The cost of road maintenance deferral

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PAVEMENT PRESERVATION & RECYCLING SUMMIT
PPRS PARIS 2015
FEBRUARY 22-25

INTRODUCTION

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Three ways to measure cost of underfunding road maintenance

- Maintenance backlog in forecast annual spending needs
  - first year or average over a period of years
    - for comparison with actual or budgeted annual spending
- Benefit cost ratio (BCR) or marginal BCR (MBCR)
    - for comparison with BCRs for capital projects or the cut-off BCR for capital spending
- Equivalent interest rate for deferred maintenance
  - maintenance deferral viewed as borrowing
    - for comparison with the interest rate for government borrowing

CASE STUDY AND MODEL | 2

Case study

- Non-urban parts of the National Network in Victoria
- 1977 kilometres (92% sprayed seal, 8% asphaltic concrete)
- 573 non-contiguous strategic segments of road
- HDM-4 callibrated by ARRB Group using monitored test sites

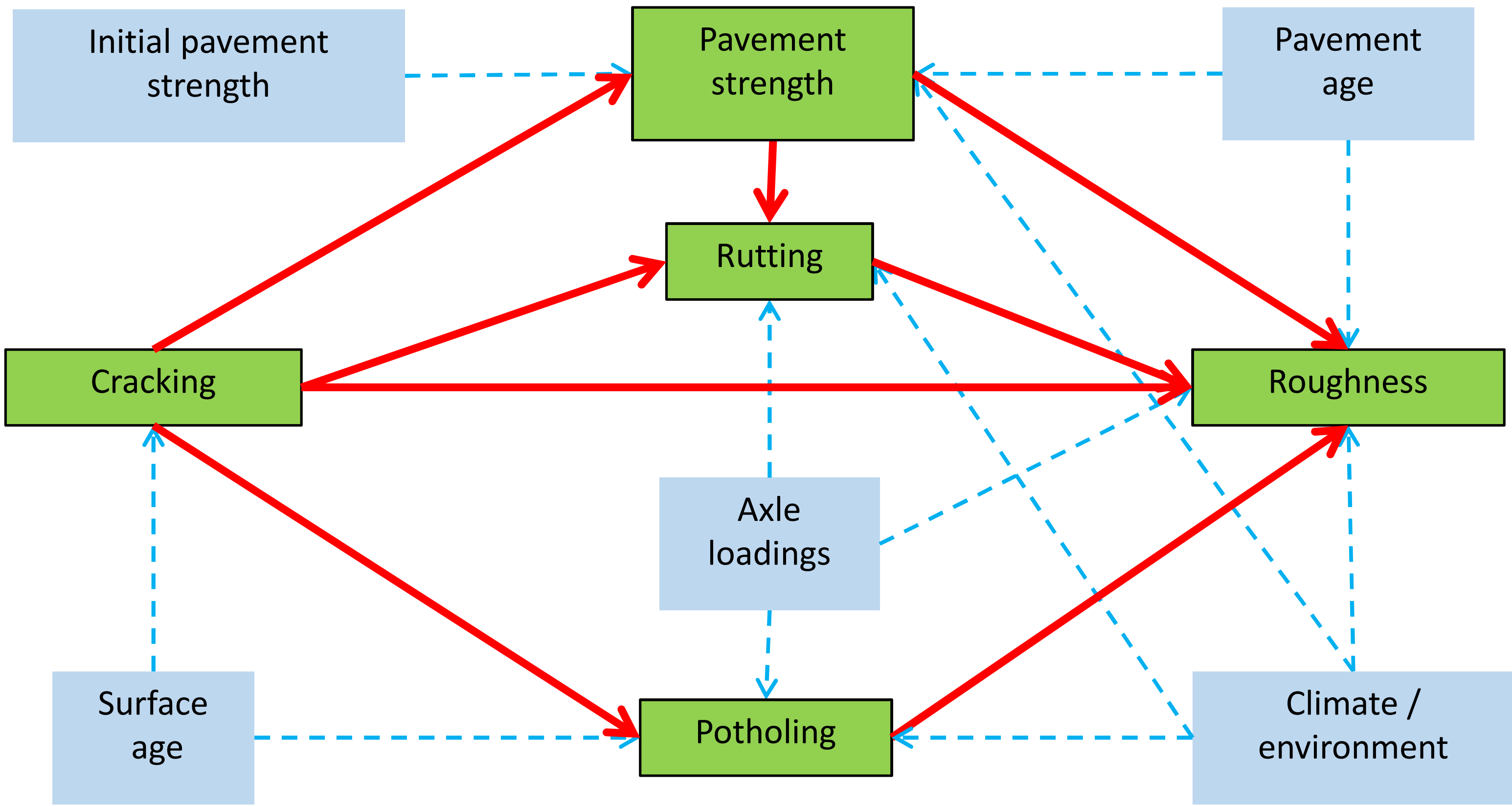
- Same data and calibration coefficients in two models
  - HDM-4, undertaken by ARRB in consultation with VicRoads
  - Spreadsheet model with simplified HDM-4 algorithms by BITRE
    - Results presented here are from BITRE's model except where otherwise indicated.

Pavement model

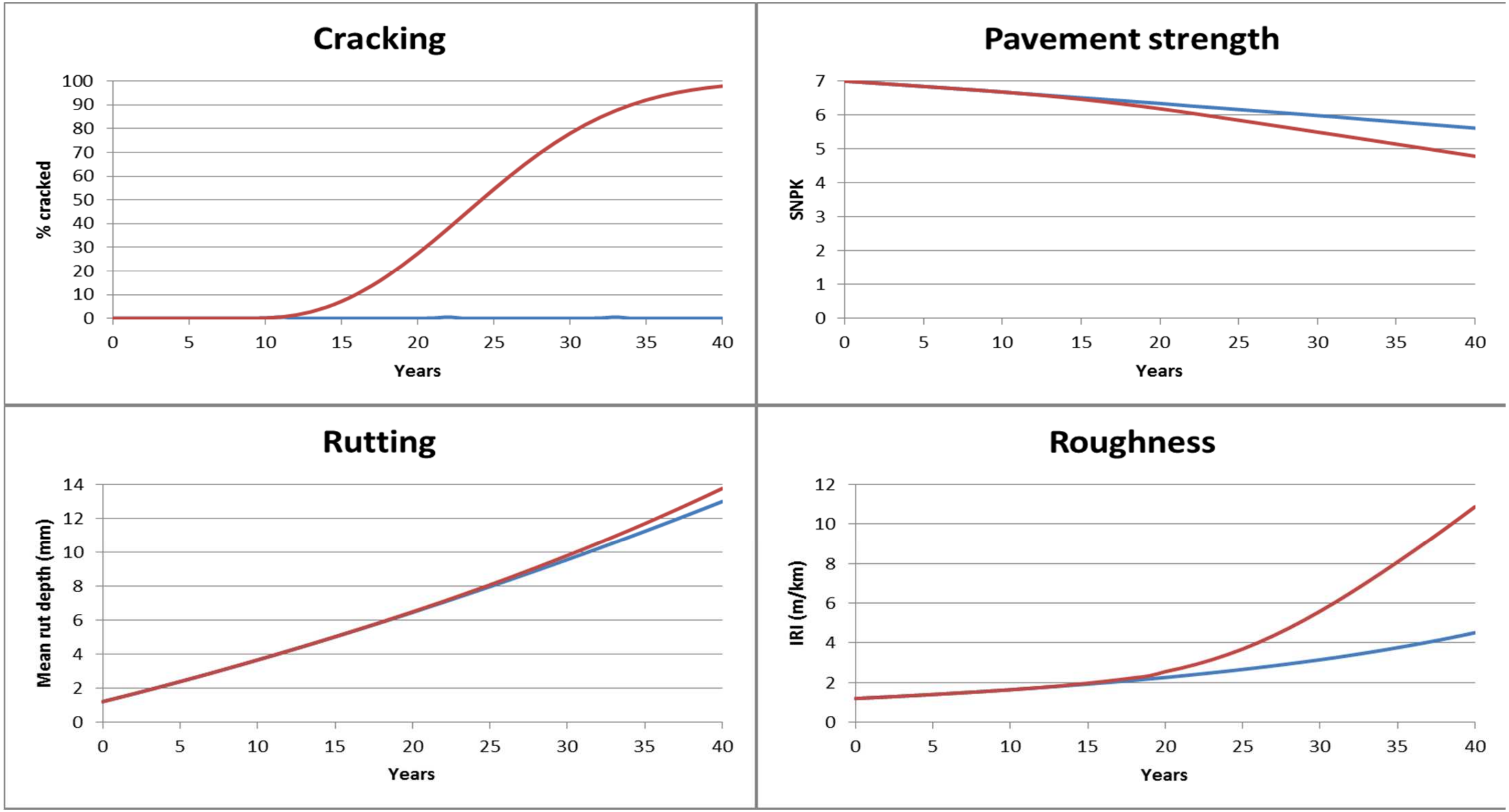
› Periodic maintenance only
  - excludes routine maintenance except for patching potholes

› Main elements
  - deterioration algorithm
  - alternative treatments
  - road user cost relationship
  - technical constraints
  - budget constraints
  - optimisation

Deterioration model: processes and main drivers



Pavement deterioration with and without regular resurfacing: sprayed seal pavement



Treatment types for case study

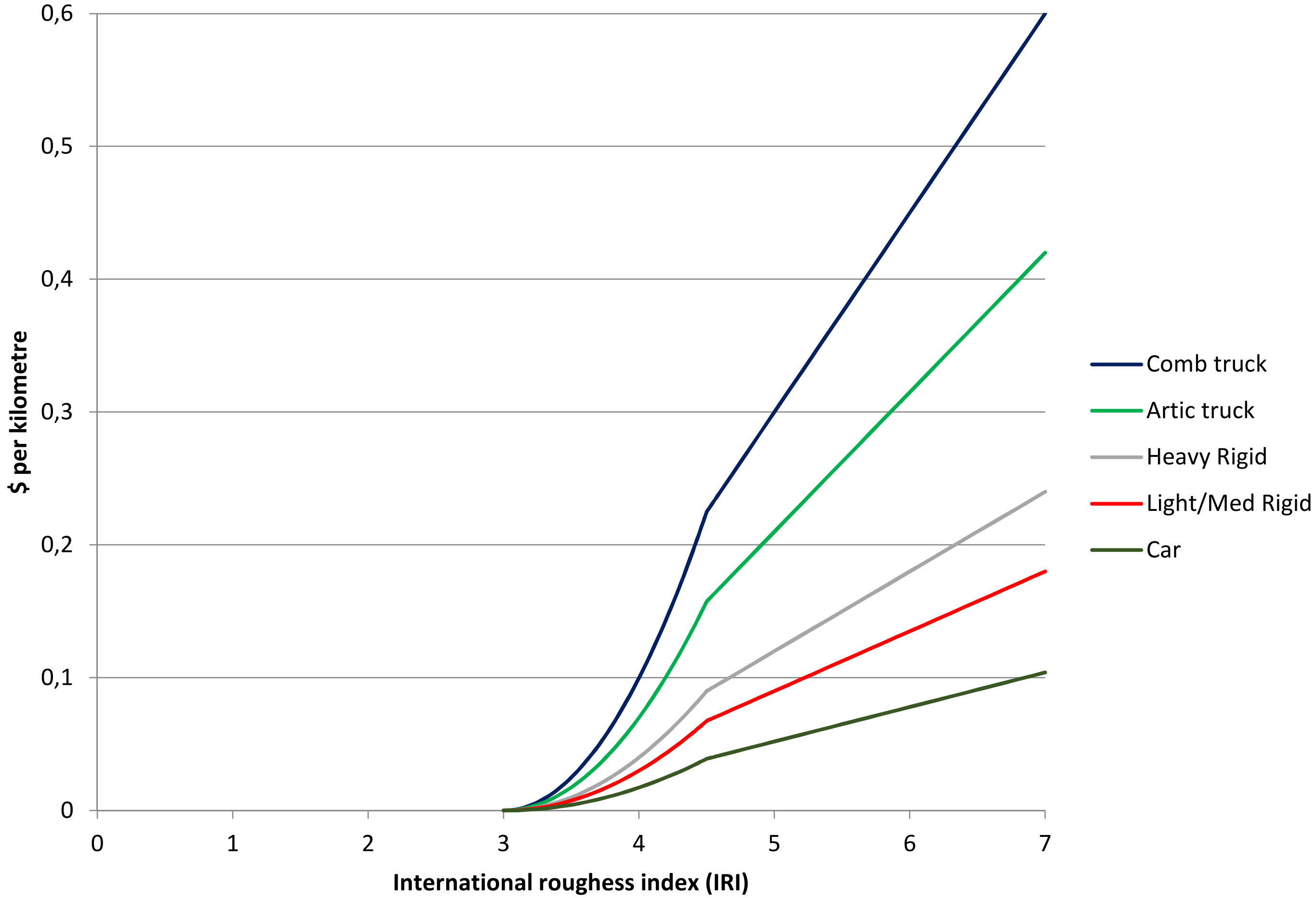
- Resurface (overlay 10mm SS, 20mm AC)
- Resurface with shape correction (overlay 20mm SS, 40mm AC)
- Partial rehabilitation (90% design pavement strength)
- Full rehabilitation (100% design pavement strength)
  - full rehabilitation never selected by the model

- Each treatment type has
  - a cost per square metre
  - reset impacts on surface age, cracking, pavement age, pavement strength, rut depth and roughness.

Key model features

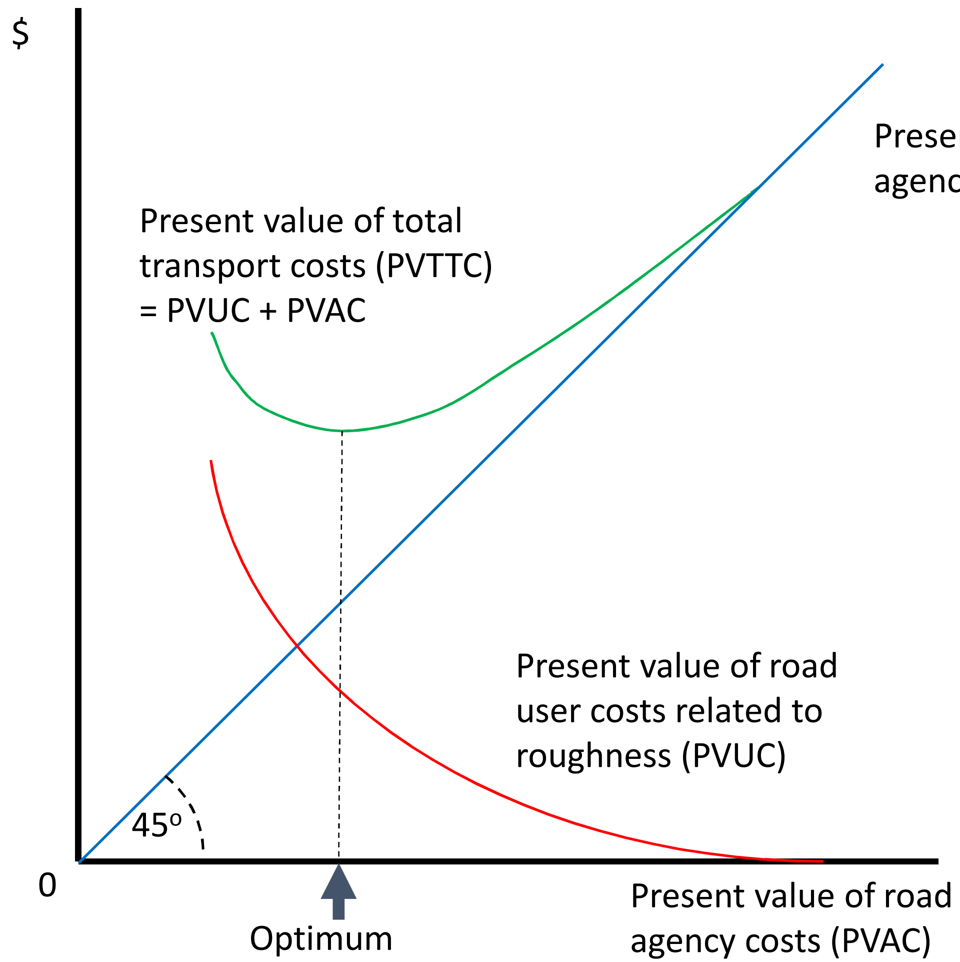
- 40 year analysis period
- 4% discount rate
- Minimises present value of either
  - ‘total transport costs’ (PVTTC) = PVUC + PVAC
  - road agency costs (PVAC) subject to minimum standards constraints
    - PVUC = road user costs
    - PVAC is minus residual value which is asset value minus depreciation
- Tests all feasible combinations and timings of treatments
- Optimisation subject to annual budget constraints performed in separate spreadsheets.

User cost – roughness relationships



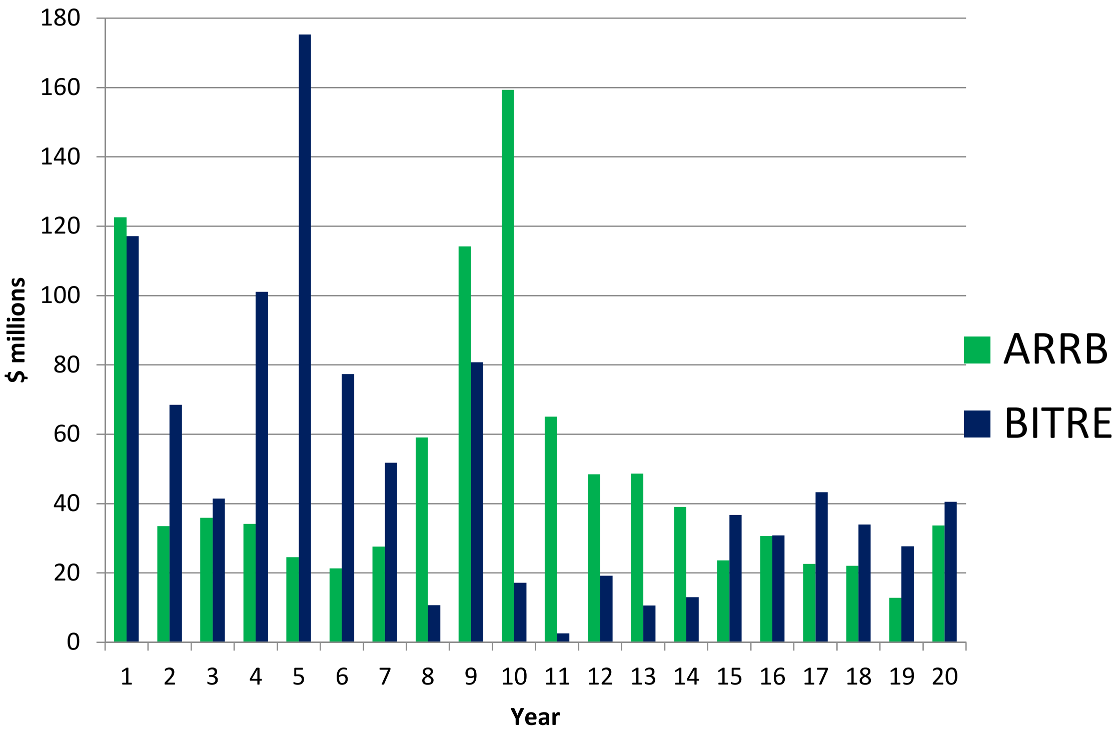
MINIMISING TOTAL TRANSPORT COSTS | 3

Economical optimal maintenance spending



Forecast expenditure needs

- ARRB – HDM-4
  - first year $123m
  - annual average for first ten years: $63m
- BITRE
  - first year $117m
  - annual average for first ten years: $74m
- Actual spending at the time
  - around $15m to $20m per year or 25% of optimal requirement



Some sensitivity analysis

› Annual spending needs highly variable from year to year

› First year value can vary greatly with assumptions

› Ten year average more stable, and hence a better measure

› Discount rate increase from 4% to 7%

- first year spending 38% reduction; ten year average 4% reduction

› Initial pavement strength (SNP_0)

- +20%: first year 5% decrease, ten year average 18% decrease
- –20%: first year 75% increase, ten year average 20% increase

Benefit–cost ratio for individual maintenance treatments

- Difficult to obtain a BCR for an individual maintenance treatment
  - numerous options for treatment types and timings
  - arbitrary base case.

Benefit–cost ratio for maintenance: for a network: definitions

› BCR for a large increase in PVAC

$$BCR = -\frac{\Delta PVUC}{\Delta PVAC}$$

› Marginal BCR for a small increase in spending

- equals one minus the slope of the PVTTC curve

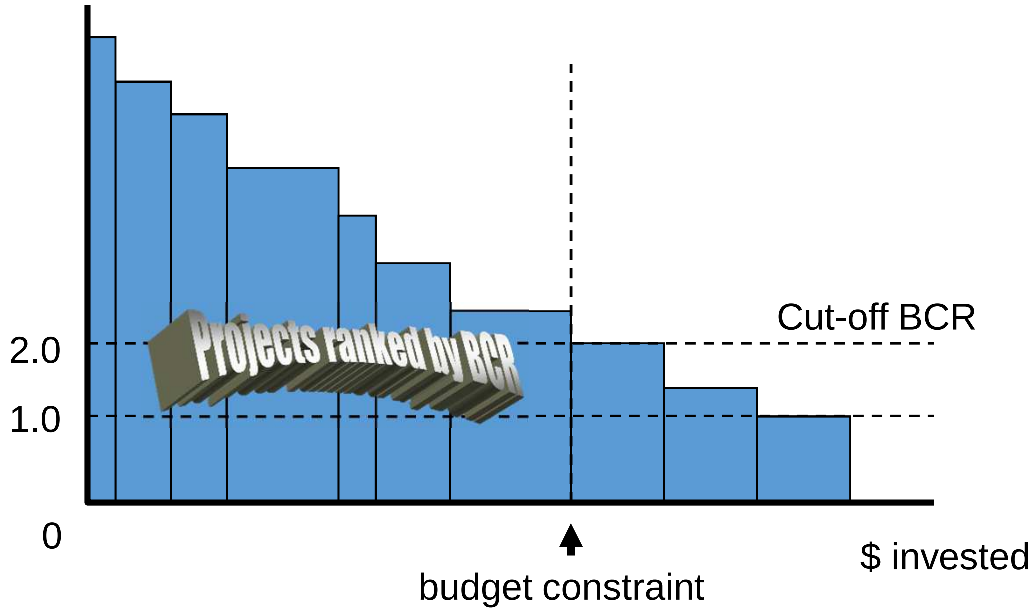
$$MBCR = -\frac{dPVUC}{dPVAC} = 1 - \frac{dPVTTC}{dPVAC}$$

› Example from model setting the MBCR = 3

- estimated expenditure needs reduced: first year by 1%; ten year average by 41%
- PVTTC $114m higher

Optimal split between maintenance and capital spending

- The MBCR for a whole network can show the economic value of shifting funds between the maintenance and capital budgets.
- Comparing the MBCR for maintenance with the cut-off BCR for capital spending:
  - If MBCR = cut-off BCR: funds split is optimal
  - If MBCR > cut-off BCR: gain from shifting funds from capital to maintenance
  - If MBCR < cut-off BCR: gain from shifting funds from maintenance to capital



MBCR with short-term budget constraints

- MBCR as defined previously assumes the budget constraint is a present value
  - Implies the road agency can shift funds through time by borrowing and lending at the discount rate, which is not realistic

- Redefine MBCR as $MBCR \cong \frac{-\Delta PVUC - \Delta PVAC + \Delta PVB}{\Delta PVB}$
  - where ΔPVB is the present value of the annual budget increases
    - ΔPVB is the PV of a series of increases in annual spending over the first few years.
    - ΔPVAC includes ΔPVB, so –ΔPVAC + ΔPVB nets out to the PV of agency costs saved after the budget period
    - Formula reduces to previous simple BCR formula if ΔPVAC = ΔPVB

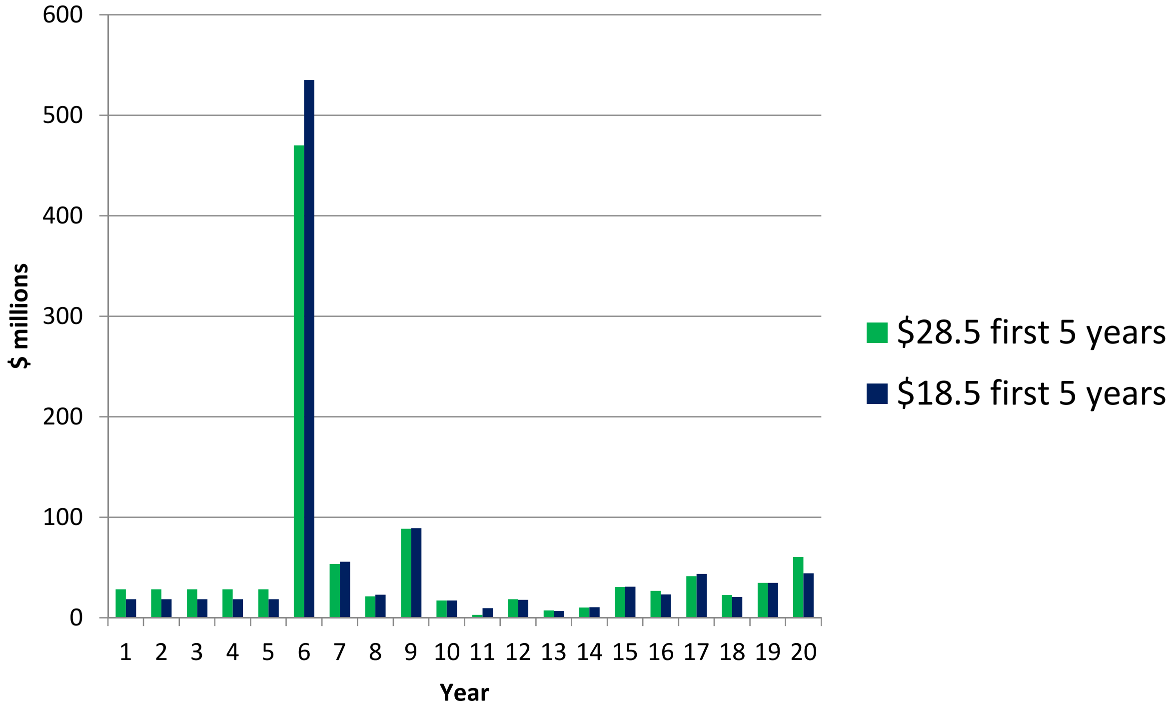
Example of MBCR with short-term budget constraints

- Example from case study: Impose 25% of average annual requirement ($74m × 0.25 = $18.5m) constraint for the first 5 years, then ease to $28.5M. PVAC falls.
  - ΔPVTTC = –$18m
  - ΔPVUC = –$14m   ΔPVAC = –4m   ΔPVB = $44m
  - MBCR = (14 + 4 + 44) / 44 = 62/44 = 1.4

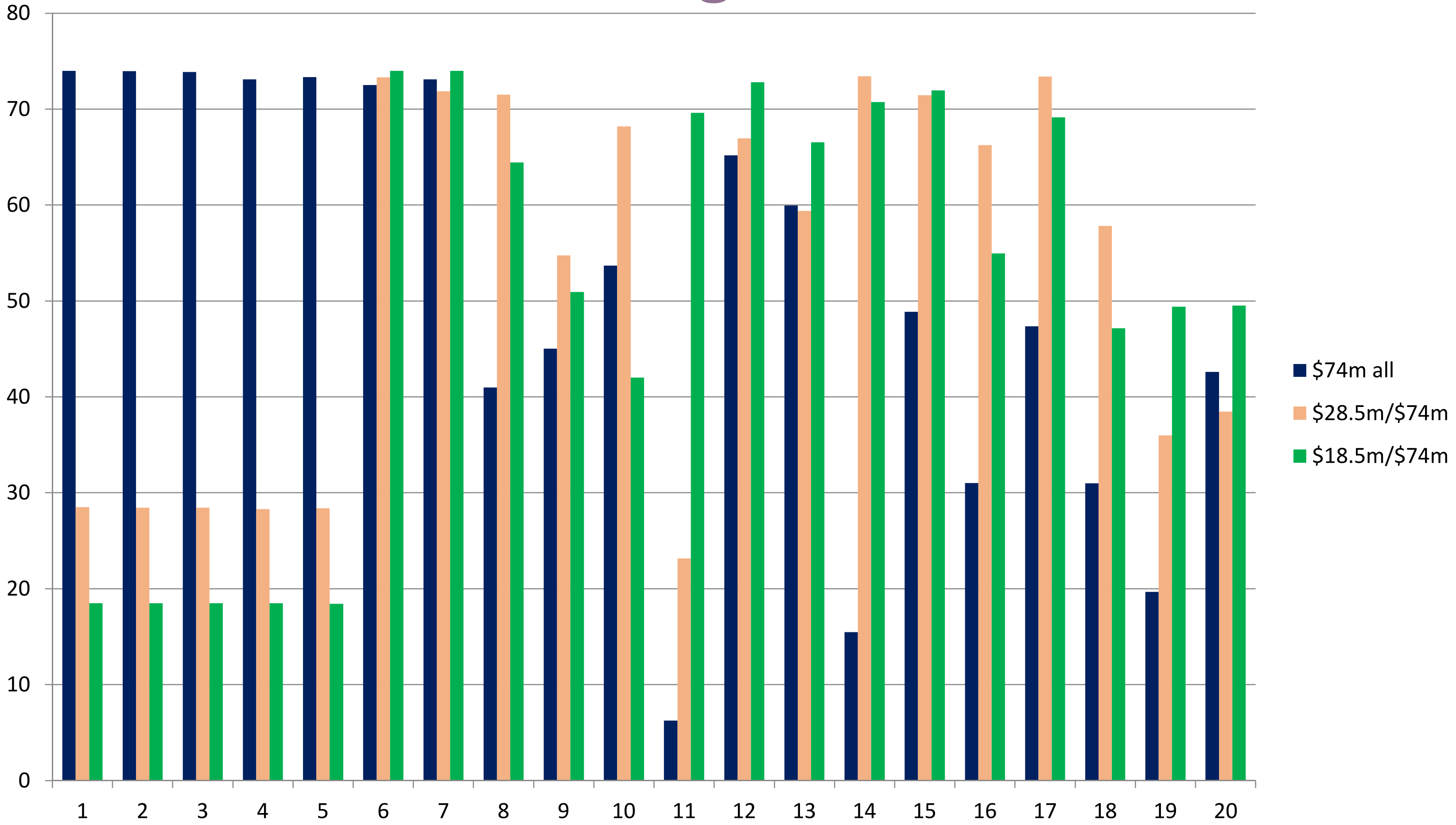
- Why so small?
  - Expenditure unconstrained after year 5, backlog quickly eliminated which is unrealistic.

Optimal expenditure profiles: annual budget constraints for first 5 years only

- Relax constraint from $18.5m to $28.5m
- Huge spike in year 6 as maintenance spending pushed into the future
- More realistic to assume ongoing annual budget constraints



Optimal expenditure profiles: ongoing annual budget constraints



Benefit–cost ratios

- Relax annual constraints for first 5 years from \$18.5m to \$28.5m
  - then \$74m for next 15 years in both cases
    - ΔPVTTC = –\$140m
    - ΔPVUC = –\$106m ΔPVAC = –34m ΔPVB = \$44m
    - MBCR = (106 + 34 + 44) / 44 = 184/44 = 4.2
    - Approximate 'marginal' BCR because relatively small change

- Relax constraints from \$18.5m to \$74m for the first 5 years
  - then \$74m for next 15 years in both cases
    - ΔPVTTC = –\$317m
    - ΔPVUC = –\$316m ΔPVAC = –1m ΔPVB = \$245m
    - BCR = (316 + 1 + 245) / 245 = 563/245 = 2.3

MINIMISING ROAD AGENCY COSTS WITH MINIMUM STANDARDS | 4

Realistic approach for a cash-strapped road agency

- A realistic approach for a cash-strapped road agency is to minimise PVAC subject to minimum standards constraints
  - discounting at the government's borrowing rate
- Assumed minimum acceptable standards
  - Australia Government National Network: boundary between 'mediocre' and 'poor' ride quality standards

Average annual daily traffic	Max permitted roughness (IRI)
0 – 500	6.3
501 – 1500	5.7
1501– 10 000	5.2
> 10 000	4.6

Deferring maintenance as borrowing

- BITRE model, minimising PVAC subject to minimum standards constraints
  - average annual expenditure needs for the first 10 years: $65m per year
  - compared with $74m for minimising PVTTC without constraints
- Constrained scenario holds $18.5m annual spending constraint for as long as possible. Three years only.
- Constraints used to smooth the expenditure profile in subsequent years.

Equivalent interest rate for deferred maintenance (EIRDM)

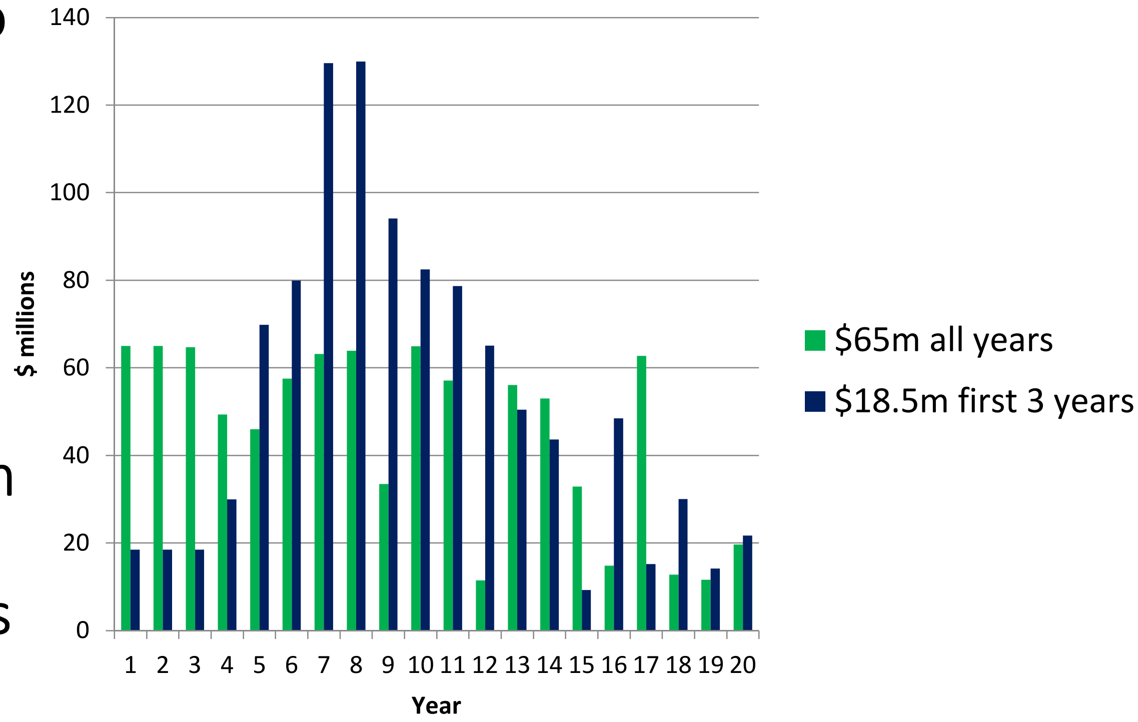
- Short-term budget constraints save money in the short-term but can cost more in the long term
  - The long-term costs can outweigh the short-term gains, even with discounting.
  - Increases PVAC by $96m
    - which is a measure of the cost of maintenance deferral to the government.

- The EIRDM is the internal rate of return for the difference between the cash-flows for the cost minimising and budget constrained spending profiles.

Expenditure profiles: optimal spending and tight short-term spending constraints

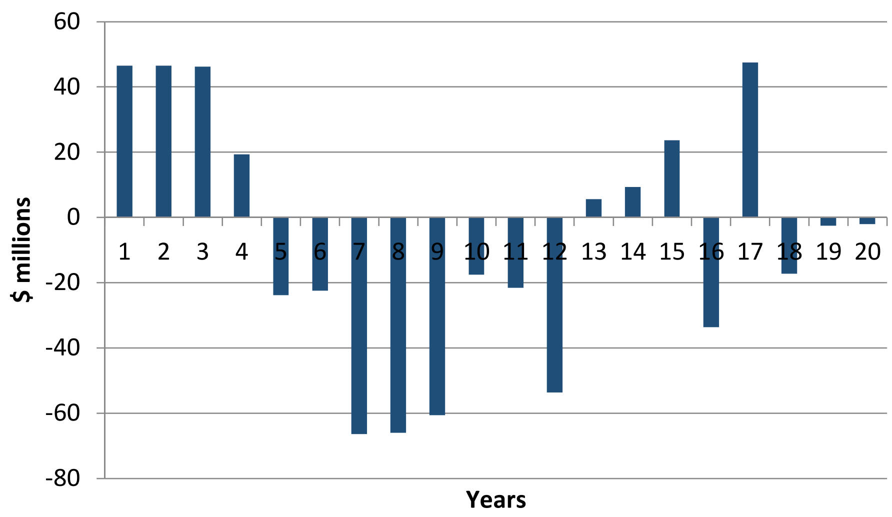
› Minimises PV of road agency costs subject to minimum standards constraints

› Higher expenditures in years 5 to 12 essential to stay above minimum standards after underspending in years 1 to 4



Cash-flow difference between optimal and constrained spending

- Comparing the two scenarios: positive cash flows in years 1 to 4, negative cash flows in years 5 to 12
- EIRDM = 12% (internal rate return for the cash flows)
  - an expensive rate at which to borrow
- There would be a smaller cash outflow in years 5 to 12 if the road agency borrowed for years 1 to 4 and then repaid the loan



LESSONS LEARNED | 5

Lessons learned

- Ways to measure and communicate the cost of deferring maintenance, as presented here.
- Model results can be highly sensitive to assumptions, hence the importance of good data and model calibration.
- Further lessons on modelling and optimisation to be presented in BITRE's forthcoming report.
  - Note: All figures presented here are preliminary. They will be different in the report as the modelling will be reviewed.