REPLACEMENT OF BRIDGES

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VERSION 1.1

EXECUTIVE SUMMARY

A new bridge may be required to replace an existing bridge for:

- Condition reasons (having reached the end of its economic service life) and/ or
- Improved levels of service reasons

The replacement of a bridge for condition reasons must be justified via a 'present value end-of-life' (PVEOL) analysis. This establishes the bridge economic remaining life and hence the timing of replacement with a new bridge to current design standards. In summary the economic analysis is a theoretical exercise that compares the net present value of maintaining the existing bridge and replacement with a "like for like" bridge (providing the same levels of service as the existing bridge), for various remaining life scenarios. The remaining life option with the least cost is the preferred option. The replacement bridge will actually be constructed to current design standards.

The replacement of a bridge for deficient level of service reasons should consider both the economic remaining life of the existing bridge (to establish the 'do-minimum' option) and the BCR for early replacement. This will therefore address both condition and level of service issues.

It is recommended this guidance is read in conjunction with the guidance on *Point of entry for structure renewals* to ensure consistency with the Waka Kotahi business case approach.

Point of entry for structure renewals

INTRODUCTION

As part of their lifecycle, all bridges have an economic end-of-life, whereby their condition deteriorates to the stage where bridge replacement (for condition reasons) is the most economic management option.

Also as bridges age, the level of service provided may become significantly deficient, such as bridge width, load capacity, barrier capacity, etc. Bridge replacement (for level of service reasons) may be the most economic means to achieve such level of service improvements.

Commonly, older bridges are replaced for a combination of condition (approaching end-of-life) and level of service deficiencies.

The Waka Kotahi NZ Transport Agency's Investment Assessment Framework (IAF) describes the requirements for funding of projects such as bridge replacements[1]. The purpose of this memo is to elaborate on those processes.

Note that improvements to existing bridges are frequently undertaken to mitigate deficient levels of service. This memo does not address such cases and is limited to instances where replacement is being considered.

[1] The Investment Assessment Framework applies to activities included in the 2018-2021 National Land Transport Programme. From July 2021, the IAF will be replaced by the Investment Prioritisation Method (IPM), which is being finalised at the time of writing.

BRIDGE REPLACEMENT FOR CONDITION (END-OF-LIFE) REASONS

As bridges near their economic end-of-life, their condition deteriorates and defects requiring significant maintenance or renewal become apparent. At this stage, options for continued maintenance/renewal and bridge replacement need to be addressed and a decision made on the most economic option, based on sound knowledge of the bridge condition, imminent future needs and costs.

The IAF requires the determination of a benefit/cost ratio (BCR) to demonstrate delivery of net positive benefits that exceed the project whole-of-life costs. However, for a bridge being replaced principally for condition based 'end-of-life' reasons, the IAF recognises that a BCR evaluation is not applicable. Instead, the cost-benefit appraisal uses least whole-of-life economic cost. Instead of a priority rating, the bridge replacement is given a present value end-of-life (PVEOL) rating.

The economic service life of a bridge is reached when the net present value (NPV) of constructing a hypothetical replacement (like-for-like) bridge is less than the net present value to continue maintaining the existing bridge and replace with a like-for-like bridge in the future.

For meaningful comparison, the hypothetical like-for-like bridge replacement should have the same levels of service as the existing bridge but be built using modern materials and methods. For example, the like-for-like replacement bridge for an existing 3 x 8m span, single lane (3.5m wide) timber bridge, could be a single 25m span hollow core unit bridge with 3.5m lane width.

It should be noted that the hypothetical bridge design used for costing purposes is to ensure a rational financial analysis is undertaken assuming the same level of service as the existing bridge. In most cases, the actual replacement bridge design will be quite different from the existing bridge (and the hypothetical bridge), in order to meet current design standards. For example, the alignment may be significantly improved, the width increased, and so on.

The PVEOL analysis is essentially an investment decision methodology to demonstrate when investment in maintenance and renewal of an existing bridge should cease and a new bridge be constructed. If it is demonstrated that investment in a new bridge is economically justified, the new bridge design will then be developed in accordance with current requirements, including current standards (levels of service). Any other additional improvements must be justified through a Business Case and incremental BCR analysis.

Bridge 'end-of-life'

Bridge asset management requires that bridge 'end-of-life' (remaining life) be determined in order to identify future funding demands. There are two 'end-of-life' scenarios for bridges:

a) End-of-life (level of service)

b) End-of-life (condition)

End-of-life (level of service) is driven by the need to replace a bridge to achieve an improvement in a deficient level of service such as a single lane bridge with traffic delays or high accident history. The end-of-life is determined from the optimum timing of the improvement as justified through a BCR analysis.

End-of-life (condition) identifies when a bridge should be replaced due to the condition of the bridge. It is driven by the need to replace a bridge when the whole-of-life cost of continued maintenance/renewal exceeds the cost of 'like-for-like' bridge replacement. The PVEOL analysis is a rational process for determining the timing of end-of-life. It is an 'evidence-based' process that requires a thorough knowledge of the bridge condition, the anticipated future condition and future maintenance needs. From this knowledge, maintenance/renewal options for a bridge can be developed. While it is common to base ‘remaining life’ on the ‘expected lIfe’ less the bridge age, as a bridge gets older (say more than about 60 years old or within say 10 years of its likely replacement date) this approach becomes inappropriate. As a bridge nears end-of-life, the condition is usually very well known (the bridge has by this time exposed its weaknesses) and the necessary maintenance interventions at a component level are relatively easy to determine through engineering judgement and/or investigation. The NPV of the different maintenance options (as well as like-for-like bridge replacement) can be used to determine the lowest whole-of-life cost and hence the optimum timing for bridge replacement. It should be noted that such assessments are commonly undertaken informally by experienced practitioners on a day to day basis. But once the forward maintenance/renewal task becomes significant and the remaining life is relatively short, it is usually necessary to document and formally verify the process.

The assessment of maintenance options as a bridge approaches end-of-life, usually involves:

a) Stretching the existing bridge life as much as practicable in order to maintain the level of service but delay the cost of bridge replacement, to get best economic value from the ‘discounted cost’ of the replacement bridge, and

b) Spending as little as possible on maintenance/renewal and managing (controlling or dictating) the maintenance programme to have as much large expenditure as possible happening at once (but as far out in time as possible) – this becomes the date for the new bridge to be in service.

Commonly, one or two maintenance options (including timing of bridge replacement) are developed based on a thorough knowledge of the bridge existing and future maintenance/renewal needs and the effectiveness and life of the maintenance interventions. This usually requires assessment at component level. The options for maintenance and/ or replacement usually develop intuitively based on component by component assessment. Once the options are identified, the NPV analysis is used to identify the least whole-of-life cost.

Present value end-of-life (PVEOL) process

It is recommended that the PVEOL analysis should be undertaken in two stages, in order to minimise costs. The preliminary stage should be a quick assessment using approximate information. A template to assist this process is available. Subject to the preliminary stage indicating that bridge replacement within say 10 years is justified, a detailed stage should follow.

The recommended approach to the PVEOL analysis for bridge replacement for condition reasons, involves the following:

- Well in advance (say up to 10 years) of likely bridge replacement, assess the bridge condition at component level and identify for each component the maintenance/renewal options to allow continued use of the bridge (scope of work, timing, life and cost). This will require a detailed inspection and may require further specific investigations.

- Based on knowledge of all components, identify pragmatic bridge maintenance options that either maximise the remaining life (timing of bridge replacement) or delay the need for high maintenance expenditure (scope of work, timing and cost).

- Calculate the NPV of each maintenance option.

- Identify the configuration and cost of a like-for-like replacement bridge providing the same level of service (ie similar width, live load capacity, alignment, resilience etc) as the existing bridge. The use of modern materials and construction methods are assumed for this step.

- For each maintenance option (and hence timing of bridge replacement), calculate the NPV for the replacement bridge.

- The option with the lowest total NPV for maintenance and bridge replacement is the least whole-of-life cost option and hence the preferred option. This then defines the optimum maintenance/renewal programme and timing for bridge replacement.

- For the least whole-of-life cost option, confirm that the NPV of ongoing maintenance/renewal (beyond the time of proposed bridge replacement) exceeds the NPV of the replacement bridge.

- The planning and design for the new bridge should meet current design standards or standards acceptable to the road controlling authority. If other enhanced design standards or features are desired, then these improvements should be justified through a Business Case supported by a BCR.

BRIDGE REPLACEMENT FOR LEVEL OF SERVICE REASONS

It is not uncommon for older bridges to have significant level of service deficiencies (for example narrow width, load restrictions, barrier deficiencies, accident history due to poor alignment etc). Improvements to the levels of service should consider and compare both improvements to the existing bridge (not addressed in this document) as well as replacement of the bridge, particularly if the economic remaining life of the bridge is relatively short (say less than about 25 years).

The business case for the option of replacement of the bridge for level of service reasons, needs to consider both the existing bridge condition (remaining economic life) and the level of service deficiencies.

By defining the economic remaining life, this establishes the 'do-minimum' option; the least 'whole of life' cost option for the bridge, in effect the timing for bridge replacement ignoring level of service deficiencies. When the bridge is replaced, the levels of service will be to the required standards. Until the bridge is replaced, the deficient levels of service will remain.

The improvement option should therefore consider earlier bridge replacement to achieve the level of service improvements sooner.

The following business case approach is suggested.

a) Undertake a PVEOL analysis as described above. This will identify when the bridge should be replaced based on condition factors. In effect, it identifies the 'do-minimum' option - the least 'whole of life' cost option. This option retains the deficient levels of service until the bridge is replaced with a new bridge.

b) Undertake a BCR analysis for the option of 'Early Replacement of the Bridge' to alleviate the deficient levels of service. Essentially it is an incremental BCR evaluation based on the timing of bridge replacement.

- The benefits are the NPV of the level of service improvements from the time of early bridge replacement (say year 2) until the time of bridge replacement derived from the PVEOL analysis – the 'do-minimum' option.
- The costs are the NPV for early bridge replacement (say year 2) less the discounted cost of bridge replacement at the time derived from the PVEOL analysis, less the cost of maintenance/renewal in the intervening period.

RESOURCES

Template for preliminary PVEOL analysis

A spreadsheet template for use when calculating preliminary PVEOL:

PVEOL analysis report template

Example of PVEOL Analysis

An example of a present value end-of-life analysis:

PVEOL analysis report sample: SH25 Pepe Stream Bridge