that road surface type (unsealed or sealed) was significant, other than in its effect on road surface roughness. This view was reinforced from data on vehicle operating costs obtained from a survey of a number of transport operators.

The conclusion is that, while a number of factors related to road surface type were identified from the Workshop, their combined effect would be unlikely to exceed 5% of total vehicle operating costs.

The study reinforced the notion that road surface roughness is a significant determinant for vehicle operating costs and found that the relationship currently used in the Transit New Zealand (1991) Project Evaluation Manual (PEM) for sealed roads is broadly appropriate for unsealed roads. The study also showed that the vehicle operating costs derived from transport operators were consistent with costs in the Manual for roads with average grades of up to ±4%.

Further research on the vehicle operating cost differences between sealed and unsealed roads is not a high priority for improving the accuracy of Transit New Zealand PEM evaluations for road sealing projects. Instead research efforts would be better directed to other aspects of the user benefit evaluation in the Manual, particularly the effects on travel times of sealing unsealed roads.

ABSTRACT

The study undertaken in 1992 identified the factors that contribute to the costs of operating vehicles on unsealed roads compared to those costs on sealed roads in New Zealand. However, the results of a review of international literature and of the vehicle operating costs obtained from a survey of New Zealand transport operators indicated that road surface type (unsealed or sealed) was not a significant source of cost differences over that attributed to increased road surface roughness. Any effect of road surface type is unlikely to exceed 5% of total vehicle operating costs.

The study reinforced the notion that road surface roughness is a significant determinant for vehicle operating costs. Also it showed that the relationship currently used in the Transit New Zealand Project Evaluation Manual (1991) is appropriate for unsealed roads.

1. INTRODUCTION

1.1 Background

Economic evaluation of roading improvements involves comparing the construction and recurrent maintenance expenditure over an analysis period (typically 25 years) with the benefits resulting from savings in road user costs over the same period. An important component of the road user benefits is the savings in vehicle operating costs (VOCs) resulting from improved road characteristics, such as roughness and geometry.

Large scale road user cost studies were conducted during the 1970s in four developing countries to determine the relationship between VOCs, vehicle characteristics and road design parameters. These studies, conducted in Brazil, Kenya, the Caribbean and India, suggest that VOCs are significantly affected by road roughness and geometry. They have been complemented with later work in South Africa where VOC relationships appropriate to that country have been developed.

The research focused on establishing the effect of variables, such as fuel consumption, tyre wear, repairs and maintenance, and depreciation, on the components of VOCs. In some cases the effect of road surface type, i.e. whether the road was paved or unpaved, was studied and reported separately from road roughness.

The terms "paved" and "unpaved" used in these studies for Brazil, Kenya, the Caribbean and India are not directly equivalent to the terms "sealed" and "unsealed" that are used in New Zealand. However, for the purposes of this report, the findings have been interpreted to reflect the relationships that might apply to sealed and unsealed roads in New Zealand.

In New Zealand, the roughness profile of an unsealed road surface is considered to be particularly severe on VOCs, particularly tyre wear. Also other factors unique to unsealed roads, such as dust, stone damage, and loose stones, may also be significant and may not have been adequately reflected in previous studies.

The research recorded in this report was undertaken in 1992 to investigate whether the above mentioned factors were significant in affecting the VOCs of vehicles using unsealed roads in New Zealand.

1.2 Terms of Reference

The Transit New Zealand (1991) Project Evaluation Manual (PEM) provides estimates of VOCs for sealed roads for evaluation of road proposals (Appendix A2, Vehicle Operating Cost Values).

To refine these estimates in the PEM, both the different factors affecting the VOCs of unsealed roads compared to sealed roads and the relative significance of these factors were to be established through a process of consultation and interview. The factors were then to be benchmarked against actual running costs obtained from transport operators in New Zealand.

If appropriate, graphs and/or tables were to be derived for estimating the incremental cost of operating vehicles on unsealed roads compared to VOCs on sealed roads. Such graphs and/or tables were to be designed for inclusion in the PEM.

The study did not require assessing the effect of road surface type on vehicle speed, although some costs such as fuel consumption are highly dependent on speed, and therefore on road surface type.

PEM (p.A2-2) defines VOCs as comprising the cost of fuel and oil consumed, tyre wear, vehicle repairs and maintenance, and that portion of depreciation related to vehicle use. The operating costs are expressed as resource costs, as opposed to financial costs. Therefore, any data obtained from transport operators were to be reduced by the taxation component. Further, the portion of depreciation attributed to vehicle use is small, being only 30% for passenger cars and 15% for other vehicle classes (Bennett 1989).

1.3 Study Approach

The study involved three stages, summarised as follows:

Stage 1: Literature review of current and recent international research, and of current practices in New Zealand, Australia and South Africa.

This first stage involved reviewing the literature to identify any research that quantified the effect of road surface type on VOCs separately from road surface roughness.

Stage 2: A process of consultation and facilitation to identify the various factors and their significance, that affect VOCs on unsealed roads over and above the VOCs incurred on sealed roads.

This process involved establishing, through a Workshop environment, the factors affecting the VOCs of unsealed roads compared to sealed roads and placing them in order of significance. The Workshop comprised representatives of the New Zealand transport industry, including engineers, plant workshop managers, researchers and consultants.

Stage 3: To quantify as far as possible the effect of the factors, identified in Stage 2, from the data collected in discussions with New Zealand transport operators.

Quantifying these effects involved surveying New Zealand transport operators who operate vehicle fleets on both unsealed and sealed roads, to establish cost differences in running vehicles on the two types of pavement surfaces.

Specific vehicle fleets could not be attributed exclusively to using sealed or unsealed roads as, inevitably, all vehicles operated on both types of road surface. In consequence, an attempt was made to identify vehicles from districts that operated on different proportions of sealed to unsealed roads.

The terrain and roughness of the roads over which the fleet operated could not be accurately established either. Therefore, a general description of the terrain and the percentage of sealed to unsealed roads had to be obtained from the operator of each of the vehicle fleets.

VOCs obtained from transport operators would identify the magnitude of any difference that could be attributed to road surface type. These costs (if any) would then need to be attributed to specific factors and this was achieved from a delphi survey of the transport operators that participated in the vehicle operating cost survey.

2. LITERATURE REVIEW

2.1 Introduction

Current knowledge on road user costs, including VOCs, is mostly derived from the road user studies carried out in Brazil, Kenya, the Caribbean and India by international funded research agencies (e.g. World Bank). Later research in South Africa has also contributed to the knowledge on road user costs.

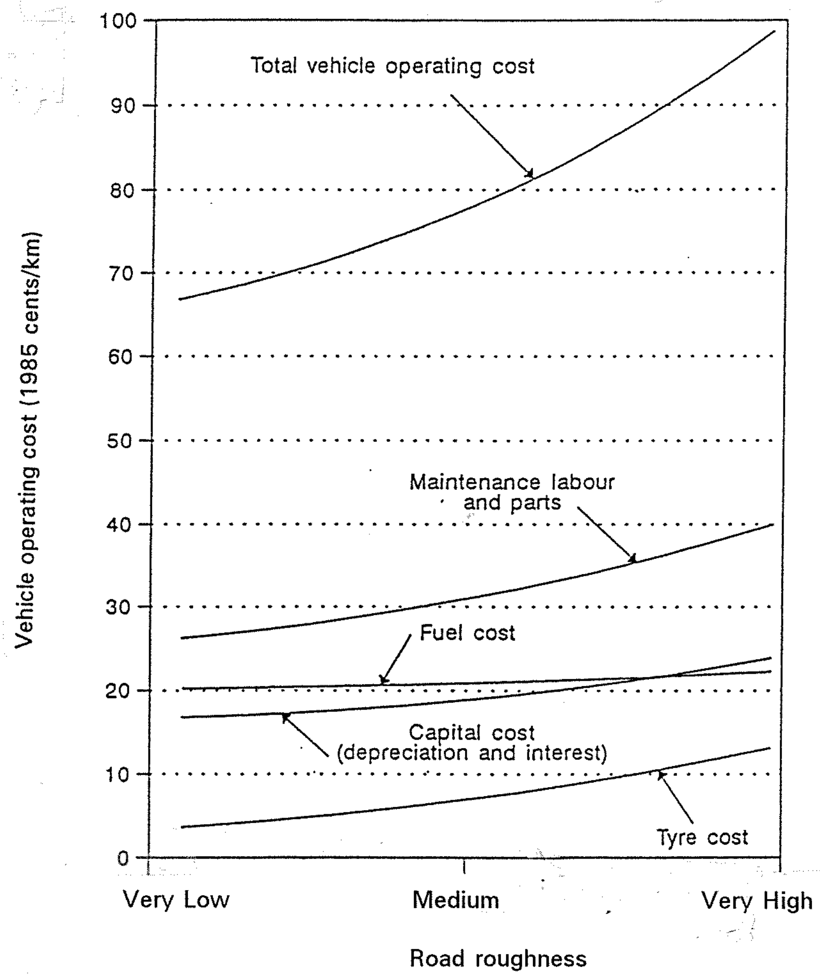
The literature review presented in this report represents a critique of these studies, as they relate to the interaction between VOCs and road surface type.

VOCs comprise the cost of fuel and oil consumed, tyre wear, vehicle repairs and maintenance, and vehicle depreciation. The relative contribution of each was reported by Curtayne et al. (1987) for a bus on rolling terrain. The relative contribution of each component to VOC and their sensitivity to road surface roughness are shown by this generalised relationship in Figure 1 and Table 1. Repairs and maintenance make the greatest contribution to total vehicle operating costs, while tyre wear makes the least contribution. It is also shown that the costs associated with tyre wear are the most sensitive to roughness, while fuel consumption costs are the least sensitive. Depreciation and repairs and maintenance costs are more sensitive to roughness than fuel consumption but less than tyre wear.

Table 1. Contribution of each component, and their sensitivity to an increase in roughness, to VOCs for Buses (Curtayne et al. 1987).

VOC component	Average contribution to total cost (%)	Increase in VOC related to increase in roughness (%)
Tyre wear	10	120
Fuel/oil consumed	25	5
Vehicle depreciation	25	30
Repairs and maintenance	40	40
Weighted Average		40

Figure 1. Components of VOC for a bus on rolling terrain (adapted from Curtayne et al. 1987).



The three literature sources reviewed to study the interaction of VOCs, road surface roughness and road surface type were:

- Analysis of the Kenyan and Caribbean road user studies by Hide et al. (1983);
- An overview of the road user studies in Brazil, India, Caribbean and Kenya by Chesher and Harrison (1987);
- Research and calibration of the road user studies for South African conditions by the South African Roads Board (1991).

2.2 Hide, Abaynayaka and Morosiuk (1983)

The results of the Caribbean and Kenyan studies were used to develop vehicle operating cost relationships for the then new Transport and Road Research Laboratory (TRRL) road investment model for developing countries (RTIM2). The relationships are instructive in that they cover both paved and unpaved roads for essentially free-flow traffic conditions.

The results show that roughness and hence road surface type was not a significant factor in determining fuel consumption in these two countries. However, a separate relationship was established between tyre wear and roughness for paved and unpaved road surfaces for trucks and buses but not for cars and light vehicles. Further, the differences related to road surface type were only significant for very high roughness levels and these levels would be outside the normal range of roughness likely to be encountered on New Zealand roads.

The consumption of engine oil for unpaved roads was double that for paved roads. However, this could be attributed to differences in roughness between the two types of road surface. In any event, engine oil is only one of three lubricants used in vehicles and lubricant costs generally account for only 3% of total VOCs.

Road surface type was particularly significant for vehicle parts consumption (i.e. a component of vehicle repairs and maintenance) for both light and heavy vehicles over the full range of road surface roughness encountered. The effect was greatest for trucks where the difference in parts consumption increased from 0% at low roughness to 40% at high roughness. The corresponding differences for light vehicles was 0% and 20%.

The vehicle parts consumption for the paved road surface was higher than for the unpaved road surface, possibly reflecting the effect that different road surface types had on vehicle speed.

2.3 Chesher and Harrison (1987)

Chesher and Harrison (1987) reviewed road user studies undertaken in Brazil, India, the Caribbean and Kenya and, while holding reservations about the general applicability of the VOC relationships, considered that such relationships were useful in providing information on cost differentials associated with different highway conditions.

They reported that the only difference in fuel consumption attributed to both road surface roughness and road surface type was in the Brazilian study and the differences were small (0-8%). The other three studies showed no differences with road surface roughness or road surface type (a finding that is consistent with the results reported by Hide et al. (1983)).

They also reported that the effect on fuel consumption of loose material on an unsealed road as measured in the Kenyan study, was also small, of the order of 5%. Nevertheless, this is a cost that can be attributed to an unsealed road independently of road surface roughness.

Chesher and Harrison found that the effect of road surface roughness on tyre consumption was significant for all the studies. The increase in tyre consumption cost for the Brazilian and Indian studies ranged from 18-30% per 1000 mm/km roughness counts (equivalent to 50 NAASRA counts/km) for cars and 3-5% per 1000 mm/km roughness counts for trucks and buses.

The percentage increases were similar for the Caribbean study but greater for the Kenyan study. However, it is not clear whether these differences were related to differences in road surface roughness, road surface type or vehicle speed. If the Kenyan and Caribbean results as reported by Hide et al. (1983) are any guide for the Brazilian and Indian studies, the effect of road surface type would have been small.

Chesher and Harrison also summarised the effect of road surface roughness on the cost of vehicle maintenance. The increase in vehicle maintenance cost per 1000 mm/km roughness counts in the Brazil and Indian studies varied between 16-24% for cars and 12-23% for trucks. However, there is no indication whether road surface type was a significant factor other than in terms of its effect on road surface roughness.

2.4 South African Roads Board (1991)

Research by Roads and Transport Technology for the South African Roads Board (1991) did not specifically address the question of road surface type separately from road surface roughness. However some of their general conclusions, particularly on depreciation and interest, are relevant to the present study.

They adopted a "coast-down" technique (i.e. disengaging the engine over the test strip) to estimate fuel consumption for a range of speeds using a mechanistic model based on rolling resistance. Their results are generally consistent with the results of the Brazilian study.

Comparing the South African results with those of the earlier road user studies in Brazil, India, the Caribbean and Kenya, showed that the South African research reflected the Kenyan and Caribbean relationships rather than the Indian or Brazilian relationships for tyre wear, but it reflected more closely the Brazilian relationship for maintenance parts consumption.

Roads and Transport Technology used a mathematical model to establish a relationship between depreciation and interest charges, and road surface roughness and vehicle age but no attempt was made to separate out road surface type effects. Therefore it is assumed that these effects were regarded as not being significant.

Depreciation and interest costs are generally of the same order of magnitude as vehicle maintenance and repair, and therefore constitute an important and significant portion of VOCs. However, depreciation has less significance in New Zealand where only that portion of depreciation attributed to vehicle use is included in the vehicle operating costs calculation.

2.5 Summary

The literature reviewed establishes *road surface roughness* as a significant factor in determining VOCs and there is no doubt that *road surface type* is one of the most significant factors affecting road surface roughness. However, little in the literature indicates that road surface type is significant other than in its effect on road surface roughness.

Differences in *fuel consumption* for paved compared to unpaved roads were reported for the Brazilian road user cost study, but the differences were small (0-8%). There is some evidence to suggest that loose road surface is a factor contributing to increased fuel consumption and that the effect may be of the order of 5%. As fuel consumption represents 25% of the total VOC, the combined effect would only be of the order of 3%.

Tyre wear is affected more significantly by road surface roughness than is fuel consumption. However, little in the literature indicates that road surface type is significant for tyre wear other than in its effect on road surface roughness.

Differences in *vehicle parts consumption* are attributed to road surface type in the Kenyan and Caribbean studies. The results however may merely reflect a speed effect as the speeds on unpaved roads were significantly lower than those on paved roads.

3. WORKSHOP CONSULTATION

A Workshop was organised to:

1. establish the factors which affect the VOCs of unsealed roads compared to sealed roads, and
2. place them in order of significance.

The Workshop comprised representatives of the New Zealand transport industry and included engineers, plant workshop managers, researchers and consultants. Appendix 1 lists the participants.

The Workshop involved establishing, through a brainstorming session, all the factors likely to affect differences in VOCs on unsealed compared to sealed roads in New Zealand. The factors were written onto cards and placed on a table. The participants were asked to agree to the order of significance for the factors. The nine most significant factors are shown in Table 2.

A procedure by which the effect of road surface type could be considered separately from road surface roughness was found to be difficult to establish. Dealing with each in turn, the most significant factor affecting VOCs is the effect of roughness profile on maintenance costs. This is more likely to be a road surface roughness factor rather than a road surface type factor.

The next seven levels of significance, however, all relate to the effects of loose material and dust/dirt/slurry on fuel consumption, tyre wear and vehicle maintenance costs. These effects could be attributed to road surface type rather than to road surface roughness. The ninth level related to the effect of road surface roughness on capital depreciation.

Table 2. Outcome of Workshop consultation.

List of factors contributing to differences in components of VOCs for unsealed and sealed roads, in their order of significance.

Significance	Component	Factor	Comment
1	Maintenance	Roughness profile	Causing vibration and failure of springs, drive train, exhaust etc. from corrugations in the road.
2	Maintenance	Dust/dirt/slurry	Penetrating oils, brakes, working parts etc. and causing corrosion of undercarriage.
3	Maintenance	Loose material	Flying stones causing damage to windscreens and paintwork when passing other vehicles.
4	Tyre wear	Loose material	Caused mainly by angularity and sharpness of surface stone and thickness of loose material.
5	Capital	Loose material; dust/dirt/slurry	Flying stones causing damage to the exterior of the vehicle. Dust/dirt/slurry affecting the exterior gloss and rusting of underbody.
6	Maintenance	Dust/dirt/slurry	Requiring the inside and outside of a vehicle to be cleaned more often.
7	Fuel consumption	Loose material; dust/dirt/slurry	Caused by mud, slush and loose material and dust in air filter.
8	Fuel consumption	Loose material; dust/dirt/slurry	Caused by driver behaviour (lead foot) and grade effects.
9	Capital	Roughness profile	Resulting in increased depreciation.

4. SURVEY OF TRANSPORT OPERATORS

4.1 Survey Design

The survey of transport operators was in two main parts, viz:

1. A delphi survey in which plant workshop managers were requested to identify the cost differential between the different factors identified from the Workshop; and

2. Identification of the components of VOCs in the operators' accounts; then attributing them to specific fleets of vehicles operating on sealed and unsealed roads, according to the different proportions of travel on either road surface type.

4.2 Surveyed Operators

A number of transport operators who used a range of light and heavy vehicles on both sealed and unsealed roads were invited to participate in the survey. The operators were:

- Hawkes Bay Transport Holdings
- Northland Dairy
- Anchor Milk
- Transport (Wairarapa)
- Rangitikei District Council
- Gisborne District Council
- Telecom Central

4.3 Delphi Survey

The results of the delphi survey are summarised in Tables 3 and 4 for light and heavy vehicles respectively. Costs in each table are expressed relative to the cost of the least significant factor. The responses showed considerable scatter, as would be expected, and the ranges in the responses are summarised in Appendix 2.

Although participants did not have an opportunity to refine their responses, as would normally be done in a delphi survey, the responses gave an overall picture that reinforced the findings obtained from the Workshop.

Table 3. Ranking of VOC components and relative costs attributed to different road surface factors by delphi survey for light vehicles.

Component	Factor	Comment	Relative cost
Maintenance	Roughness profile	Vibration and failure of springs etc.	1.7
Tyre wear	Loose material	Angularity/sharpness of surface stone and thickness of loose material.	1.7
Maintenance	Dust/dirt/slurry	Cleaning of inside and outside of vehicle.	1.6
Maintenance	Dust/dirt/slurry	Penetrating oils, brakes, working parts etc. and causing corrosion.	1.3
Maintenance	Loose material	Flying stones causing damage to windscreens and paintwork.	1.3
Capital	Loose material; dust/dirt/slurry	Damage to the exterior of the vehicle.	1.0
Fuel consumption	Loose material; dust/dirt/slurry	Mud, slush and loose material and dust in air filter.	1.0
Fuel consumption	Loose material; dust/dirt/slurry	Driver behaviour and grade effects.	1.0
Capital	Roughness profile	Increased depreciation	1.0

Table 4. Ranking of VOC components and relative costs attributed to different road surface factors by delphi survey for heavy vehicles.

Component	Factor	Comment	Relative cost
Maintenance	Roughness profile	Vibration and failure of springs, etc.	2.2
Maintenance	Dust/dirt/slurry	Penetrating oils, brakes, working parts etc. and causing corrosion.	1.7
Maintenance	Loose material	Flying stones causing damage to windscreens and paintwork.	1.3
Tyre wear	Loose material	Angularity/sharpness of surface stone and thickness of loose material.	1.3
Capital	Loose material; dust/dirt/slurry	Damage to the exterior of the vehicle.	1.3
Maintenance	Dust/dirt/slurry	Cleaning of inside and outside of vehicle.	1.3
Fuel consumption	Loose material; dust/dirt/ slurry	Mud, slush and loose material and dust in air filter.	1.3
Fuel consumption	Loose material; dust/dirt/slurry	Driver behaviour and grade effects.	1.0
Capital	Roughness profile	Increased depreciation	1.0

The road surface factors show that the factors for heavy vehicles (Table 4) are in the same order of significance as they were placed by the Workshop (Table 2), but for light vehicles the factors were re-ordered slightly.

The review of literature found that loose material had a 5% effect on fuel consumption, equating to approximately 1% of the total VOC. Using this figure as a benchmark, the delphi survey indicates that the effect of loose material on tyre wear and maintenance (average of light and heavy vehicles) is likely to be of the order of 1.5% and 1.3% respectively. Other factors could account for another 1% and in consequence the total effect is unlikely to exceed 5% of the total VOC.

4.4 Vehicle Operating Cost Analysis

Transport operators' fleets were categorised into the following five types:
A-train; Truck and trailer; Truck; Utility; Station sedan.

The ranges in vehicle operating costs, provided by the transport operators, are shown in Table 5. The breakdown of these costs into the four main VOC components (fuel and oil, tyres, repairs and maintenance, and depreciation) is shown in Table 6. These two tables are expressed as resource or economic costs, derived from the financial costs by reducing the fuel costs by an estimated taxation component of 50%. No adjustments were made for the other components. These VOCs are consistent with those derived from the PEM for terrains with average grade of ±4%.

Table 5. Range of vehicle operating costs from transport survey (using all road surface types).

Vehicle	No. of vehicles in sample	Vehicle operating cost NZ cents/km (1991)
A-train	20	75-100
Truck and trailer	20	55-75
Truck	7	40
Utility	20	20-25
Station sedan	6	10

Table 6. Breakdown of VOCs into their four components (using all road surface types).

Vehicle	Fuel & oil %	Tyres %	R&M* %	Depreciation %
A-train	15	20	58	7
Truck and trailer	25-30	10-20	40-50	10
Truck	22	11	53	14
Utility	25	5	40-55	15-30
Station sedan	43	7	26	24

* Repairs and maintenance

The analysis involved comparing the VOCs on unsealed roads with those for sealed roads. The costs obtained from the transport operators for the five vehicle fleets are shown in Table 7, while the average additional cost of operating these vehicles on unsealed compared to sealed roads for each of the VOC components, are itemised in Table 8.

To compare VOCs on unsealed against sealed roads, adjustments have to be made for terrain, speed and road surface roughness. The unsealed roads were invariably on more difficult terrain, which would increase the VOC. However, vehicles generally travel at slower speeds on unsealed roads, which would lower the VOCs. The higher roughness level of the unsealed roads would also increase the VOC.

Table 7. Differences in VOCs of vehicles operating on sealed and unsealed roads (operator data).

Vehicle	Vehicle operating cost (1991 NZ cents/km)	
	Sealed Roads	Unsealed Roads
A-train	78.4	78.1
	78.4	100.8
Truck and trailer	58.4	61.0
	58.4	73.2
	53.2	57.8
Truck	41.4	43.0
Utility	21.4	20.7
	21.9	26.7
Station sedan	8.9	10.9

Table 8. Additional costs in fuel, tyres, repairs and maintenance of vehicles operating on unsealed roads compared to sealed roads.

Vehicle	Additional cost for unsealed road over sealed road		
	Fuel %	Tyre %	R&M* %
A-train	13	80	0
Truck and trailer	0	70	15
Truck	-1	0	8
Utility	24	35	0
Station sedan	-5	60	120

* Repairs and maintenance

Typical adjustments were derived from PEM, based on an assessment of the terrain and vehicle speed by the operators, and on assumptions of the road characteristics. The total VOC adjustments are compared to the measured differences in Table 9.

The results show that the differences in VOCs estimated using the PEM tend to be of the same order as those measured. No consistent difference was identified between the *estimated* and *measured* VOCs for all vehicle types to suggest that road surface type should be another factor in estimating VOCs.

Table 9. Adjustments to VOCs related to terrain, speed and roughness.

Vehicle	Adjustments in VOCs (NZ cents/km) related to				
	Terrain	Speed	Roughness	Estimated	Measured
A-train	3-8	-(5)	5-10	3-13	0-20
Truck and trailer	5-10	-(5-10)	5-10	5-10	2-15
Truck	5	0	7	12	2
Utility	0	0	0-5	0-5	0-5
Station sedan	0	-(-1)	1	2	2

5. CONCLUSIONS

The international literature survey did not identify road surface type as a significant factor affecting VOCs separately from road surface roughness.

This conclusion is consistent with the analysis of VOCs obtained from the transport operators. As it was not possible to directly compare the vehicle operating costs on sealed and unsealed roads, adjustments had to be made for differences in terrain, speed and roughness. These adjustments were made using the PEM, and when combined they were of the same order as the differences in VOCs for the two types of road surfaces, obtained from the transport operators. Any contribution that might have been attributed to road surface type would have been masked by the adjustments made for terrain, speed and road surface roughness.

The Workshop and delphi survey identified the main factors likely to affect operating costs between sealed and unsealed roads, and their magnitude. The literature indicates that loose material has a 5% effect on fuel consumption. By benchmarking the other factors associated with loose material and dirt against this value, the total effect of road surface type is considered unlikely to exceed 5% of total operating costs.

The conclusion is therefore that the differences in VOCs between sealed and unsealed roads (all other factors being equal) are likely to be small and not more than 5%.

A more robust approach involving measurements of route characteristics and control over the collection of VOCs would be required to establish these differences more accurately.

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APPENDICES

APPENDIX 1. LIST OF WORKSHOP PARTICIPANTS

Date Wednesday 17 June 1992
Venue 1st Floor, Turnbull House, Bowen St, Wellington

Name	Representative	Organisation
Terry Brown	New Zealand Government	Transit New Zealand Regional Office, Auckland
Ian Melsom	"	Transit New Zealand Head Office, Wellington
Ted van Geldermalsen	"	Transit New Zealand Head Office, Wellington
Peter Ritter	District Council	Ex Rangitikei District Council
Lewis Boeyer	"	Gisborne District Council
Chris Bennett	Consultant	Auckland
Ian Bone	"	Beca Carter Hollings and Ferner Ltd, Auckland
Graeme Beattie	"	Works Consultancy Services Ltd, Lower Hutt
Peter Clouston	Industry	Cement and Concrete Association
Jim Pollard	"	Transport (Wairarapa)
Neil O'Callaghan	"	Mitsubishi Motors, Porirua

APPENDIX 2. RESPONSES FROM DELPHI SURVEY

Questions presented to Plant Workshop Managers

Question 1: Does the vibration caused by the roughness profile have a greater effect on maintenance costs than dust, dirt and slurry penetrating oils, brakes, working parts, etc? If yes, or less effect, how much - 10%, 50%, 100% or 300%?

Response: Number and type of responses

Response	Light vehicle	Heavy vehicle
Yes	4	3
Same	1	0
Less	1	2

Percentage difference between the two factors

Difference	Light vehicle	Heavy vehicle
Range	(-10) -100%	(-10) -100%
Average	32%	34%

Question 2: Does dust, dirt and slurry have a greater effect on maintenance costs than loose material causing damage to windscreens and paintwork? If yes, or less effect, by how much - 10%, 50%, 100% or 300%?

Response: Number and type of responses

Response	Light vehicle	Heavy vehicle
Yes	2	3
Same	2	1
Less	2	1

Percentage difference between the two factors

Difference	Light vehicle	Heavy vehicle
Range	(-60) -50%	(-60) -100%
Average	5%	30%

Question 3: Does loose material have a greater effect on maintenance costs than on tyre wear? If yes, or less effect, by how much - 10%, 50%, 100% or 300%?

Response: Number and type of responses

Response	Light vehicle	Heavy vehicle
Yes	0	2
Same	1	0
Less	4	2

Percentage difference between the two factors

Difference	Light vehicle	Heavy vehicle
Range	(-100) -0%	(-50) -50%
Average	-50%	-10%

Question 4: Does dust, dirt and slurry have a greater effect on maintenance costs by penetrating oils, brakes and working parts or by requiring additional cleaning, both inside and out? If yes, or less effect, by how much - 10%, 50%, 100% or 300%?

Response: Number and type of responses

Response	Light vehicle	Heavy vehicle
Yes	2	3
Same	1	0
Less	3	2

Percentage differences between the two factors

Difference	Light vehicle	Heavy vehicle
Range	(-80) -50%	(-80) -100%
Average	-13%	6%

Question 5: Does loose material and dust/dirt/slurry have a greater effect on the depreciation of capital value than vibration caused by roughness profile? If yes, or less effect, by how much - 10%, 50%, 100% or 300%?

Response: Number and type of responses

Response	Light vehicle	Heavy vehicle
Yes	1	3
Same	2	2
Less	3	0

Percentage difference between the two factors

Difference	Light vehicle	Heavy vehicle
Range	(-50) -60%	0-60%
Average	-1%	32%

Question 6: Does loose material and dust/dirt/slurry have a greater effect on fuel consumption than a lead-footed driver? If yes, or less effect, by how much - 10%, 50%, 100% or 300%?

Response: Number and type of responses

Response	Light vehicle	Heavy vehicle
Yes	2	3
Same	2	1
Less	2	1

Percentage difference between the two factors

Difference	Light vehicle	Heavy vehicle
Range	(-50) -50%	(-50) -100%
Average	7%	38%