Bridge Assessment Guidelines

Version 1.0

Bridge Engineering Section
Technical Standards Branch
Alberta Transportation

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Foreword

These guidelines cover bridge assessments performed on structures managed by Alberta Transportation. These assessments are an important tool in making bridge management decisions and to support programming activities.

Although this document is intended to be thorough, certain cases may arise where specific guidance is not provided or not applicable. Those working on these projects must exercise good engineering judgment in the application of these guidelines.

Any feedback or technical clarification requests relating to this document should be directed to the Director, Bridge Engineering Section, Technical Standards Branch, Alberta Transportation.

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1. Introduction

Bridge Assessments are an important tool in managing provincial highway bridge infrastructure. These studies are used to identify the type, cost, and timing of future actions required to address needs at a bridge site. Identification of these needs is a core part of developing construction and rehabilitation programs for bridges.

The need for an assessment can be triggered by many factors, including inspection results, road improvement plans, safety concerns, and external events (e.g. floods, slides, collisions). In some cases, the required action is fairly obvious, but others require detailed analysis.

This document supersedes 'Best Practice Guideline No. 5 – Bridge Assessments', as referenced in section 10.10.1 of the Alberta Transportation '*Engineering Consulting Guidelines for Highway, Bridge and Water Projects Vol. 1*' (***ECGv1***), which covers consultant requirements for project design and tender document preparation.

1.1 Assessment Types

There are three main categories of assessment study: "Bridge Assessment", "Rehabilitation Assessment", and "Complex Assessment". For the "Bridge Assessment", the department's internal review of the existing structure will indicate that replacement may be economically feasible or that functional improvements should be considered and a more thorough analysis of options is required. The "Bridge Rehabilitation Assessment" is for structures identified because of condition deficiencies as a result of field testing and inspection results and may require rehabilitation or maintenance in the next three to five year period.

The "Complex Bridge Assessment" or related engineering study may be required for situations where a long-term strategy for the structure cannot be determined from the "Bridge Assessment" or the "Bridge Rehabilitation Assessment". This may be the result of a need for a more detailed and comprehensive analysis of a particular aspect of the bridge site. Examples of complex assessments include the need for river protection works, detailed structural analysis, possible crossing relocation, and geotechnical instability. Typically, detailed site-specific requirements will be provided for this type of assessment.

1.2 Relevant Site Data

The following data sources should be examined for data pertinent to the bridge assessment study:

- Existing drawings, files, and reports – a thorough understanding of site constraints (highway, stream) and existing structure inventory should be developed, including a complete history of the structure, highlighting all work done since construction

- Recent BIM Level 1 (and level 1.5) inspection reports – note all items (plus comments) rated less than ‘5’, recent changes in condition ratings and any maintenance recommendations. Consider rate of change in elements over multiple inspections. In some cases, the defect may have been present for a long time, and historic Level 1 inspections should be reviewed to identify the initiation and relative stability of the defect.
- Pertinent BIM Level 2 inspection data and reports – possibly including deck inspection, steel inspection, timber coring, culvert barrel measurements, pier scour survey, and river protection works inspection
- Site inspection – confirm inventory and BIM ratings, note site constraints, collect necessary additional data
- Future plans for the highway that may impact the structure lifecycle strategy

1.3 Life Cycle Strategies

Assessment of bridges will involve developing and analyzing multiple life cycle strategies. A life cycle strategy is a combination of compatible actions taken at certain points in time through the life cycle. These actions may include maintenance, rehabilitation, functional enhancement and/or replacement. The optimum timing for each intervention shall be considered and will be based on the condition of the structure and the expected rate of deterioration.

In all cases, two base strategies will exist. These are “do minimal and replace”, and “do minimal and close”. The “do minimal and replace” option may involve cost effective life extension repair items. The “do minimal and close” option, although generally the least desirable option, is necessary to provide a comparison base case for benefit cost comparisons used in programming. Note that a realistic estimate of predicted replacement/close year is required.

Additional life cycle strategies can be developed for combinations of rehabilitation actions identified to address condition based needs. Typically, these strategies will defer replacement of the structure beyond that of the “do minimal and replace” option. In some cases, distinct alternative actions for the same deficiency may be feasible (e.g. deck overlay vs. deck replacement) resulting in distinct strategies. In other cases, multiple deficiencies may need to be addressed within one strategy (e.g. deck overlay and partial painting). Some actions may also involve additional related items in the future as part of the strategy (e.g. asphalt overlay following a waterproofing membrane replacement).

If functional deficiencies with potential remedies are observed, new strategies based on each of the strategies identified so far can be developed with the addition of the functional remedy. For comparison purposes, user costs associated with not addressing the functional deficiency can be included in the previous strategies.

The ability to follow some optimal strategies may be limited by constrained funding. For example, if bridge replacement is selected as the optimal strategy for a structure, but the project cannot make the program due to limited budgets, an alternate plan will be required. This alternate "Plan B" option should involve a lower initial capital cost within the planning window (next 5 years). This plan may involve extensive repairs and/or rehabilitation, and may result in continued functional deficiency. This plan may also prove infeasible due to funding constraints. At a minimum, a strategy should be developed to manage the structure in a safe manner should replacement be delayed for a number of years.

1.4 Reference Documents

This document provides an overview of the assessment process. References are made to additional documents that provide more detail on certain components of bridge assessments. These are:

- Alberta Transportation ***'**[Bridge Conceptual Design Guidelines](#)**'*** (***BCDG***) - this document applies to assessment of functional deficiencies in bridge and road geometry and in bridge openings. It also provides principles of use in assessing the scope and cost of a replacement option.
- Alberta Transportation ***'Bridge Management Strategy Guidelines'*** (***BMSG***) – this document contains descriptions of repair and rehabilitation options for bridge components and guidelines for selecting appropriate interventions.
- Alberta Transportation '*Bridge Load Evaluation Manual*' (***BLEM***) – this document provides guidance on evaluation of the structural capacity of a bridge due to condition or oversize loads.
- Alberta Transportation '*Bridge Inspection and Maintenance System*' manuals (***BIM***) – these document details the bridge inspection activities and rating system that are a key component of evaluating deficiencies.
- Alberta Transportation 'Design Guidelines for *Bridge Size Culvert*' (**DGBSC**) – this document details the culvert specific issues and design requirements.
- Alberta Transportation 'Roadside Design Guide' (**RDG**) – this document provides guidance on developing cost-effective roadside environments that meet the Province's safety objectives, covering elements such as barrier systems.

2 Condition Deficiencies

Identification and prediction of structural condition issues can vary greatly by structure type and complexity. Culverts are relatively simple structures, with limited rehabilitation options. This is also the case for many standard bridges, although the substructure must also be considered in strategy development. Major bridges can involve many distinct components, with potential for a range of life cycle strategies. Details on common rehabilitation actions for culverts (section 5), standard bridges (section 3), and major bridges (section 4) can be found in the latest version of the Bridge Management Strategy Guidelines (BMSG) document.

2.1 Culverts

More than 90% of culvert structures on the provincial highway network are corrugated steel culverts. Most of the other culverts are concrete, with some hybrid structures (steel and concrete), welded steel, and a few timber culverts.

Most of the common rehabilitation options are relatively low cost repair options and will likely be considered as part of a base strategy (e.g. do minimal and replace). Lining is a more significant action, and would form part of additional life cycle strategies.

These rehabilitation options may impair the functionality of the structure (e.g. struts collecting drift, liner reducing hydraulic capacity), see DGBSC. In addition, many operational and environmental issues *e.g. fish passage) related to culvert configuration (e.g. sizing, burial) cannot be addressed without replacement with a structure that meets current design standards.

Level 2 “Culvert Barrel Measurements” inspections, as presented in the Level 2 BIM Manual, are triggered by certain level 1 ratings and/or repeated ‘N’ ratings for key culvert components. These inspections provide quantitative evaluation of deflections and longitudinal seam cracking, facilitating a more precise evaluation of the Barrel General Rating.

2.2 Standard Bridges

Standard bridge superstructures typically consist of precast concrete girders with no deck. Standard bridge substructures may consist of timber, steel, or concrete. Many of the common rehabilitation options are relatively low cost repair options and will likely be considered as part of a base strategy (e.g. do minimal and replace). More significant actions, such as superstructure or substructure replacement and concrete overlay, would form part of additional life cycle strategies.

2.3 Major Bridges

2.3.1 Deck

Bridge decks are the components that interact most closely with traffic, and are subject to corrosive road salt and abrasion. As such, multiple interventions on a bridge deck are expected throughout the life cycle of a major bridge. Concrete decks at major bridge structures are managed as part of the BIM level 2 deck testing program. The latest test results and prediction model are used along with inventory data and rehabilitation history to predict the optimal timing and type of the next intervention. These predictions can be built into potential life cycle strategies for the bridge.

2.3.2 Paint

Some older structures, including trusses and welded steel girders (built before 1975) rely on protective coatings to minimize section loss due to corrosion. Depending on the paint condition, the type of structure, and the expected remaining life of the structure, painting activities should be considered within the developed strategies. Strategies should also be developed that do not address a paint deficiency, in which case predicted loss of section may limit the service life of the structure.

2.3.3 Substructure

Common materials used in major bridge substructures are steel and concrete. These components typically have limited repair options available, and in most cases, they will be expected to outlast the superstructure. Also, in-stream work may require expensive berm construction and constraining associated regulatory requirements. Therefore, in many cases, substructure issues are more likely to influence replacement options than to trigger rehabilitation activities. Some recent substructure rehabilitation activities include pier stabilization with slope stability measures and caissons, footing underpinning with caissons, and pier shaft concrete repairs.

2.3.4 Miscellaneous

Deficiencies relating to less expensive major bridge components, such as bearings, deck joints, and bridgerails, are typically addressed as part of a larger rehabilitation project or a replacement. Bearing issues can show up in damage to pier caps and girder ends. Similarly, deck joint failure can result in staining and damage to components underneath the joint. Consideration of bridgerail upgrade options will be identified as part of the project scoping exercise, and will be included in the Terms of Reference, if appropriate (note that the economic analysis portion of Appendix C of the RDG no longer applies).

3 Functional Deficiencies

Functional deficiencies at a bridge may include road geometrics (horizontal alignment, vertical alignment, clear roadway width, vertical clearance), bridge opening (hydraulic capacity, flood vulnerability, fisheries or navigation impact), and structural (load capacity).

It is not always optimal to correct bridge functional deficiencies. Correcting such deficiencies may require significant road re-construction with significant extra cost. If functional deficiencies are found, life cycles strategies that include removing the deficiencies (where feasible) should be developed based on the strategies already developed based on condition. For strategies involving retaining functional deficiencies, potential user impact costs should be considered.

3.1 Geometric Deficiencies

Roadway geometric deficiencies can be found by comparing data for the existing highway to current standards, as per the Bridge Conceptual Design Guidelines (BCDG). Potential future roadway geometric deficiencies can also be identified by reviewing any planning studies for the highway. Existing roadway geometry can often be extracted from previous drawings or data collected by the GPS video-log van (see Hwy Lookup Tool).

Geometric deficiencies specific to the bridge structure, such as those that impact preferential icing and block sight distance, should also be considered.

3.2 Bridge Hydraulic Opening Deficiencies

The sufficiency of a bridge opening can typically be addressed at the assessment stage without performing detailed design flow and hydraulic analysis calculations. In general, a review of the historic performance of the structure under highwater conditions will identify if the existing opening is problematic. The Hydrotechnical Information System (HIS) tool, information on the bridge correspondence files, comparison with u/s and d/s crossings, and bridge inspection and maintenance records are useful sources of this information. A desktop study, using GIS data, can also help in assessing the relative size of a bridge opening to the typical channel. Observations from a site inspection or available photos, such as d/s scour holes and bank slumping, may also assist in evaluating the existing bridge opening. These observations can be used, in conjunction with the principles in the Bridge Conceptual Design Guide, to estimate bridge opening size for a replacement structure. Any regulatory issues that may affect the feasibility and cost of an option should be considered.

Rehabilitation options to address bridge opening deficiencies include adding a pipe, raising the superstructure of a standard bridge, adding a span to a bridge, realigning the channel, and enhancing the river protection works system. In many cases, these solutions will not be feasible or cost-effective, and the influence of these deficiencies will be on the optimal replacement year.

3.3 Structural Function Deficiencies

Bridge load capacity deficiencies can be identified by comparing the system rating values to the legal standard. If overload vehicles are anticipated or if structural condition is affecting load capacity, evaluation of the bridge following the Bridge Load Evaluation Manual (BLEM) may be required. Options to address bridge load deficiencies include do nothing, strengthen, restrict use, and replace. Strengthening of some older structures in a cost effective manner may not be feasible.

Bridge vertical clearance may be an issue for through-truss structures and grade separation structures. Clearance requirements at grade separations are documented in section 7 of the Roadside Design Guidelines. In most cases, there are few cost-effective rehabilitation options to address vertical clearance issues, but they may affect timing and configuration of replacement alternatives. In some cases, advance warning systems may be an option to consider in order to minimize the risk of high load strikes.

4 Life Cycle Cost Analysis

Life cycle cost analysis is an important tool in the evaluation of potential strategies for a bridge. Once all feasible strategies have been developed, a net present value (NPV) cost is calculated for each strategy. All future costs are converted to present year costs and summed using the specified discount rate, life cycle analysis period, and residual value estimation.

However, costs can only be quantified to a certain degree of accuracy and some pros and cons for options cannot be readily expressed as costs (such as certain user impacts). Therefore, life cycle cost analysis results should be used in combination with engineering judgment of documented pros and cons to determine the optimal course of action, which will form the recommendation.

4.1 Calculation

The formula for present value of a future cost is as follows:

$$PV = \frac{C}{(1 + i)^{n}}$$

PV = Present Value of cost
C = Cost of work activity (expressed in current year dollars)
i = discount rate as a decimal (%/100, e.g. 0.04)
n = number of years into future for work activity

The NPV for a strategy is the sum of the present value of all work activity costs minus the present value of any residual value at the end of the analysis period. The NPV of user costs can also be calculated, but should be reported separately (see section 4.5). At the assessment stage, work activity costs are typically based on ‘level A’ estimates (unit rates, no breakdown by component). Typically, routine maintenance costs, such as concrete sealing are not large enough to be considered.

Due to uncertainty in predicting timing and extent of future work, a sensitivity analysis should be performed to assess the potential impact on analysis results from activity timing and cost assumptions. This involves performing additional calculations using a range of potential values, and noting the impact on the NPV results. The final presentation of results should be based on the most probable scenario for each strategy, with an observation on the sensitivity of the comparison analysis results provided and considered in the optimal strategy selection.

4.2 Analysis Period

The standard practice for bridges is to use a 50 year analysis period. This is considered long enough to cover most predictable life cycle events. Extending beyond 50 years is not necessary as NPV of costs beyond this point are greatly reduced and residual value accounts for remaining service life.

4.3 Discount Rate

The discount rate accounts for the time value of money. The Department's current standard practice for discount rate is to use 4% (0.04 as a decimal). For non-profit agencies, this is typically calculated as the long term difference between low risk investment returns (e.g. bonds) and the inflation rate. For-profit firms may choose higher rates based on their business objectives. A recent analysis of Canadian statistics shows that the current discount rate (as of 2012) is less than 3%, but that the long term average (last 40 years) is still very close to 4%. As such, 4% is still recommended given the length of analysis period used for bridges. This will be reviewed periodically.

4.4 Residual Value

Residual value is the negative cost entered at the end of the analysis period to account for remaining life in the structure. With proper accounting of residual value, the exact length of the analysis period does not have to match or exceed the expected life of a structure. Residual value is only applied when a bridge replacement or major bridge rehabilitation (extending life of structure by more than 40 years, such as full deck or superstructure replacement) occurs within the analysis period. It is not applied to rehabilitation activities, where only certain components of the structure are impacted. In addition, residual value is typically not included for structures that were replaced prior to the analysis period but may have some service life left at the end of the analysis period. In such cases, the magnitude of the residual value would be relatively small and would offer no difference for all non-replacement options, which would be the most likely options.

The Department calculates residual value based on linear depreciation of the asset, using the equation:

$$RV = RC \left(\frac{(Life - Age)}{Life} \right)$$

RV = Residual Value
RC = Replacement Cost
Life = Expected Life of the Replacement Structure
Age = Age of Structure at the end of the analysis period

As an extreme example, if a life cycle strategy Involves replacing the structure at year 45 in a 50 year analysis period, most of this cost would be removed at year 50 as a residual value. Note that residual value is not the same as salvage value, as salvage value would only apply at the end of the service life, and typically is of no significant value to the department.

4.5 User Costs

User costs are an attempt to account for societal costs related to the functionality of a bridge due to collisions, user time, and vehicle operating costs in the economic analysis. Impacts on road users due to bridge functionality can be significant, and should be accounted for in the selection of the optimal bridge strategy.

User costs can be more difficult to quantify than construction activity costs, as they require assumed values for certain activities (such as user time and collisions), and can require use of predictive models (difficult to calibrate) in estimating the magnitude of impact. The most common user costs to account for are vehicle operating costs and user time. Based on default parameters presented in the Project Benefit Cost Model tool (http://www.transportation.alberta.ca/5847.htm) and some typical vehicle parameters for the highway system in Alberta, the typical user costs would be $40/hr (user time) and $0.5/km (vehicle operating cost). For a detour route, this equates to ~ $1/v.km. If collision reductions can be predicted, a typical value of $100K per collision can be used (accounts for typical distribution of fatalities, injury, and property damage and current cost estimates).

While consideration of user costs in the life cycle cost analysis will assist in the identification of the optimal option for a given structure, funding constraints may still require the use of a lower cost (and sub-optimal) option at a given site. In some cases, the optimal option based on lowest NPV of life cycle costs (including user costs) may have a lower Benefit to Cost ratio for programming purposes than an option that does not minimize user costs. In addition, certain user impacts (such as risk of flood vulnerability) cannot be readily accounted for numerically. Therefore, NPV of costs both including and excluding user costs should be reported.

5 Recommend Optimal Strategy

Based on evaluation and comparison of all feasible life cycle strategies, a recommended strategy will be provided. This optimal strategy is to be supported with sufficient detail, criteria and rationale to support the recommendation.

If the recommended strategy involves significant short-term capital expense, an additional strategy that involves lower short term capital cost should be identified and presented. This option may involve more than the “do minimal and replace” option, and may include actions to ensure continued safe operation of the bridge, including restricted use or increased inspection. If no such option can be found, this should be clearly stated, and recommendations on what is required to manage the bridge to closure and what would be the likely trigger for closure should be provided.

Appendix A – Typical Culvert Work Activities

The following table of culvert work activities is based on work done in the Alberta Transportation Culvert Repair Evaluation System, which was later incorporated into the BEADS bridge management tool.

Note that functional limitations due to repair items are to be considered. Also, the criteria are intended to be applied when the structure first meets the stated condition rating value. If a structure has deteriorated significantly, these repair options may no longer be feasible.

Type	Criteria	Action
CSP	Roof or Floor <=4	Strut in 5 years, Replace 20 years later
	Side <=4	Line in 5 years, Replace 40 years later
	Seam <=4	Seam Repair in 2 years, Replace 15 years later
SP	Seam <=4, D >2.5m	Shotcrete in 5 years, Replace 20 years later
	Seam <=4, D <=2.5m	Strut in 5 years, Replace 20 years later
	Roof or Floor <=4	Strut in 5 years, Replace 20 years later
	Side or Seam <=4	Line in 5 years, Replace 40 years later
	Floor <=3 (corrosion)	Install concrete floor, Replace 15 years later

Estimation of Remaining Life:

- If barrel deflections and increasing, the replace year can be estimated by predicting when deflections reach 20% based on current rates (note that strutting can arrest deflection increases).
- If cracks at seams are increasing, the replace year can be estimated by predicting when there will be less than 15mm of steel remaining between cracks.
- Based on observed rate of increase in large perforations in floor, predict when ‘piping’ loss of fill may occur.

Appendix B – Typical Deterioration Rates

'D' is the deterioration rate expressed in years per drop of one BIM point for key structural ratings. These are the Barrel General Rating for culverts, and the Superstructure General and Substructure General ratings for standard bridges. For older structure types, these values are based on analysis of ratings across the system. For newer structure types, they are based on expected service lives. These values are used in system tools that support the development of bridge replacement programs. These values may not be representative of deterioration rates at a specific site, and are provided for context.

Culverts:

Type	D
CSP Steel	7.5
SPCSP Steel	8.5
Smooth Wall Steel	9.5
Concrete	9.5
ABC	9.5
Plastic	9.5
Timber	6.5

Standard Bridge Superstructure:

Type	D (paved)	D (unpaved)
Pre SL	7	9.5
SL series	11	11

Standard Bridge Substructure:

Type	D (paved)	D (unpaved)
Timber	8	9.5
Steel	9	11.5
Concrete	11.5	11.5