INCREMENTAL ROAD MAINTENANCE COSTS ON THE STUART HIGHWAY

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ABSTRACT:

Because of wide variation between estimates of the benefit which would accrue from construction of the Alice Springs to Darwin rail link in the form of reduced road maintenance costs, the Northern Territory Department of Transport and Works commissioned a study by the author to establish a soundly based average figure per net tonne-km (NTK) which could be used for project appraisal purposes. This paper summarises the main part of that study.

A review of previous studies revealed estimates of incremental costs nationally in the range 0.6-1.0 cents/NTK. However, conditions in the Northern Territory are very different from average Australian conditions and an analysis was undertaken using data and engineers' estimates specific to the Stuart Highway. A model was constructed which took account of the existing programme of reconstruction of the Stuart Highway and the number of years by which each section's rehabilitation and resealing could be deferred in consequence of the expected two-thirds reduction in freight volume following the opening of the rail link. NIMPAC equations were checked for their appropriateness to the Stuart Highway and then used to predict changes in routine maintenance costs.

This resulted in estimates of 0.32 cents/NTK (financial cost) and 0.30 cents/NTK (resource cost). It is suggested that these figures be used for the time being in connection with the appraisal of the rail link; and that the same method be used to predict incremental maintenance costs for other roads.

INTRODUCTION

This paper derives from a research project carried out in 1985 on behalf of the Northern Territory Government. That research was commissioned because of wide discrepancies between various estimates of the likely savings which would accrue from the construction of the Alice Springs to Darwin rail link in the form of reduced road construction and maintenance costs.

In its submission to David Hill's Independent Economic Inquiry into Transport Services to the Northern Territory, the Northern Territory Government estimated that for every net tonne-kilometre (NTK) by which the road freight task was reduced, road construction and maintenance costs would reduce by 0.75 cents. However, the report of the Independent Economic Inquiry (Hill 1983) used figures in its analysis which were equivalent to less than 0.20 cents per NTK averaged over the appraisal period. And Canadian Pacific Consulting Services Ltd, in their Preliminary Report on the rail link's viability (CPCS 1984), arrived at an even lower figure: 0.05 cents per NTK. CPCS acknowledged, however, that this was "unreasonably low in terms of road maintenance costs in other jurisdictions" and recommended more detailed analysis. The research project reported on here followed that recommendation, and its results were incorporated into CPCS's Final Report (CPCS 1985).

It soon became evident that considerable uncertainty surrounds the question of incremental road maintenance costs attributable to freight volume in Australia generally. Most research has been directed towards ascertaining whether categories of road user are meeting the total cost of road maintenance attributable to them, or towards estimating incremental costs attributable to classes of vehicle. This paper is an attempt to fill a small part of the gap by estimating incremental (or, more correctly, decremental) road maintenance costs per NTK of freight task on a specific stretch of highway at a specific point in time. The method developed for this purpose may also be useful elsewhere.

The research comprised three steps, described in subsequent sections together with our findings:

- A review of other studies of road maintenance costs in Australia.
- Computation of road construction, rehabilitation and maintenance cost savings for the Stuart Highway between Alice Springs and Darwin.
- Estimation of a factor to convert financial cost to resource cost.

REVIEW OF OTHER STUDIES

In the past decade there have been numerous studies, inquiries and papers addressing the question of the costs borne by the community at large on behalf of the road haulage industry, and the extent to which those costs are recovered from the industry through various taxes. Road construction and road maintenance have been the chief objects of such research.

The number of publications on the subject is misleading, however. They all rely on a quite narrow base of original research and data, notably the work done in the early and mid 1970s in connection with the NAASRA Study of the Economics of Road Vehicle Limits (ERVL), which in turn drew on the Model for the Economic Evaluation of Road Improvements in Rural Areas (MERRI), described in its original form in W D Scott & Co (1968) and subsequently modified (MODMERRI - see Both & Bayly 1976).

A review of several such studies was included in a paper presented to the seventh ATRF (Robinson & Rattray 1982). Our study concentrated on the conclusions of four of them, these being apparently the most representative, relevant and authoritative; they are:

- The BTE's "Darwin and Northern Territory Freight Transport Study" published in 1977, which included a section on road maintenance costs in the context of a comparison of freight carriage by road and by rail.

- Gavan McDonnell's Commission of Enquiry into the NSW Road Freight Industry, which was concerned with the extent of cost recovery from the industry.

- A paper presented to the ninth ARRB Conference by Webber, Both and Ker in 1978, describing their analysis of separable pavement costs attributable to various classes of vehicle, using ERVL data, on behalf of ATAC.

- An article by Filmer, Scott and Short in 1982 based on original research done by the BTE (1979) and Scott (1974) into road maintenance costs attributable to heavy vehicles.

The pertinent aspects and conclusions of these studies are summarised in the following sub-sections.

BTE (1977)

Based on evidence submitted to the Parliamentary Works Commttee on a proposed programme for the improvement and maintenance of the Stuart and Barkly Highways, it was estimated that marginal routine maintenance costs for sealed roads were approximately equal to average costs of 1 cent per double-axle-km or 4 cents per truck-km.

The payload of the implied 8-axle truck would be of the order of 30 tonnes. With an average load factor of 50%, therefore, routine maintenance costs would be equivalent to 4/(30 x 0.5) = 0.27 cents per NTK. Adjusted to 1984 prices by application of the appropriate BTE Road Construction Price Index (BTE 1984), this becomes 0.65 cents per NTK.

The marginal cost of reconstruction of strengthened sections of highway was estimated at 0.15 cents per tonne-km based on Department of Construction engineers' response to the question, "What would be the impact on the reconstruction programme of doubling the existing level of inter-state road freight transport?" Assuming this to be a net tonne-km figure and adjusting it to 1984 prices, it becomes 0.36 cents per NTK, making a total marginal road construction and maintenance cost of 0.65 + 0.36 = 1.01 cents per NTK.

McDonnell (1980)

McDonnell's Commission of Enquiry was concerned largely with the extent of cost recovery from the road haulage industry. Administrative, service and social costs associated with accidents, noise and air pollution were considered as well as road maintenance costs. So too were road construction costs attributable to heavy commercial vehicles as a class: i.e. the cost of accommodating such vehicles with respect to vertical grade, alignment, turning space, bridge strength etc. This approach is fundamentally different from one designed to find the cost attributable to an incremental tonne of freight or an incremental vehicle, which by itself does not affect road design parameters.

The results of the ERVL study were accepted as a basis for estimating the incremental cost of pavement maintenance, including reconstruction/ rehabilitation and resealing but excluding construction and other non-maintenance costs mentioned in the preceding paragraph. Annual costs of $4,015 per articulated truck were indicated, based on annual travel of 75,000km. Adjusted to 1984 prices and assuming an average payload of 10 tonnes, this implies costs of 0.95 cents per NTK.

Webber, Both and Ker (1978)

Northern Territory data were not included in this analysis, and the largest vehicle considered was a 6-axle articulated truck of 22.2 tonnes payload capacity. The findings are summarised in Table 1 (separable pavement costs per truck-km at 1976/77 prices) and Table 2 (adjusted to 1984 price levels and a NTK basis).

Australia-wide, costs per NTK by vehicle type range from 0.63 to 0.96 cents per NTK. Disaggregated by state, however, the range opens out to 0.23-2.28 cents per NTK: a factor of 10 separating the lowest from the highest.

Also of interest in this study is the relative significance of the four identified components of road construction and maintenance cost savings attributable to the removal of 1 truck-km from the roads:

Deferment of reconstruction	74.4 %
Reduced frequency of resealing	17.9
Reduced pavement strength	4.5
Reduced routine maintenance requirement	3.2
	100.0

Filmer, Scott and Short (1982)

The article cites two other works: BIE (1979) and Scott (1974). Like McDonnell (1980), the first of these concentrates on costs attributable to heavy vehicles as a class, arriving at a total annual cost of $232 million. Scott's analysis was restricted to pavement and shoulder damage done by heavy vehicles.

The authors conclude from these two sources that separable maintenance costs attributable to heavy vehicles lie between the extremes of 0.5 and 1.1 cents per NTK, presumably at 1982 prices. Since the higher figure includes elements which, though attributable to heavy vehicles as a class, would not apply to the removal from the road of a single member of that

TABLE 1

SEPARABLE PAVEMENT COSTS PER TRUCK-KM, AT 1976/77 PRICES

Truck type		Payload Capacity (tonnes)	Separable pavement cost (c/truck-km)				
			SA	VIC	NSW	QLD	AUST
Rigid	2-axle	8.5	2.1	1.3	1.5	4.3	1.9
	3-axle	11.7	3.9	1.1	3.2	4.9	2.6
	4-axle	14.8	5.4	1.2	3.7	6.7	3.6
Artic	3-axle	13.9	4.8	2.9	3.3	9.3	4.0
	4-axle	19.1	5.7	3.4	3.5	12.6	5.2
	5-axle	20.4	6.4	3.4	5.6	15.2	6.0
	6-axle	22.2	6.7	3.8	6.5	17.8	7.5

Source: Webber, Both & Ker, 'Commercial Vehicle Costs & Charges: A Study of Separable Pavement Costs", in Proceedings of ARRB Ninth Conference, 1978. (Breakdown by state did not appear in the original publication.)

TABLE 2

SEPARABLE PAVEMENT COSTS PER NTK, AT 1984 PRICES

Truck type		Payload Capacity (tonnes)	Separable pavement cost (c/NTK)				
			SA	VIC	NSW	QLD	AUST
Rigid	2-axle	8.5	0.70	0.43	0.50	1.44	0.64
	3-axle	11.7	0.95	0.27	0.78	1.19	0.63
	4-axle	14.8	1.04	0.23	0.71	1.29	0.69
Artic	3-axle	13.9	0.98	0.59	0.67	1.90	0.82
	4-axle	19.1	0.85	0.51	0.52	1.87	0.77
	5-axle	20.4	0.89	0.47	0.78	2.12	0.84
	6-axle	22.2	0.86	0.49	0.83	2.28	0.96

Source: Computed from Table 1 allowing for 112% price inflation and an average payload equivalent to 50% of payload capacity; and applying a factor of 0.67 to adjust from the original 25-year appraisal period and 10pa discount rate to the 50-year appraisal period and 7%pa discount rate used elsewhere in this paper.

class, the lower figure is probably the more relevant. Adjusted to 1984 price levels it becomes 0.60 cents per NTK.

Summary

All the estimates quoted above lie within the range of 0.23-2.28 cents per NTK established by Webber, Both and Ker's disaggregation by state and vehicle type:

BTE (1977)		1.01 cents/NTK
McDonnell (1980)		0.95
Webber et al (1978)	- Australian averages	0.63-0.96
	- disaggregated by state	0.23-2.28
Filmer et al (1982)		0.60

If Webber et al's disaggregation by state is omitted (it did not appear in the original publication) the range is reduced to 0.60-1.01 cents per NTK. The range is similarly reduced if the upper and lower quartiles are omitted: 0.60-0.95 cents per NTK. (The showing of all figures to two places of decimals is not intended to indicate their level of accuracy; it is merely a standard format to facilitate comparison and arithmetic manipulation.)

These figures tend to support the Northern Territory Government's original estimate of 0.75 cents per NTK (or 0.82 cents per NTK in financial rather than resource terms), but for several reasons the data and analysis which underlie them may not be appropriate to the specific purpose of estimating savings which would accrue from the Alice Springs to Darwin rail link. In particular:

- Much of the research was undertaken ten years or more ago, using data which were in many cases older still. At that time neither the roads nor the vehicles were the same as they are now.

- Moreover, nearly all the research can be traced back to a very narrow base of original data and fundamental analysis.

- Most work has inevitably been biased towards the heavily trafficked roads of Victoria and NSW, which do not necessarily offer valid comparisons for the Stuart Highway.

- Calibration of models against actual road system costs does not guarantee a correct separation of fixed costs from marginal costs; such a separation is essential to the present purpose.

- Although the 'fourth power law' (pavement wear is proportional to axle load raised to the fourth power) is very widely accepted as a basis for comparing the damaging effect of different axle loads, its validity is far from certain. There is evidence that for some axle configurations and suspension systems a higher power should be used. Moreover analysts usually base their calculations on a notional average load, and fail to address quantitatively the question of vehicle overloading, known to be widespread and to have a more than proportional effect on pavement wear - probably more than is implied by the fourth power law because of the risk of total pavement or seal failure.

- No work has been directed towards road trains specifically or, indeed, any vehicles which approach their size and capacity. It can only be by inference that the results of research relating to smaller vehicles can be applied to the road trains which would be chiefly involved in the transfer of freight from road to rail in the Alice Springs to Darwin corridor.

COST SAVINGS FOR THE STUART HIGHWAY

Working from first principles and with the best estimates available from engineers in the Northern Territory Roads Division, we computed costs with and without the rail link and the expected consequent freight shift. Three quite separate analyses were performed:

- Savings accruing from the deferment of pavement rehabilitation and resealing, and their performance to a lower standard.
- Savings accruing from the reduction in design standards used during the current programme of reconstruction of the Stuart Highway, appropriate as soon as a decision to build the railway were taken.
- Reduced routine maintenance costs.

(The terms reconstruction and rehabilitation are often used interchangeably. In this paper we make the following distinction:

- Reconstruction is taken to mean the major rebuilding of a road or road section, including realignment and/or other works which substantially upgrade its standard. The cost of reconstruction, so defined, is usually little different from that of construction.
- Rehabilitation, on the other hand, is essentially a restoration of a road or road section to its original state by re-sheeting and resealing but without improvements to drainage, alignment etc. Pavement thickness may, however, be increased to accommodate higher projected traffic volumes.)

Rehabilitation and Resealing

National Highway design standards require that the number of equivalent standard axle (ESA) repetitions be projected for twenty years and pavement thickness in millimetres be computed as:

$$[\ 219 - 211\ (\ \log CBR\ ) + 58\ (\ \log CBR\ )\ ] \times \log\ (\ N\ /\ 120\ )$$

where:
CBR = California Bearing Ratio (measure of subgrade strength - typical value 10 on Stuart Highway alignment);
N = Cumulative total ESA repetitions over twenty years.

If the value of N has been correctly projected, then rehabilitation of the road will be necessary and justifiable twenty years after its construction (or reconstruction or last rehabilitation). However, if the value has been over-estimated, rehabilitation can and should be deferred to a later date. In the case of the Stuart Highway, pavements are currently being designed for 1 million ESA repetitions typically. In the event that the rail link is built it will be many more than twenty years before that total is reached.

A simplified model has been employed here in which each kilometre of the Stuart Highway would carry an average of 900,000 tonnes of freight in the year 1992, of which two-thirds would be captured by the rail link. These figures take account of local as well as long-distance freight haulage and are a fair reflection of minimum-to-average expectations expressed in both Hill (1984) and NT Government (1983).

Such a reduction in road freight, with an average projected growth rate of 3%pa after 1992, would in theory be sufficient to extend the life of a newly reconstructed section of pavement from twenty years to forty years. However, the real life situation is rather more complex. A 20-year reconstruction programme for the Stuart Highway was commenced in 1971, to design standards which implied rehabilitation after 20 years. A decision to accelerate that programme has meant that it will be completed by 1988, with work originally planned to take at least six years compressed into the last four. Table 3 shows the present reconstruction programme, together with the date of the first rehabilitation under each of two scenarios:

- The Alice Springs to Darwin rail link is <u>not</u> built, and the original traffic forecasts for the Stuart Highway <u>are</u> realised.

- The rail link is built and opens in 1992, the decision being made in 1985 followed by an immediate adjustment of road design standards to accommodate a two-thirds reduction in freight carried by the Stuart Highway. Under this scenario, reconstruction is deferred by between 0 and 17 years, with a weighted average of 7 years.

Spending deferred is of course money saved. But in addition to the deferment of pavement rehabilitation, there would be savings resulting from the performance of that rehabilitation to a lower standard, appropriate to the reduced number of ESA repetitions expected over a 20-year period. After consultation with road engineers in the Northern Territory and interstate, the following equations were adopted in order to model rehabilitation costs:

$$R = \$ [70{,}000 + 500 \times (Y - 1984)]$$

$$R' = R \times 0.9$$

where:
R = Rehabilitation cost per km, without the railway.
R' = Rehabilitation cost per km, with the railway.
Y = Year of rehabilitation.

The increase in the value of R (and hence R') over time results from the projected growth in traffic volume. Factors which cause rehabilitation costs to rise with traffic volume include:

- Greater attention needed to sub-soil drainage.

- Greater pavement depth.

- Faster depletion of locally available good quality gravels with consequently longer hauls.

TABLE 3

STUART HIGHWAY RECONSTRUCTION PROGRAMME AND THE TIMING OF THE FIRST REHABILITATION, WITH AND WITHOUT THE RAILWAY

Year of reconstruction........	1971	1972	1973	1974	1975	1976
Percent of road affected.....	5.0	5.0	5.0	5.0	5.0	5.0
Year of first rehabilitation						
- Without railway.....	1991	1992	1993	1994	1995	1996
- With railway..........	1991	1992	1995	1997	2000	2002
Year of reconstruction.......	1977	1978	1979	1980	1981	1982
Percent of road affected.....	5.0	5.0	5.0	5.0	5.0	5.0
Year of first rehabilitation						
- Without railway......	1997	1998	1999	2000	2001	2002
- With railway..........	2005	2007	2010	2012	2014	2016
Year of reconstruction........	1983	1984	1985	1986	1987	1988
Percent of road affected......	5.0	5.0	7.5	7.5	7.5	7.5
Year of first rehabilitation						
- Without railway......	2003	2004	2005	2006	2007	2008
- With railway.........	2018	2020	2022	2006	2007	2008

Note: Assumed effect of the railway is to divert two-thirds of freight traffic from the Stuart Highway; traffic growth of 3%pa is assumed in both cases.

- Higher quality of seals - e.g. use of larger stones and additives such as rubber

As with rehabilitation, savings associated with resealing take two forms: the resealing may be performed to a lower standard and it may be repeated less frequently. We have made the following assumptions:

- The cost of resealing is 10% lower with the railway in place.
- When a road is trafficked in accordance with its design standard, a reseal frequency of 6-7 years is required.
- But with a two-thirds reduction in traffic below its design capacity, that frequency can fall to 10 years.

The combined effect of the above estimates and assumptions on the present value of a 50-year stream of rehabilitation and resealing costs, detailed in Tables 4 and 5, is as follows:

	Without Railway	With Railway
PV of rehabilitation costs	$ 64,000 per km	$ 42,900 per km
PV of resealing costs	$ 21,200 per km	$ 17,200 per km
	$ 85,200 per km	$ 60,100 per km

A saving of $25,100 per km is apparent, attributable to the railway's taking two-thirds of the freight volume off the Stuart Highway. This is a weighted average over the whole length of the Highway, a device found to be convenient since reconstruction does not necessarily take place on an integral section in any one year. The "present" for present value computation purposes is 1992 - the supposed first year of railway operation.

Reconstruction

A further saving is achieved during the last three years of the reconstruction programme, after the decision to build the railway is taken and design standards can be adjusted accordingly. A very round estimate of $10,000 per km was made for reconstruction undertaken in 1986, 1987 and 1988. Since 22.5% of the Highway's length is affected, the average saving is $10,000 x 0.225 = $2,250 per km over the whole length. Expressed as a present value in 1992, this becomes $3,200 per km.

Routine Maintenance Costs

In 1976 NAASRA published its study of the Economics of Road Vehicle Limits - ERVL. Study Report T4 entitled "Pavements" deals with the effect of axle loads and traffic volume on pavement design and maintenance (Stevenson 1976). Although based on work done at least ten years ago, this study has not been superseded by any more recent analysis and is incorporated in NAASRA's widely used NIMPAC model (NAASRA 1981). The recently published Review of Road Vehicle Limits - RoRVL - contains only very minor revisions, concerning standard axle equivalencies and pavement damage exponents (NAASRA 1985, page 118).

After updating values in line with the BIE's published Road Construction Price Indexes (BIE 1984) the ERVL model appears to be a reasonably

STUART HIGHWAY MAINTENANCE COSTS

Tables 4 and 5 on following pages

TABLE 4

PRESENT VALUE OF REHABILITATION AND RESEALING COSTS
WITHOUT THE ALICE SPRINGS TO DARWIN RAIL LINK

Reconstrn Programme (Table 3) — Year of rehabilitation(1)/reseal(2).....

Year	%	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1971	5.0	1						2							2							1					
1972	5.0		1						2							2							1				
1973	5.0			1						2							2							1			
1974	5.0				1						2							2							1		
1975	5.0					1						2							2							1	
1976	5.0						1						2							2							1
1977	5.0							1						2							2						
1978	5.0	2							1						2							2					
1979	5.0		2							1						2							2				
1980	5.0			2							1						2							2			
1981	5.0				2							1						2							2		
1982	5.0					2							1						2							2	
1983	5.0						2							1						2							2
1984	5.0							2							1						2						
1985	7.5	2							2							1						2					
1986	7.5		2							2							1						2				
1987	7.5			2							2							1						2			
1988	7.5				2							2							1						2		

Year	%	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
1971	5.0	2							2							1						2					
1972	5.0		2							2							1						2				
1973	5.0			2							2							1						2			
1974	5.0				2							2							1						2		
1975	5.0					2							2							1						2	
1976	5.0						2							2							1						2
1977	5.0	1						2							2							1					
1978	5.0		1						2							2							1				
1979	5.0			1						2							2							1			
1980	5.0				1						2							2							1		
1981	5.0					1						2							2							1	
1982	5.0						1						2							2							1
1983	5.0							1						2							2						
1984	5.0	2							1						2							2					
1985	7.5		2							1						2							2				
1986	7.5			2							1						2							2			
1987	7.5				2							1						2							2		
1988	7.5					2							1						2							2	

PV of costs........		
	Rehabilitation	$ 64,035
	Resealing	$ 21,156
	Total	$ 85,190

Note 1: In the above matrix, 1 denotes rehabilitation and 2 denotes resealing.

Note 2: Interpretation: The top left-hand figure in the matrix indicates that the 5% of the Stuart Highway which was reconstructed in 1971 is due to be rehabilitated in 1991. The next figure to the right indicates that the same section of road should be resealed in 1997.

Note 3: Present value of costs is expressed as an average amount per kilometre, in constant 1984 dollars, discounted to the year 1992 at 7%pa.

TABLE 5

PRESENT VALUE OF REHABILITATION AND RESEALING COSTS
WITH THE ALICE SPRINGS TO DARWIN RAIL LINK

Year of rehabilitation(1)/reseal(2)....

Reconstrn Programme (Table 3) Year	%	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1971	5.0	1						2							2							1					
1972	5.0		1						2							2							1				
1973	5.0					1						2							2							1	
1974	5.0							1						2							2						
1975	5.0										1						2							2			
1976	5.0												1						2							2	
1977	5.0							2								1						2					
1978	5.0	2								1								1						2			
1979	5.0			2								2									1						2
1980	5.0				2									2									1				
1981	5.0					2									2										1		
1982	5.0						2										2										1
1983	5.0								2										2								
1984	5.0									2								2							2		
1985	7.5										2								2							2	
1986	7.5		2							2							1						2				
1987	7.5			2							2							1						2			
1988	7.5				2							2							1						2		

Reconstrn Programme (Table 3) Year	%	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
1971	5.0	2							2							1						2					
1972	5.0		2							2							1						2				
1973	5.0					2							2							1						2	
1974	5.0	1						2							2							1					
1975	5.0				1						2							2							1		
1976	5.0						1						2							2							1
1977	5.0		2							1						2							2				
1978	5.0				2							1						2							2		
1979	5.0							2							1						2						
1980	5.0		2							2							1						2				
1981	5.0				2							2							1						2		
1982	5.0						2							2							1						2
1983	5.0		1						2							2							1				
1984	5.0				1						2							2							1		
1985	7.5						1						2							2							1
1986	7.5			2							1						2							2			
1987	7.5				2							1						2							2		
1988	7.5					2							1						2							2	

PV of costs........		
	Rehabilitation	$ 42,945
	Resealing	$ 17,168
	Total	$ 60,113

Note 1: In the above matrix, 1 denotes rehabilitation and 2 denotes resealing.

Note 2: Interpretation: The top left-hand figure in the matrix indicates that the 5% of the Stuart Highway which was reconstructed in 1971 is due to be rehabilitated in 1991. The next figure to the right indicates that the same section of road should be resealed in 1997.

Note 3: Present value of costs is expressed as an average amount per kilometre, in constant 1984 dollars, discounted to the year 1992 at 7%pa.

accurate means of predicting routine maintenance costs on the Stuart Highway. The equation which appears in Stevenson (1976) for sealed roads of greater than 4.3 m width is (with all values in 1971/72 dollars):

$$C = 0.0000365 \times NAX + 0.04 \times AADT + 50$$

plus the lesser of:
(i) $(0.0000816 \times NAX + 0.12 \times AADT + 17 \times NL) \times ([A + 5] / 5)$
(ii) $(0.0000354 \times NAX + 0.039 \times AADT + 78 \times NL) \times ([A + 5] / 5)$

where:
C = Annual maintenance cost in $ per mile at 1971/71 prices.
NAX = Number of ESA repetitions over 20 years.
AADT = "Equivalent AADT" - see below.
NL = Number of lanes.
A = Sealed surface age in years.

"Equivalent AADT" is defined by Stevenson (1976) as follows:

Car	1 AADT
Truck (2-axle, 6-tyred)	5 AADT
Heavier trucks	10 AADT

Clearly these equivalences are inadequate in a Northern Territory context, where heavy semi-trailers and road trains are responsible for a significant proportion of freight traffic. The following additional equivalences have therefore been adopted here:

Road train, double-bottom	20 AADT
Road train, triple-bottom	30 AADT

Based on the typical traffic mix on the Stuart Highway the "equivalent AADT" count amounts to about 2.5 times the AADT count defined in terms of double axles. Likewise based on the typical traffix mix on the Stuart Highway it was calculated that 1 "equivalent AADT" represented 52 ESA per year.

In Table 6 the ERVL equation is applied to the Stuart Highway in each of the four regions for which separate maintenance costs are recorded, with the following factors applied:

4.36 to bring the original 1971/72 prices into line with 1984 price levels, using BTE (1984).

0.62 to convert costs per mile to costs per km.

In each region the routine maintenance cost per km predicted by the model is close to the amount actually budgeted for the 1984/85 financial year - slightly higher in each case as would be expected in a situation of financial constraint. This not only tends to validate the model in absolute terms; more significantly it lends credence to the model's ability to predict the incremental (decremental) maintenance cost associated with increased (decreased) traffic.

Let us consider the incremental component of the ERVL equation. After adjusting for inflation and metrication this becomes:

$$(0.0000987 + [0.0000957 \times ([A + 5] / 5)]) \times NAX$$
$$+ (0.108 + [0.0105 \times ([A + 5] / 5)]) \times AADT$$

TABLE 6

ROUTINE MAINTENANCE COSTS FOR THE STUART HIGHWAY, 1984/85

	Note	Region			
		Darwin	Katherine	Tennant Creek	Alice Springs
AADT (double axles)		700	500	300	300
Equivalent AADT		1,750	1,250	750	750
ESA per year	1	91,000	65,000	39,000	39,000
Million ESA over 20 years	2	2.45	1.75	1.05	1.05
Number of lanes	3	2	2	2	2
Age of sealed surface (years)	4	5	5	5	5
Predicted maintenance cost ($/km)		2,250	1,890	1,520	1,520
Budgeted maintenance cost ($/km)	5	2,230	1,640	1,120	1,330
Budgeted/predicted		99%	87%	74%	88%

Note 1: In both directions, though for pavement design purposes only the dominant direction is taken into account.
Note 2: Based on 3%pa growth.
Note 3: Close to Darwin the Stuart Highway is 4-lane divided, but for most of its length it has 2 lanes.
Note 4: Average of 5 years is assumed, based on reseal frequency of 10 years.
Note 5: Excluding roadside maintenance (rest areas, verges, lighting, bridges etc) and resealing.

With an average sealed surface age of five years this may be simplified to:

0.000290 x NAX + 0.318 x AADT

One tonne of cargo carried annually by road train is estimated to generate 2.0 ESA over a 20-year period and 0.0016 "equivalent AADT". Incremental (decremental) routine maintenance costs per NTK may therefore be computed as:

0.000290 x 2.0 + 0.318 x 0.0016
= 0.000580 + 0.000509
= 0.00109

In other words, 1 NTK of freight task removed from the Stuart Highway will reduce routine maintenance costs by 0.11 cents.

Total Maintenance Cost Savings

We have computed routine maintenance cost savings in the form of cents per NTK, but savings associated with rehabilitation and reconstruction are still in the form of an average present value per km and cannot be related directly to net tonne-km. They must be divided by the present value of the projected stream of NTKs which would be tranferred from road to rail: 600,000 NTK in the first year of the railway's operation, growing by 3%pa. Using a discount rate of 7%pa, the present value of this stream is:

$$\sum_{n=0}^{49} 600{,}000 \times (1.03 / 1.07)^{n} = 13{,}661{,}400 \text{ NTK}$$

The rehabilitation/reconstruction saving attributable to each NTK is therefore:

$ (25,100 + 3,200) / 13,661,400 NTK = $0.0021/NTK, or 0.21 c/NTK.

This result is quite sensitive to the discount rate used, and unlike other aspects of the appraisal of the railway this one is favoured by a higher discount rate. If 4%pa were substituted for 7%pa, the saving would fall to 0.14 cents per NTK. With a discount rate of 10%pa the saving would rise to 0.27 cents per NTK. However, a discount rate of 7%pa has been generally accepted by all parties to the Alice Springs to Darwin Railway debate, therefore a figure of 0.21 cents per NTK is adopted as the average saving in respect of deferred and reduced rehabilititation and reconstruction costs attributable to the railway.

Adding all components together we arrive at a total incremental (decremental) cost of 0.32 cents per NTK, attributable as follows:

		c/NTK	%
Reconstruction	- cost reduction in 1986-88	0.02	7
Rehabilitation	- cost reduction	0.05	15
	- deferment	0.11	34
Resealing	- cost reduction	0.02	5
	- deferment	0.01	4
Routine maintenance		0.11	35
		0.32	100

CONVERSION OF FINANCIAL TO RESOURCE COSTS

The resource cost factor (RCF - that factor which is applied to financial costs to obtain economic resource costs) of 0.91 used in the Northern Territory Government's submission to the Hill Inquiry (NT Government 1983) was derived from information supplied by a major civil engineering contractor in the Territory, and was held to be broadly applicable to road and rail construction and maintenance activities.

A new approach was made in the course of our study of road maintenance costs, and the composition of the BTE's road maintenance cost index (BTE 1984) was ascertained. This new information suggests a somewhat higher RCF. The original and new figures are summarised below. The RCF for each of the four identified cost components is our own estimate and does no more than net out transfer payments to Government. The Overall RCF is a weighted average after combining the component RCFs with a given set of component shares:

	Labour	Fuel	Plant & Parts	Materials	Overall RCF
RCF for cost component	1.00	0.75	0.83	0.95	
Component shares according to three sources:					
NT Government (1983)	30%	5%	40%	25%	0.91
Contractor, 1985	30%	6%	24%	40%	0.92
BTE (1984)	60%	12%	7%	21%	0.95

The BTE component shares are based on 1979-80 data. It is possible that less labour-intensive methods have been generally adopted in the intervening five years. It is also possible that contractors, used extensively for road maintenance in the Northern Territory but less so in other states, have a substantially different cost structure to that of state road authorities or local government authorities using direct labour. The BTE figures are also weighted by urban road maintenance conditions, being national averages.

Nevertheless, the spread between the highest and lowest RCF arising from this analysis is not great. We adopted a figure of 0.93, as a simple average of the three. This brings our estimated financial saving of 0.32 cents per NTK to 0.32 x 0.93 = 0.30 cents per NTK.

CONCLUSIONS

The results of previous research seem superifically to confirm the estimate of 0.75 cents per NTK included in the Northern Territory Government's submission to the Hill Inquiry. Our analysis, specific to the Stuart Highway and to the traffic decrement forecast in the event that the Alice Springs to Darwin rail link is opened in 1992, indicates a much lower figure. This figure is, however, substantially higher than that used by Hill (1984).

It is not suggested that the figure of 0.30 cents per NTK (resource cost) be carved in granite, nor that it is appropriate to other roads in other circumstances. Our use of data specific to the Stuart Highway should not obscure the fact that we have relied heavily on theoretical values and relationships, albeit ones which have been widely accepted and refined over a number of years.

One particular feature of our analysis is open to serious question: whether the postponement of pavement rehabilitation by twenty years, leaving an interval of forty years during which only routine maintenance and resealing takes place, is realistic. We therefore conducted a sensitivity test in which the interval was restricted to thirty years - not unheard-of in situations of financial constraint and little political pressure from users. This restriction reduced the saving by less than 5%, which is well within any reasonable confidence limits.

All we would suggest as a result of our analysis is that the benefit accruing to the community in the form of road maintenance cost savings following construction of the Alice Springs to Darwin rail link is closer to 0.3 cents per NTK than either 0.2 or 0.4; and that since this estimate is based on values and relationships which are widely used for decision-making related to the allocation of funds for road construction and maintenance throughout Australia, if it is wrong then it is likely that much of that decision-making is also wrong. For the time being, therefore, it seems appropriate that our figure be accepted, at least in the limited context for which it was intended.

It should be pointed out that the analysis described here has not dealt with savings outside the Northern Territory. It is estimated that 18% of the transferred freight task will affect roads interstate - predominantly in South Australia, but also in Queensland, NSW and Victoria. In two respects it is to be expected that interstate savings will exceed those in the Northern Territory:

- Vehicles permitted and commonly used on roads outside the Territory are smaller and less efficient, in that the ratio of payload to ESA is lower (e.g. triple-bottom road train 18.1t/ESA, rigid heavy truck 13.6t/ESA).

- Previous studies, based largely on data from the larger states, indicate higher incremental road maintenance costs per NTK than we have estimated for the Stuart Highway.

In one respect it is to be expected that they will be lower:

- The greater the traffic volume for which a road is designed, the smaller the effect - both relative and absolute - one would expect to be attributable to an incremental unit of freight. This expectation is consistent with the formula for pavement thickness given in the subsection headed "Rehabilitation and Resealing" above.

The net effect is not at all certain, and an exercise similar to the one described above but applied to a more heavily trafficked road in another state would be of value.

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