Road Maintenance Taskforce economics

Economic Issues Paper

Report to Road Maintenance Taskforce

6 February 2012

About NZIER

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NZIER is also known for its long-established Quarterly Survey of Business Opinion and Quarterly Predictions.

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NZIER was established in 1958.

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Executive summary

NZIER reviewed potential issues with how maintenance is appraised

The NZIER has been commissioned by the Road Maintenance Taskforce (the Taskforce) to review possible issues with the economic appraisal of maintenance-related works. The Taskforce is concerned with how to improve the value for money of road maintenance initiatives from a ‘whole of lifetime’ perspective.

The NZIER has considered:

1. problems accounting for different length lives appropriately (e.g. comparing on a fair basis pavements with a 25 year life against long-life pavements of 40+ years)
2. if maintenance appraisals can better accommodate benefits and costs to road users and other people affected (e.g. disruption and environmental externalities)
3. the appropriateness and the effect of the social discount rate on capital and operating expenditure appraisals.

Appraisals can be improved to account for the risk of early pavement failure

Alternative options need to be compared over the same discounting period so they have the same opportunity to accumulate costs and benefits. This is important for roads, as a common question is whether building them stronger to last longer is value for money.

Various factors can increase the risk of early pavement failure, such as poor site investigation, design, treatment selection, and/or construction; spikes in road use (say from forestry traffic); and from excessively heavy vehicles (say, from non-compliance to road rules).

To account for pavement costs with different length lives we derived a general formula that applies to a probabilistic setting. We demonstrate that the shorter a pavement’s life may be, the larger its whole of life cost relative to a more durable pavement.

Incorporating these features into pavement appraisals will support more informed decision making.

The BCR formula can be adjusted to be more generally applicable to maintenance-related works

At times economic appraisals may have too heavy a focus on cost-savings to road controlling authorities rather than considering costs and benefits generally. Quirks in the BCR formula may drive some of this. We propose an alternative BCR formula for projects that have a material maintenance component that is consistent with the existing BCR formula.

Advantages of the alternative BCR are that it is not prone to exaggerating results, and helps to ensure an appropriate comparison of benefits to costs when funding is scarce.

The alternative BCR can be used in conjunction with the rolling over method proposed, to better represent the risk of maintenance disruption from less durable pavements.

New Zealand's 8% social discount rate is arguably too high, and it has a particularly large effect on any decisions relating to maintenance

New Zealand's social discount rate is high compared to values used in many countries overseas. The economic basis of the 8% used in New Zealand is based on what the private sector is deemed to earn. Whilst basing the social discount rate on this basis is superficially plausible, we argue that it does not stand up to scrutiny.

Too high a discount rate leads to the wrong mix of projects being done from a given budget, causing higher maintenance costs on future generations with correspondingly larger road user charges and fuel excise duties. No research has been done to estimate the social cost from using a discount rate that is excessively high.

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1. Introduction

The NZIER developed this report within the month of December 2011 to review concerns raised in previous NZTA-funded research on the economic appraisal of maintenance-related projects.

This report describes some general economic principles and uses previous appraisal examples to illustrate the various points made. We suggest ways to improve appraisals to help make better and more informed decisions.

What we have not done is apply the suggested approaches to sample programmes of appraisals, and so the materiality of the changes at a programme level is currently unclear.

2. Short-run versus long-term interventions

2.1 What's the problem?

Shorter-life projects in NZ currently look artificially attractive…

The economic appraisal techniques currently used in New Zealand transport attempt to account for projects with different time frames, but this is not done as well as it could be. This matters because a common question is whether one should invest more up-front to make a structure or pavement last longer versus spend slightly less and redirect funds elsewhere.

…which leads to under-investment, and higher costs over time

If appraisals don't appropriately reflect the merits of longer-lasting initiatives then there may be overinvestment in shorter-life options. In this case over time the annual spend on maintenance will trend higher than it would have, as pavements come up for replacement when they otherwise would not have. Higher maintenance costs imply higher road user charges, fuel excise duties and rates.

Project appraisals need to correct for different timeframes…

The leading CBA textbook Boardman et al (2006 p145) says:

> *Projects should always be compared over the same discounting period so that they have the same opportunity to accumulate costs and benefits.*

The example in section 2.2 below has two projects: Project A is a 25-year pavement with a present value (PV) cost of $94,539; and Project B is a 40-year pavement with a PV cost of $104,968. Is the shorter life pavement preferred because it has the lower PV cost? Boardman et al explain that it is not. The two projects are not commensurable because they have different lifespans.

As Project A is very nearly two-thirds the length of Project B, the analyst should compare three project As back-to-back with two project Bs back-to-back. The NPV costs of Projects A and B become $110,359 and $109,799 respectively, meaning that Project B should be built.

…but appraisals don't do this well, and guidance is lacking

Parker (2009, chapter 13) found that the sample of New Zealand appraisals obtained did not appropriately correct for different timeframes, and that the NZTA's Economic Evaluation Manual (EEM) did not provide clarity on this matter.

One previous Land Transport NZ research project (Deakin 2002) provided an economic appraisal of a 40-year pavement relative to a 25-year pavement. The method used *did try* to account for the different length lives, but it implied the long-life project was highly inefficient relative to the return required — requiring a 4.8% discount rate (i.e. the 'internal rate of return') when the going rate was 10%.

Findings such as Deakin's could potentially help to explain New Zealand's reliance on pavements with designed life cycles of 25 years, and why maintenance spend is so high compared to other countries. (New Zealand's topography and climate will also be factors.)

However, Parker (2009) found that the internal rate of return for the long-life option in the Deakin example was actually at least 8.3%, meaning it would be the cost effective option using the now 8% social discount rate. Taking account of rising real maintenance costs, and other costs such as road user disruption and risk of pavement failure, and in many cases long-life pavements could have been historically economically efficient even under a 10% discount rate regime.

Another NZTA appraisal we saw accounted for different length lives by using a 40-year appraisal instead of the normal 30-year. Although the effect of the discount rate is normally regarded as making effects after 40 years completely immaterial, the rolling over method described here can still be materially affected by costs at and after 40 years.

2.2 How the rolling over method works with known lives

The example below is based on one historical example to demonstrate the general method.[1] The tables duplicate those from Parker (2009), which were originally sourced from Deakin (2002), but are adjusted for the 8% discount rate now used. They show the undiscounted capital cost and routine and periodic maintenance costs, and that the NPV cost of the 25-year option is less than that of the 40-year option.

Table 1 Cashflow profile of 25-year 160mm structural asphalt pavement (2002 dollars, 8% discount rate)

Description	**Amount**	**SPPWF$^{(1)}$/ USPWF$^{(2)}$**	**Discounted cost**
Cost works ($80/m^2)	$80,000	0.926	$ 74,074
Cost annual maintenance year 1			$500
Cost annual maintenance following works (years 2–25)	$250	10.134	$2,533
Periodic maintenance costs			
year 8	$20,000	0.5403	$10,805
year 16	$20,000	0.2919	$5,838
year 24	$5,000	0.1577	$788
Total periodic maintenance costs			$17,432
Total cost:			**$ 94,539**

Notes: (1) Single payment present worth factor
(2) Uniform series present worth factor — note this factor represents 'continuous time' rather than annual lump sums.
(3) Cost per area of 1000m^2

Source: Parker (2009) and NZIER

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[1] We tried to obtain more examples of appraisals of different length lives that we could apply our analysis to, but we were unsuccessful.

Table 2 Cashflow profile of 40-year 190mm structural asphalt pavement (2002 dollars, 8% discount rate)

Description	**Amount**	**SPPWF/ USPWF**	**Discounted cost**
Cost works ($90/m^2)	$90,000	0.926	$83,333
Cost annual maintenance year 1			$500
Cost annual maintenance following works (years 2–40)	$250	11.433	$2,858
Periodic maintenance costs			
year 8	$17,000	0.5403	$9,185
year 16	$17,000	0.2919	$4,962
year 24	$17,000	0.1577	$2,681
year 32	$17,000	0.0852	$1,448
Total periodic maintenance costs			$18,276
Total cost:			**$104,968**

Source: Parker (2009) and NZIER

The simplest way to correct for different time frames is the 'rolling over the shorter project' method. Suppose the road controlling authority builds the 25-year pavement, and in 25 years' time builds another one. The present discounted cost of building such a pavement now is $94,539. As at year 25 the discounted cost of building another one remains $94,539 — if there are no real price changes — but this must be discounted back 25 years to be expressed in present value terms. Doing likewise in year 50 results in:

Present value cost (25 year project rolled over three times) =

$$\$94{,}539 + \frac{\$94{,}539}{(1+0.08)^{25}} + \frac{\$94{,}539}{(1+0.08)^{50}} = \$110{,}359$$

Rolling over the 40-year project twice is close enough to make a valid comparison, as the difference of five years 80 years from now is immaterial at an 8% discount rate[2].

Present value cost (40 year project rolled over twice) =

$$\$104{,}968 + \frac{\$104{,}968}{(1+0.08)^{40}} = \$109{,}799$$

As said earlier, the longer-life project is shown to be economically efficient, with a slight cost advantage of $560 per 1000m^2. Figure 1 demonstrates graphically what is happening with the procedure. The thick black lines show the roll-over points. The apparently cheaper short-life option incurs more frequent capital costs, which over a comparable period of time is shown to be more expensive overall.

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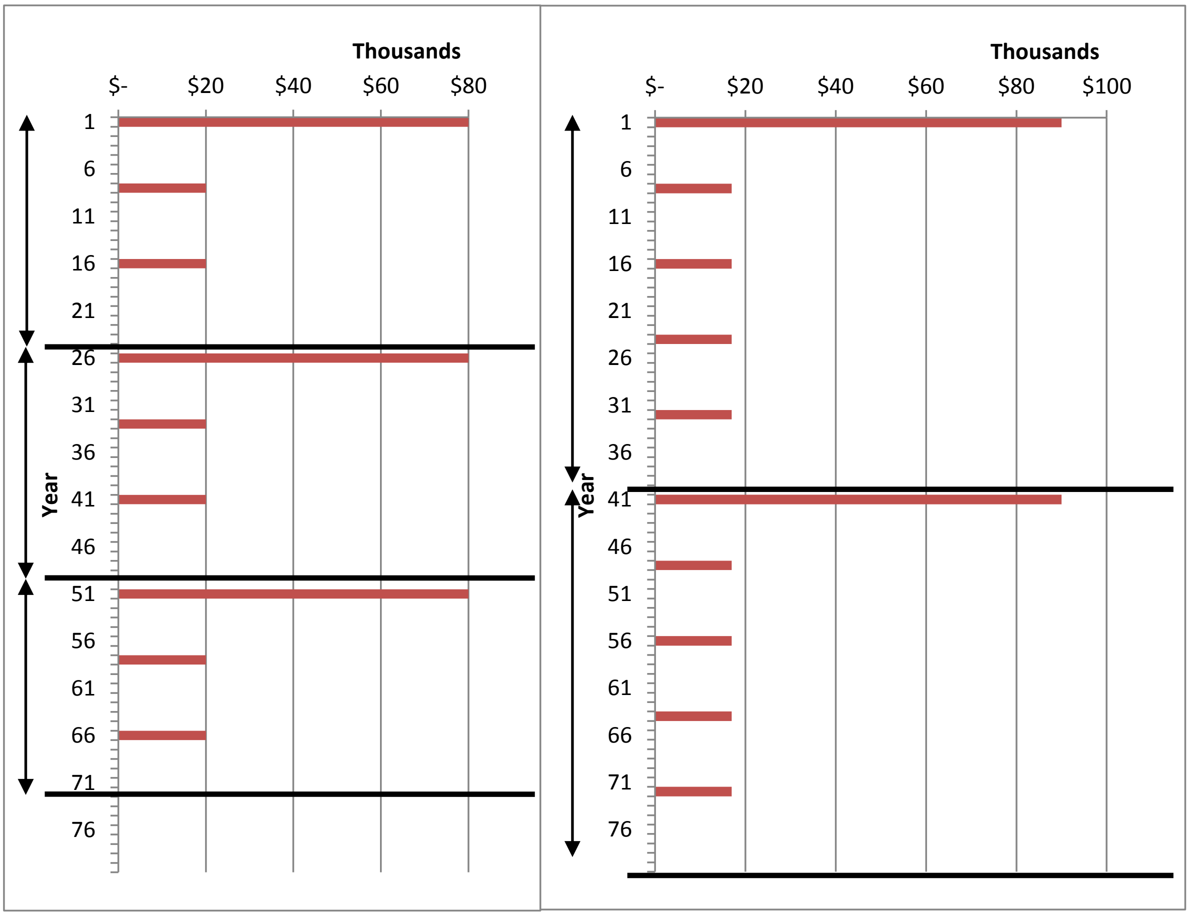
[2] Rolling over the projects in perpetuity leads to marginally higher values of $110,704 and $110,032 for the 25-year and 40-year pavements respectively.

Figure 1 Graphical demonstration of the rolling over project method

LHS is 25-year 160mm structural asphalt pavement. RHS is 40-year 190mm structural asphalt pavement. Capital, annual and periodic maintenance costs for 1000m^2 area, expressed in 2002 (constant-price) dollars.



Source: NZIER

2.3 The rolling over method with uncertain length lives

2.3.1 Pavement early failure is a key risk

A key risk with pavements is early failure. Several factors influence this, including whether the site investigation, design, treatment selection, and construction was up to standard. An abrupt cause is a spike in heavy commercial vehicles (HCVs), say because logging starts in an area. Discussions with RMT members highlight some dramatic incidences of this, including where State Highway 31 had the equivalent of 20 years' of traffic occur in the space of three months because of logging. Another potential cause of early failure is illegal overloading of HCVs.

The risk of pavement failure means alternative options have different and uncertain length lives. Unless analysts take appropriate account of uncertain length lives in appraisals, there is a risk that road controlling authorities spend too many resources over time.

2.3.2 A general formula for the rolling over method

The rolling over method described above is straightforward when the length of life is certain. But what if the length of life is uncertain? For example, some cheaper road pavements may have a higher risk of failing prematurely, whereas some that are more expensive up-front may have a better chance of meeting or exceeding their design lives.

The NZTA considers pavement duration probabilistically in some of its detailed appraisals. But there's scope to apply the rolling over method in those cases.

We could not find in the literature a general formula to apply the rolling over method for projects with different, but uncertain, length lives. So as part of this project we developed the formula below, with our derivation contained in Appendix A. It is like the method applied above, but with two differences: the top line is the *expected* (i.e. probability weighted) present value cost; and the bottom-line represents the project being rolled over in perpetuity with probability-weighted project durations.

Equation 1 Rolling over method with uncertain length lives

$$PV\ cost = \frac{\sum_{i=1}^{I} p_i C_i}{1 - \sum_{i=1}^{I} p_i R^{t_i}}$$

The items in the formula are as follows:

- there are I scenarios of how the pavement may perform, where pavement duration in scenario i is t_i with probability p_i (that sum to 1 across all scenarios)
- the discounted capital, routine maintenance, and periodic maintenance cost for the first 'life' in each scenario is C_i, at the prevailing social discount rate r
- R is the discount factor $1/(1+r)$. If undiscounted real costs grow at a compounding rate g then R can be reinterpreted as $(1+g)/(1+r)$.

2.3.3 The risk of early failure raises costs; an example

Risk can switch priorities

The following example is not a real world example, but one we contrived to demonstrate how an increased risk of pavement failure increases the expected whole of life cost of the pavement.

The examples in Table 1 (25-year design-life) and Table 2 (40-year design-life) above are adjusted, first by making the durable pavement more costly up-front. If the durable pavement cost \$105k initially, rather than \$90k, then it would be rejected under the rolling over method. Its cost is ~\$124k, which is higher than the 25-year pavement cost of ~\$110k over the same discounting period.

Now consider that there is a probability of 0.3 that the thinner pavement will fail at year 5 and probability 0.7 it will last to year 25. The durable pavement is expected to last 40 years with certainty.

Table 3 shows the steps taken to apply Equation 1, which results in a present value expected cost of $127,487. This now exceeds the $124,178 cost of the durable pavement over a comparable discounting period[3].

Table 3 Example of rolling over value of thinner pavement with risk

Description	Item	Scenario *i*=1	Scenario *i*=2	Combined scenarios
Duration	t_i	5	25	
Probability	p_i	0.3	0.7	
PV cost of first life[4]	C_i	$75,055	$94,157	
Present worth factor at last year of life	R^{t_i}	0.6806	0.1460	
Expected PV cost of first life	$\sum p_i C_i$			$88,427 =0.3 * $75,055 + 0.7 * $94,157
Mark-up factor for rolling-over method	$\frac{1}{1-\sum_{i=1}^{I} p_i R^{t_i}}$			1.442 =1/(1–(0.3 * 0.6806 + 0.7 * 0.1460))
Whole of life cost	**PV cost**			**$127,487** = 1.442 * $88,427

Source: NZIER

The larger the risk of early failure, the more costly it is

Figure 2 shows the expected present value cost of a pavement option increases with the probability of early failure. The light grey upward sloping curve generalises onthe example above for different probabilities of early failure. When there is no risk the present value cost is $110k, as per the standard rolling over method. As the risk of failure increases, the thin pavement's cost increases, and becomes inefficient (by exceeding $124k) if the probability of early failure at year 5 exceeds 0.25.

The figure also shows that if early failure is delayed (occurring at 10 years rather than 5) then the thinner pavement is more viable all else equal. The thinner pavement requires a chance of failure in excess of 0.37 before it is more costly.

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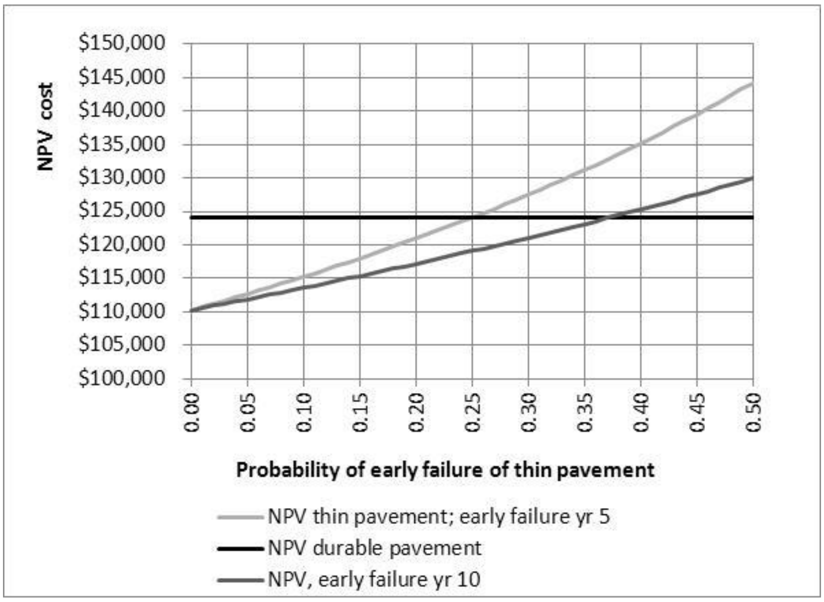
[3] The present value cost for the durable option does not materially differ whether it is extended to 80 years or extended to perpetuity, at an 8% discount rate.

[4] The figure $94,157 is essentially the same as the result in Table 1. There's a small difference of $382 that can be ignored. It is caused by the calculations in Table 1 assuming the annual maintenance cost is incurred continuously over each year (a 'uniform series'), whereas the calculations Table 3 are based on them being annual lump sums (a 'single payment').

$74,055 comes about by considering only the first 5 years in Table 1.

Figure 2 Example of risk of early pavement failure

Durable pavement has cheaper whole of life costs if the chance of failure of thin pavement at year 5 is 0.25 or more.



Source: NZIER

More upfront investment is warranted provided alternative is sufficiently risky

A key question concerning decision makers is whether to spend more up-front to reduce risk and improve whole of life value for money. Figure 3 below continues the above example showing what chance of early failure in the cheaper option is required to warrant spending between 14% to 40% more initially ($91k–$112k versus $80k).[5] If the chance of thin pavement failure at year 5 is 0.30 or more, then spending up to 36% more is economically justified.

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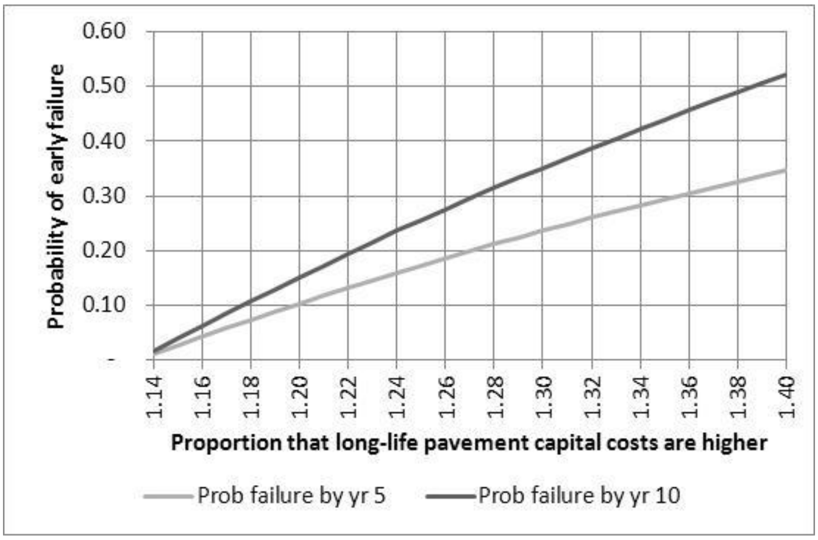
[5] If the durable pavement were up to 13% more costly in year 1 only it is present value cost minimising under the standard rolling over method.

Figure 3 Example of break-even risk of failure

The higher the risk of failure in the thin pavement option, the more that can be justified to make it stronger.



Source: NZIER

The second curve in Figure 3 shows that it is not just a matter of the chance of early failure, but *when* it would fail that contributes to how much more can be justified spending initially. If failure of the cheaper pavement can be delayed, then its economic viability increases, all else equal. In this example, if thin pavement failure means failing at year 10 and the chance of failure is 0.30 or more, then spending up to 27% more on the durable pavement is economically justified.

A fuller analysis would consider a range of scenarios of when each pavement option would expire relative to their design lives, each with a respective probability.

2.3.4 Getting more good data on pavement duration is important

The probability distribution over multiple scenarios of a pavement's duration should be carefully considered. It should have close regard to the frequency of pavement failure in similar conditions elsewhere, and take account of local circumstances, such as the chance that the travel patterns of HCVs will change materially for whatever reason.

Discussions with the RMT indicate that road controlling authorities can do much better at reporting quality data on actual pavement lives versus design lives. NZTA could encourage authorities to be better at collating and reporting data by restricting access to the more flexible appraisal technique proposed here to only authorities that apply it on a 'sufficiently informed basis'.

2.4 Where 'quasi-option value' fits

There is an additional benefit from providing decision makers with some flexibility as to how to manage the road. There are two types of flexibility relevant here:

i. Avoiding premature commitment and getting locked into a technology that is inferior (important if pavement technologies are progressing at pace)

ii. Providing decision makers with more leeway to let extra heavy vehicles use it if needs be.

The first source of flexibility would tend to favour under-providing on durability to avoid costly ‘legacy’ regrets. The second tends to favour over-supplying capacity and/or strength. These are considerations that can apply in addition to the rolling over method described in this report.

3. Including ‘top-line’ analysis too

3.1 What’s the potential problem?

NZ maintenance CBAs often have a heavy focus on the bottom-line only

The appraisal of maintenance-related works in New Zealand often focuses on whether one approach is cheaper in PV terms than another. The procedures in the EEM and the sample CBAs we obtained reflect a strong focus on the bottom-line only.

This broadly makes sense when the question is how to maintain a given service standard of an asset. But appraisals of actions relating to maintenance may need to have a broader perspective if:

- the maintenance work itself directly affects the utility (wellbeing) of road users and neighbours (eg disruption)
- a given maintenance intervention provides an opportunity to change (improve or degrade) the quality of service the asset provides (eg laying down a less noisy pavement)
- maintenance interventions, or even the original capital works, influence the frequency of future interventions and associated user disruptions (eg lay an incrementally thicker layer of pavement and increase the expected time for the next intervention).

The purpose of maintenance in itself is not to increase user utility. But if alternative maintenance options affect users’ utility as a by-product in different ways, then it should be taken into account.

Authorities try to avoid major maintenance disruptions when it matters

Discussions with RMT members highlight that arterial roads in Auckland are now being built with more durable pavements because they are so highly trafficked that maintenance disruptions would be too detrimental. The trade-off is that stronger pavements are more costly up front, implying fewer investments elsewhere.

But how much should be spent to avoid disruption?

Getting more general social costs and benefits into pavement and maintenance appraisals on a proper basis will help to ensure/demonstrate value for money.

Fit for purpose CBAs can help to decide when the detriments that stronger pavements avoid warrants their extra cost. For instance, when is a road ‘highly trafficked enough’?

A tweak to the BCR formula makes it more useful for maintenance appraisals

In our previous NZTA-funded research (Parker 2009) we found problems with the BCR formula. We researched a version that worked better for maintenance-related initiatives. The alternative BCR treats future cost savings as benefits on the top-line, but scales them up to reflect the tightness of budget constraints. Being able to express all projects in a BCR format allows for including all forms of net benefits to be consistently included in appraisals.

This may be useful if alternative pavements have quite different road user performance (e.g. smoothness, skid resistance, quietness), and/or if avoiding maintenance disruption was particularly beneficial. This approach also reduces the risk of including user benefits on a like basis as cost reductions, which is of questionable appropriateness when budgets are constrained.

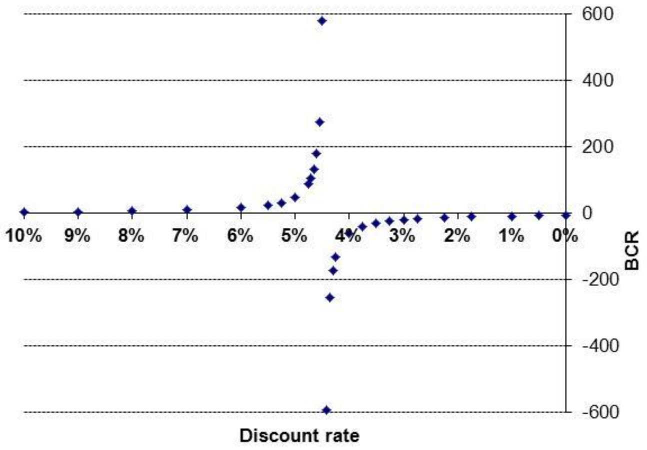
3.1.2 The problem with the current BCR

BCRs are sometimes unstable

Our earlier research found that the BCRs of projects with a major maintenance component went haywire depending on how close the projects were to being economically viable on a bottom-line only basis.

Figure 4 provides a graphical illustration, where the combination of future cost savings and capital costs meant that the project had a zero present value cost at a discount rate of 4.5%, and negative costs at lower discount rates.[6]

Figure 4 Typical seal extension BCR as discount rate reduced
Operating costs are in the denominator



Source: Parker (2009)

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[6] In practice a BCR of 99 is assigned to projects with BCRs that are negative or exceed +99. However, this doesn't change the general point here that BCRs become misleadingly large when costs and cost-savings govern the appraisal and the project is close to being viable.

Currently, future cost savings appear on the bottom-line

The economic efficiency problem NZTA faces is how to maximise net benefits from the funds it has available. This gives rise to the current BCR formula as follows, which is used for expenditure rationing:

Equation 2 The current BCR formula

$$\frac{\textit{Present value of benefits less disbenefits to users}}{\textit{Present value of costs less cost savings to government}} = \frac{B}{IC + OC}$$

where:

- *B* = the present value of benefits less detriment to users
- *IC* = the present value of investment costs
- *OC* = the present value of operating and maintenance costs.

The current BCR formula makes decision making harder, and perhaps reinforces a bottom-line only focus

The magnitude and comparability of BCRs is potentially undermined for some major classes of maintenance works, such as pavement smoothing and preventative maintenance. This risks:

- making the activity classes the wrong size
- making the wrong trade-offs against other non-economic measures, and so allocating funds within the activity class inefficiently; and
- BCRs losing influence because of suspicion they are not consistent, informative and intuitive.

These features of BCRs may make it harder to include user utility in maintenance activities, and contribute to why a cost-minimising basis only is used.

3.2 How the alternative BCR formula works

3.2.1 Description of the alternative BCR formula

The Australian Transport Council National Guidelines (ATC 2006) proposes the following formulation for the BCR. As well as treating cost savings as a benefit, it takes account of the fact that when budgets are constrained then $1 of cost corresponds to more than $1 of benefit.

Equation 3 The alternative BCR formula proposed

$$\frac{\begin{array}{c}\textit{Present value of benefits less disbenefits to users, less operating}\\ \textit{costs to government factored by the assumed future marginal BCR}\end{array}}{\textit{Present value of investment costs to government}} = \frac{B - \mu \cdot OC}{IC}$$

where:

- *B* = the present value of benefits less detriment to users
- *IC* = the present value of investment costs
- *OC* = the present value of operating and maintenance costs.

- μ = the assumed future marginal BCR, the factor by which operating and maintenance costs are multiplied to reflect the opportunity cost of funds in the future.

This is the form the BCR should take if it is used to ration constrained capital; strip out all non-capital items from the denominator.

3.2.2 The role of the mark-up factor in the BCR

Budget constraints increase the value of each dollar of transport funds

When budgets are constrained, a cost saving of, say, $100k is worth more than it seems. If the $100k saved funds a project with a BCR of, say, 4 then society gains by a net $300k ($400k of benefits less the $100k cost).

The mark-up factor for the cost savings, μ, is equal to the expected BCR of the borderline unfunded project, otherwise known as the marginal project. As a general rule of thumb the EEM uses a target incremental BCR 4.0 for certain types of appraisals (page A12-4), which is perhaps ok to use in this context. This mark-up factor is called many things, including: ‘uplift factor’, ‘marginal BCR’, ‘cut-off BCR’, or ‘shadow price of funds’.

The mark-up factor on cost savings has the following properties:

- the tighter the budget constraint, the higher the mark-up factor
- if there is no budget constraint, the mark-up factor is 1, and can be ignored
- it effectively reduces the importance of benefits relative to cost savings.

How much to factor future costs/cost savings by is uncertain

The NZTA’s Investment and Revenue Strategy trades off the BCRs of projects against other factors, such as ‘Strategic Fit’ (which is basically how the project aligns with the objectives in the Government Policy Statement). No BCR cut-off is applied in practice, and large ‘strategically important’ projects usually have low BCRs.

Does this make the idea of a mark-up factor, as proposed here, academic?

The issue stands: society gains more by $1 of cost saving than by $1 of benefit

A lack of precision shouldn’t unduly obscure the broad issue. Budgets are tighter than ever. We understand that BCRs now have a larger influence for discretionary funding decisions than in previous years.

The Roads of National Significance are taking the lion’s share of funding, and it is granted that they (and other major projects) do not have relatively strong BCRs. However this is a red herring. Forthcoming NZIER research indicates that major transport strategies that induce land use change are likely to have a completely different economic efficiency story than what the current BCRs indicate. The ‘Strategic Fit’ criterion could be regarded as an attempt to address the shortcoming of current economic appraisal methodologies.

A mark-up factor on future costs/cost-saving does not constitute double-counting

Claiming the benefits of a future project in the BCR of the earlier project raises a question of double-counting. Double-counting benefits is certainly a potential concern when projects are related (i.e. a package of projects) — the concern being that the first project appears unduly beneficial and is funded on a false basis.

This is not the case when projects are only related because they are funded by the same 'activity class'. The BCR of the subsequent project is unaffected by the former going ahead, and so its net-benefits are not misrepresented. The BCR of the earlier project reflects additional wider opportunity costs (or cost savings) the project causes when budgets are constrained.[7] If we were to not apply a mark-up to the costs on the top line of the alternative BCR then we would be forgetting the fact that future budgets are constrained: projects that impose more costs in future would be unduly prioritised ahead of those that save funds.

3.2.3 Example applications

Road renewal projects such as preventative maintenance, pavement rehabilitation, drainage renewals, and associated improvements (seal widening) are based on a PV cost-minimisation basis, as per the EEM's SP1 (simplified procedure). The EEM indicates that 'the preferred option is justified if the PV cost saving is positive'.

A PV cost-minimising requirement can be expressed as a BCR

Suppose a road renewal project is cost effective. Then relative to a business as usual (BAU) counterfactual the sum of investment costs and operating cost savings is less than zero ($IC + OC < 0$, where the term OC is negative). The project is then regarded as the 'do-minimum' (provided it ensures a minimum acceptable level of service).

However, to demonstrate the robustness of the alternative BCR formulation when projects are at or near cost-breakeven this project can be expressed as a BCR that exceeds the required cut-off as follows:

$$IC + OC < 0$$

$$\Rightarrow \mu IC + \mu OC < 0$$

$$\Rightarrow \frac{-\mu OC}{IC} > \mu$$

For instance, if investment costs are \$150k and operating costs are –\$225k relative to the do-minimum, the NPV is –\$75k. If the cut-off BCR is 4, then this project's BCR is 6 (=900/150, in thousands) (assuming the BAU is the counterfactual).

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[7] The alternative BCR recommended here would lead to the same decisions as the current BCR if a BCR cut-off was rigidly applied, because in that case they are algebraically equivalent. That is, a mark-up factor greater than one in the top line of the alternative BCR formula doesn't unduly (i.e. via double counting) advantage the project.

Any cost-minimising assessment can instead be expressed as a BCR maximising assessment

Cost saving projects (that don't breach minimum standards) can be regarded as always having BCRs that exceed any cut-off ratio provided that the cut-off is the same over the appraisal period (and there are no net-negative benefits).

The alternative formula corrects exaggerated BCRs

Consider a seal extension project that has capital costs of \$90k, user benefits of \$140k, and cost savings of \$85k. Its typical BCR is 28 (=140/5), whereas if the cut-off was 4 then its alternative BCR is 5.3 (=(140+4*85)/90).

The latter BCR figure of 5.3 is arguably of a more informative and useful kind than the exaggerated figure of 28 if the BCR is just one part of a multi-criteria decision framework (such as the 'Investment and Revenue Strategy' that the NZTA uses).

3.3 Applying general social costs and benefits to the alternative BCR

Benefits and costs to road users include maintenance disruption/delay and pavements' performance relating to safety, vehicle operating costs (VOC), and in-vehicle noise. Wider (non-traveller) benefits and costs relating to roads and pavements include vehicle noise and crash risk to people and property, as well as disruption from maintenance activities.

Disruption avoidance benefits are sometimes included in overseas appraisals, but specifics are lacking

We undertook a literature search for maintenance appraisals in New Zealand and overseas that included avoided detriment from maintenance disruption. We could not find specific examples of disruption costs that would allow us to apply to New Zealand appraisals, even as 'what if' analyses. Geara (2008), USDoT (2002), and BTCE (1997) describe that some appraisals take it into account, but no standardised approach is evident. Decicorp (1996) argued that the limited use of continuously reinforced concrete pavements in Australia in part reflected the exclusion of maintenance-induced disruption costs from lifecycle cost analyses.

We suggest combining the 'rolling over method', the alternative BCR formula, and a cost for maintenance disruption

The rolling over method in Equation 1 on page 6 also applies BCRs[8], as per below:

Equation 4 Rolling over method with uncertain length lives

$$BCR = \frac{\sum_{i=1}^{I} p_i BCR_i}{1 - \sum_{i=1}^{I} p_i R^{t_i}}$$

Using the alternative BCR formula proposed allows traditionally PV cost-minimising projects to be expressed as BCRs and to include a cost per vehicle delayed.

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[8] One thing to be careful of is that benefits usually grow over a project's life in line with traffic volumes. The proposed rolling over method formula can cope with this, but works best when this growth occurs geometrically (like compound interest) rather than linearly.

The maintenance cost impacts may differ significantly by project, depending on the steps taken and costs incurred to mitigate impacts. Transport modelling is too costly to apply routinely, but some scenario modelling may give indicative estimates that can be used in appraisals.

Alternatively, analysts could ‘back-calculate’ the value per vehicle required to make the more durable (or less risky) pavement efficient relative to the base case option and compare the result to the scenario modelling results to check plausibility.

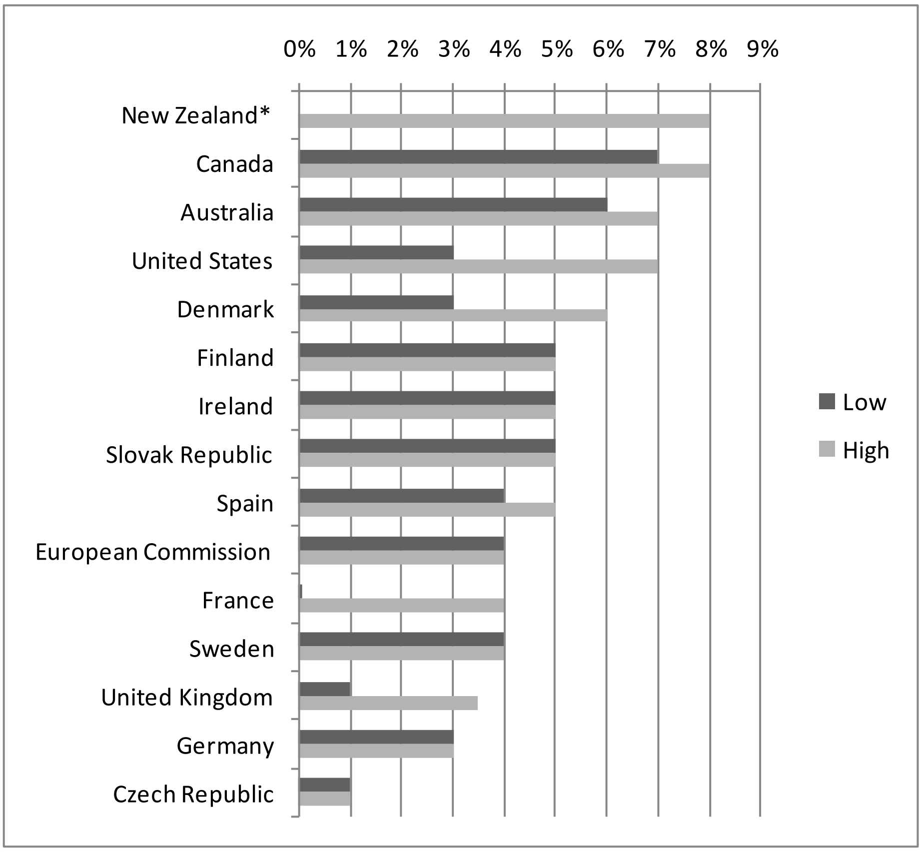
4. Does the discount rate matter?

4.1 New Zealand uses a high social discount rate

New Zealand's social discount rate is relatively high compared to overseas

As Figure 5 shows, New Zealand uses a very high social discount rate relative to many other developed nations we compete against. There are plausible arguments why the value of 8% real that is used is appropriate: the private sector earns 8%, and thus so should the public sector. But the arguments contained in Parker (2011a, a report for Auckland Council, and 2011b, a public-good Insight article) are that the value used is much too high.

Figure 5 Comparison to international approaches
Social discount rates (real)



Note: * = 8% is the required social discount rate for infrastructure, the focus of this report

Source: NZIER (2011a)

4.2 The original source of NZ's high discount rate

New Zealand's current policy is founded on a historical misunderstanding of the purpose of the social discount rate

We very recently obtained the Treasury's original 1971 papers on the setting of the 10% rate. The NZIER provided key advice to the Treasury (NZIER 1971), making essentially the same argument as we made for Auckland Council this year:

- that New Zealand applies a social rate of time preference (which is lower than the return the private sector earns)
- that if one is concerned about displacing private sector investment that this is treated as a dollar cost item in the appraisal rather than by lifting the discount rate
- that cut-off BCRs are used to ration investment given that not all economically viable projects can be funded.

That is, there are three distinct issues of time preference, wider costs/benefits, and capital rationing/budget-setting that should be separately addressed because they are very different things.

The team of Treasury officials tasked with reviewing the various arguments tentatively agreed with the NZIER's recommended approach.

However, B. Tyler, the Assistant Secretary to the Treasury, argued that all three of these issues could be addressed by using the one high discount rate; in fact, that's what Tyler thought the discount rate was exactly for. Using a discount rate that is lower than the rate the private sector earned would lead to too large a public sector (Treasury 1971):

> *It [the social rate of time preference] would seriously reduce such degree of rationality as we have been able to introduce into Government investment decision making and would point the way to a marked and quite unjustified expansion of the public sector.*

Perhaps in 1971 there was a view that cost-benefit analysis was to govern what was invested and what was not, and that anything with a BCR bigger than one *must* be funded. However, CBA is used as a rationing device, and although it will influence the size of government budgets it certainly does not determine them. After all there are, and have always been, a great deal of unfunded transport projects with BCRs larger than one.

The philosophy that underpins New Zealand's current social discount rate policy is unchanged since 1971 (although the specific value decreased from 10% to 8% in 2008). It does not appear to be grounded in robust economic theory.

4.3 The effect of the discount rate on appraisals

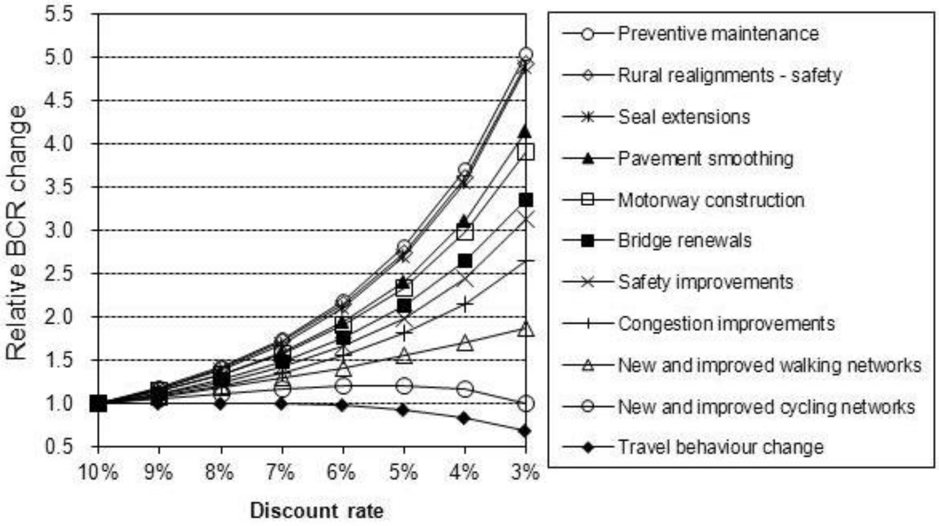
Maintenance-related works heavily affected by the discount rate

The NZTA-funded research on the effects of the discount rate on transport priorities (Parker 2009) found that the discount rate probably matters most to maintenance-related works. Although the BCRs of the largest and most expensive capital works projects can increase substantially, investment in reducing future maintenance costs will arguably always be the first cab off the ranks.

Regardless of how high the cut-off BCR gets following a reduction in the social discount rate used, cost-saving maintenance works will have BCRs that exceed the cut-off. (This is assuming the cut-off is uniform over time, and the works don't have omitted disbenefits.) Figure 6 demonstrates this effect on relative priorities, where projects that save costs in future have the largest relative improvement in economic performance.

Figure 6 Effect of the discount rate

80-year appraisal period for long-lasting infrastructure, and tight budget constraints



Source: Parker (2009)

4.4 The effect on long-term expenditures

A higher discount rate leads to building roads to a lower standard of durability, because the distant benefits that arise are too small in present value terms. This is not in itself a problem; there is only a problem if we are using the wrong discount rate. If it is too high we under invest in durability; if it is too low we over invest.

The arguments summarised above are that we use too high a discount rate. Over time this will lead to more expenditure to maintain the road network. One could consider what the costs are over time from using 8% when the correct value is less than this (eg supposing it is 3%, 4% etc).

Analysis like this has not been undertaken in New Zealand, and so it is not possible for us to give an indication of the social cost of using too high a discount rate (if it is deemed to actually be too high). However, this sort of assessment would not in itself indicate the appropriateness of the discount rate used.

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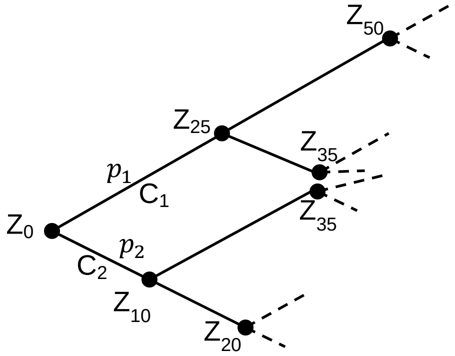
Appendix A Derivation of formula for roll over method with uncertain length lives

Suppose that:

- there are two scenarios, 1 and 2, for when a pavement lasts $t_1=25$ years and $t_2=10$ years respectively
- at the time any pavement is laid the discounted cost for each scenario is C_1 and C_2 for each scenario (incorporating the capital, routine maintenance, and periodic maintenance costs), at the prevailing social discount rate r, and there are no real price changes over time (an assumption that is relaxed later)
- the probability of scenario 1 is p_1, and 2 is p_2, where $p_1 + p_1 = 1$
- the discount factor $\mathrm{R} = 1/(1 + \mathrm{r})$
- let Z_t be the discounted expected cost of the pavement at time t.

Assuming the pavement is laid back-to-back the decision tree is as follows:

Figure 7 Decision tree for roll over method with uncertain length lives



Source: NZIER

In the first year, t=0, with probability p the pavement will cost C_1 dollars in present value terms plus cost Z_{25} discounted back 25 years (which equals $R^{25}Z_{25}$). With probability p_2 the pavement will cost C_2 plus cost Z_{10} discounted back 10 years. This is expressed as:

Equation 5 Rolling over method derivation: the first life

$$Z_0 = p_1(C_1 + R^{25}Z_{25}) + p_2(C_2 + R^{10}Z_{10})$$

The term above contains the terms Z_{25} and Z_{10}, each of which are expressed as:

$$Z_{25} = p_1(C_1 + R^{25}Z_{50}) + p_2(C_2 + R^{10}Z_{35})$$

$$Z_{10} = p_1(C_1 + R^{25}Z_{35}) + p_2(C_2 + R^{10}Z_{20})$$

Substituting these into Equation 5 results in:

$$\begin{aligned} Z_0 = p_1C_1 + p_2C_2 &+ p_1R^{25}\big(p_1(C_1 + R^{25}Z_{50}) + p_2(C_2 + R^{10}Z_{35})\big) \\ &+ p_2R^{10}\big(p_1(C_1 + R^{25}Z_{35}) + p_2(C_2 + R^{10}Z_{20})\big) \end{aligned}$$

Z_0 is a function of Z_{50}, Z_{35}, and Z_{20}, which will all themselves be functions of further future discounted expected costs *ad infinitum*.

The assumption that C1 and C2 don't change over time means all the Z_t are equal; thus let Z_t=Z. This then simplifies to the following:

$$Z_0 = p_1C_1 + p_2C_2 + (p_1R^{25} + p_2R^{10})\big(p_1(C_1 + R^{25}Z) + p_2(C_2 + R^{10}Z)\big)$$

Expanding further yields:

$$\begin{aligned} Z_0 = p_1C_1 + p_2C_2 \\ &+ (p_1R^{25} + p_2R^{10})[p_1C_1 + p_2C_2 \\ &+ (p_1R^{25} + p_2R^{10})[p_1C_1 + p_2C_2 + (p_1R^{25} + p_2R^{10})[p_1C_1 + p_2C_2 \\ &+ (p_1R^{25} + p_2R^{10})[\ldots \end{aligned}$$

Let $p_1C_1 + p_2C_2 = a$, and let $p_1R^{25} + p_2R^{10} = b$. The form of the geometric progression becomes clear in Equation 6.

Equation 6 The geometric progression

$$\begin{aligned} Z_0 &= a + b(a + b(a + b(a + b(a + b(\ldots \\ &= a + ab + ab^2 + ab^3 + ab^4 + \cdots \end{aligned}$$

Using the well-known expression for the sum of a geometric progression (that holds when b<1, which is the case here) results in:

$$Z_0 = \frac{a}{1 - b}$$

Substituting a and b back in again results in Equation 7:

Equation 7 The two-scenario rolling over method formula

$$Z_0 = \frac{p_1C_1 + p_2C_2}{1 - (p_1R^{25} + p_2R^{10})}$$

This formula can be generalised to any number, I, of probabilistic scenarios of when the pavement fails. The present discounted expected cost of the pavement in perpetuity becomes:

Equation 8 The rolling over method with uncertain length lives derived

$$PV\ cost = \frac{\sum_{i=1}^{I} p_iC_i}{1 - \sum_{i=1}^{I} p_iR^{t_i}}$$

If undiscounted costs are expected to increase in real terms over time, then the discount factor R can be reinterpreted as $(1 + g)/(1 + r)$, where g is the compounding (i.e. not linear) growth rate. Growth in undiscounted real costs and benefits within a project life should already be captured in the term C_i by analysts if needs be.