Cross Asset Management – the Alaska Highway Corridor

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Paper Prepared for Presentation

at the: Cross Asset Analysis and Optimization – Solutions for Informed Decisions Session

of the 2016 Conference of the

Transportation Association of Canada

Toronto ON

Submission date: April 29, 2016

Word count: 5139

ABSTRACT

In 2013 Public Works and Government Services Canada (PWGSC) retained a consultant to develop a comprehensive cross asset management plan (AMP) to inform the development of 50 years of capital projects and the long term management of the 800 km portion of the Alaska Highway through British Columbia.

This paper highlights the key features of the methodology used namely:

- Development of a strategic AMP concentrating on improving safety, preserving existing assets, upgrading the highway and bridges/culverts where necessary;
- Identification of major asset works for 50 years using life cycle cost analysis;
- Development of engineering economics to include as benefits the reduction of: accident costs, user delay costs, user detour costs, user vehicle operating costs, environmental costs associated with greenhouse gas emissions at current carbon trading rates and cost of risk for bridges/culverts;
- Development of risk assessment and mitigation measures;
- Perform life-cycle cost analysis comparing multiple pavement preservation, geometric upgrades and bridge/culvert works; and
- Development of a risk based Bridge Management System.

The key innovation in this project was that it monetized risk, reliability and user costs allowing a true financial cross asset optimization solving a problem faced by agencies around the world. The intent of this paper is to highlight these innovations and provide a framework for other agencies that may wish to implement them.

INTRODUCTION

Public Works and Government Services Canada (PWGSC) is responsible for preserving and improving the Alaska Highway corridor in British Columbia. There has been an ongoing program to improve this corridor, originally built in 1942, to make it safer, handle more traffic, accommodate increasing highway speeds, and permit larger commercial loads. Most of the highway has now been upgraded to Rural Arterial Undivided 100 km/hr design speed standard (RAU-100). However, a 221 km section within PWGSC’s jurisdiction is geometrically sub-standard with design speeds as low as 50 km/hr.

A consultant was retained to develop a comprehensive strategic asset management plan that lays out the strategy for initiating capital projects and for the long term management of the Alaska Highway Corridor. The plan provides guidance related to maintaining and improving this corridor for the foreseeable future, in a cost effective manner, given limited financial resources.

PROJECT PRIORITIES

The central goals of the strategic plan are asset preservation and capital improvements driven by health and safety. It was agreed to use an economics driven analysis to develop the rational for prioritizing preservation and capital improvement projects. The engineering economics include as benefits the reduction of:

- Collision (accidents) costs;
- User delay costs;
- User vehicle operating costs;
- Environmental costs associated with greenhouse gas emissions at current carbon trading rates; and
- The risk for bridges and bridge-culverts closure. This is defined as the probability of unacceptable performance (i.e. closure) multiplied by the consequences which will be a combination of repair time, detour distance, traffic volume, and the value of users' time.

ASSET DEFINITION

This project concentrated on the portion of the Alaska Highway located from km 133 to km 967.5, excluding a small section within Fort Nelson, with a length of 827.7 km. The major assets included Roadway, Pavements and Structures; bridges and major culverts.

The pavements comprised ACP (Asphalt Cement Pavement) and Bituminous Surface Treatments (BST). There were three types of BST within the project:

- Class 1: BST applied directly to unimproved subgrade;
- Class 2: BST applied on top of 75 to 150 mm of crushed gravel; and
- Class 3: Initially full depths of sub-base and base are placed with a BST surface.

The length and percentage of each pavement type in the network is:

- AC, 177.2 km (21.4% of road network);
- BST Class 1, 149.2 km (18.0%);
- BST Class 2, 27.3 km (3.3%); and
- BST Class 3, 474 km (57.3%).

There were 25 Bridges and 31 major bridge-culverts (i.e. span greater than or equal to 3 m). The bridges are divided into 4 types:

- Concrete;
- Steel Box Girders;
- Steel I-girder; and
- Steel Truss.

The distribution of the average traffic volume (passenger car and truck) in 2012 varied considerably along the length of the highway from a high of 2200 vehicles per day (vpd) in the south to a low of about 400 vpd at the north end. An annual growth rate of 2.4% was also assumed to calculate future traffic volumes.

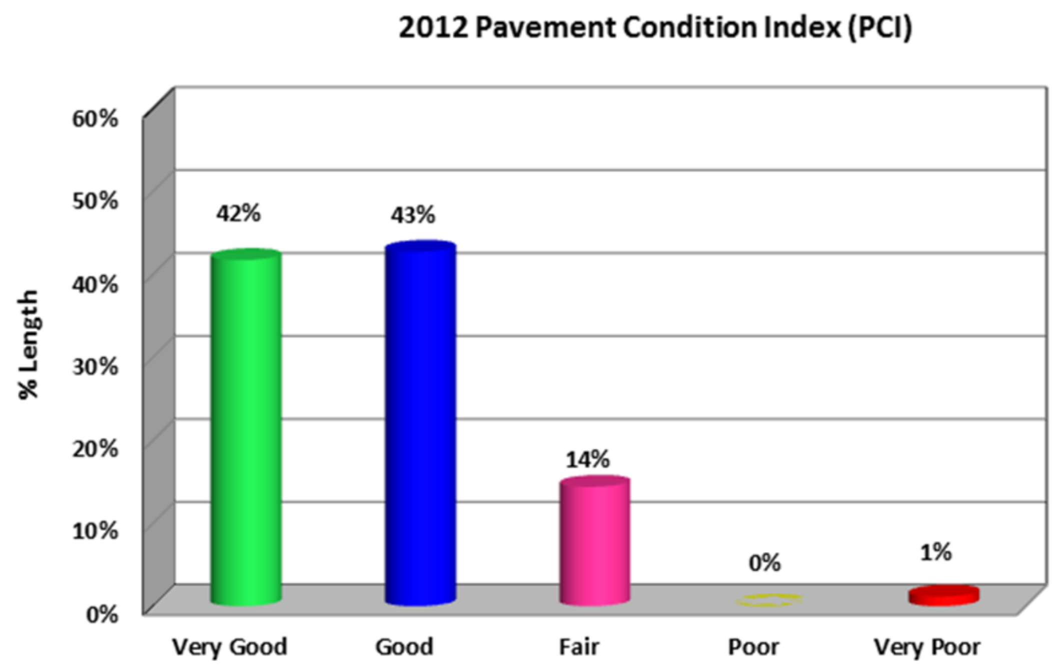
In addition to the traffic volumes, the following is a list of other data that was accumulated from previous work and provided to the consultant for use in this project.

- Construction history including pavement surface age and treatment type;
- Pavement layers thickness and structural capacity data from km 206 to km 553 were also available based on FWD testing and coring data (*1*);
- Posted Speed Analysis (*2*);
- Clear Zone Analysis;
- Location of horizontal curves along with curve radius;
- Location of vertical curves along with k factor;
- Lane and shoulder width data;
- Road profile, cross fall, rut and roughness data;
- Digital Photo Inventory;
- Visual distress ratings were used from the 2012 PWGSC ACP and BST surveys reports (includes PCI – Pavement Condition Index, BCI – Bituminous Condition Index, and RCI – Riding Comfort Index) (*3,4*);
- All police-reported collisions within the corridor (km 133-km 968) from 2008 to 2012 summarized by fatal, personal injury or property damage only and cause; and
- For bridges and culverts, the primary data source was the ongoing inspections of every bridge and bridge culvert (*5*). During the inspection, the bridge/culvert is rated for structural (SCR) and functional (FCR) condition rating of bridges and culverts from 1 to 6 (6 perfect, 1 failed) and an assessment of each *component* of the bridge or culvert assigned a material condition rating (MCR) and a performance condition rating (PCR) from 1 to 6.

ASSET PRESENT STATUS

Pavements

The following figure and table show the condition of the highway and bridges as of the latest survey taken. The distribution of the PCI for the ACP sections and the BCI for the BST sections is shown in Figure 1.



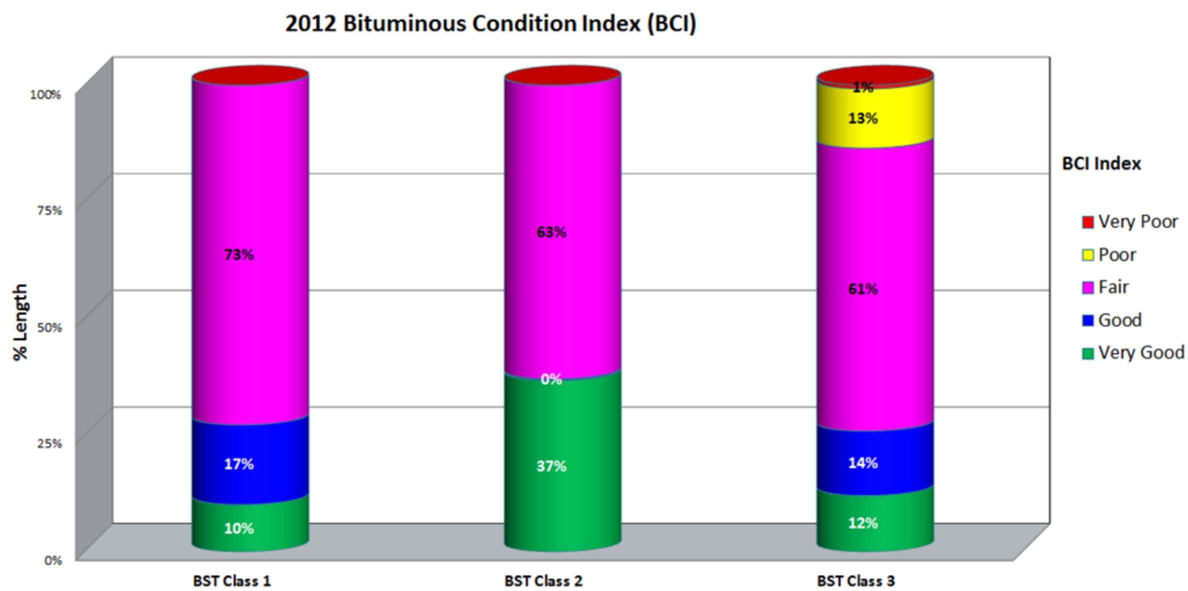


Figure 1: 2012 Pavement Condition Distributions in terms of PCI and BCI

The condition of the roadway as measured in 2012 with respect to average International Roughness Index (IRI) and RCI is summarized below:

- ACP, average IRI is 1.2 m/km, average RCI (ride score) is 6.4 (10 is perfect);
- BST Class 1, average IRI is 2.8 m/km, average RCI is 5.5;
- BST Class 2, average IRI is 2.5 m/km, average RCI is 5.8;
- BST Class 3, average IRI is 2.5 m/km, average RCI is 5.4; and

- BST Class 1, average IRI is 2.3 m/km, average RCI is 5.6.

Bridges

The structural condition rating of a bridge or bridge-culvert takes into account the structural capability of the components that make up the bridge. The Overall Structural Condition Rating (OCR) is calculated by taking the lowest primary component material condition rating (MCR). The functional rating of a bridge or bridge culvert takes into account how well the bridge is performing according to its intended purpose and current design standards. A bridge can be categorized as being deficient functionally by having substandard lane widths or narrow shoulders. The Overall Functional Rating (OFR) is an overall condition rating from 6 (as new) to 1 (critically inadequate). Table 1 shows the historical average of OCR and OFR for the bridge and culvert network based on bridge type.

Table 1: Historical Average of OCR and OFR in terms of the Bridge Type

Bridge Type		OCR_2011	OCR_2009	OFR_2011	OFR_2009
Bridge	Concrete	5.0	4.5	4.5	5.0
	Steel Box Girders	5.3	4.7	4.7	4.5
	Steel I-girders	4.6	3.6	3.6	3.6
	Steel Truss	4.0	3.0	3.0	3.0
Bridge-Culvert	Galvanized Corrugated "Super Span" Steel Arch	5.0	6.0	6.0	6.0
	Galvanized Corrugated Steel Arch	3.0	6.0	6.0	6.0
	Galvanized Corrugated Steel Arch on Concrete Footings	6.0	6.0	6.0	6.0
	Galvanized Corrugated Steel Plate Barrel	4.4	5.9	5.9	6.0
	Total	**4.6**	**5.0**	**5.0**	**5.0**

ANALYSIS METHODOLOGY

The next several sections of this paper discuss the analysis methodology that was developed for the project.

The basic premise is that each of the assets attracts user costs in the event of inaction. For example failure to maintain a bridge or culvert results in a higher probability that the structure will be load rated or fail. This would result in higher user costs in the form of additional freight costs and/or detour costs. Failing to preserve the pavements results in more roughness and associated vehicle operating costs (VOC). Failing to improve deficient geometry incurs accidents with associated costs.

If all user costs are monetised, the cost of deferring action can be calculated and conversely, the financial benefit, (reduction in user costs), of performing a series of improvements (called a preservation or improvement strategy), over a fifty year period for any given asset can then be calculated.

Several strategies are generated for each individual asset. Each strategy has an associated life-cycle cost and life cycle benefit value. If funding was unconstrained, the strategy with the highest net benefit (benefit minus cost), for each asset could be selected as the optimum.

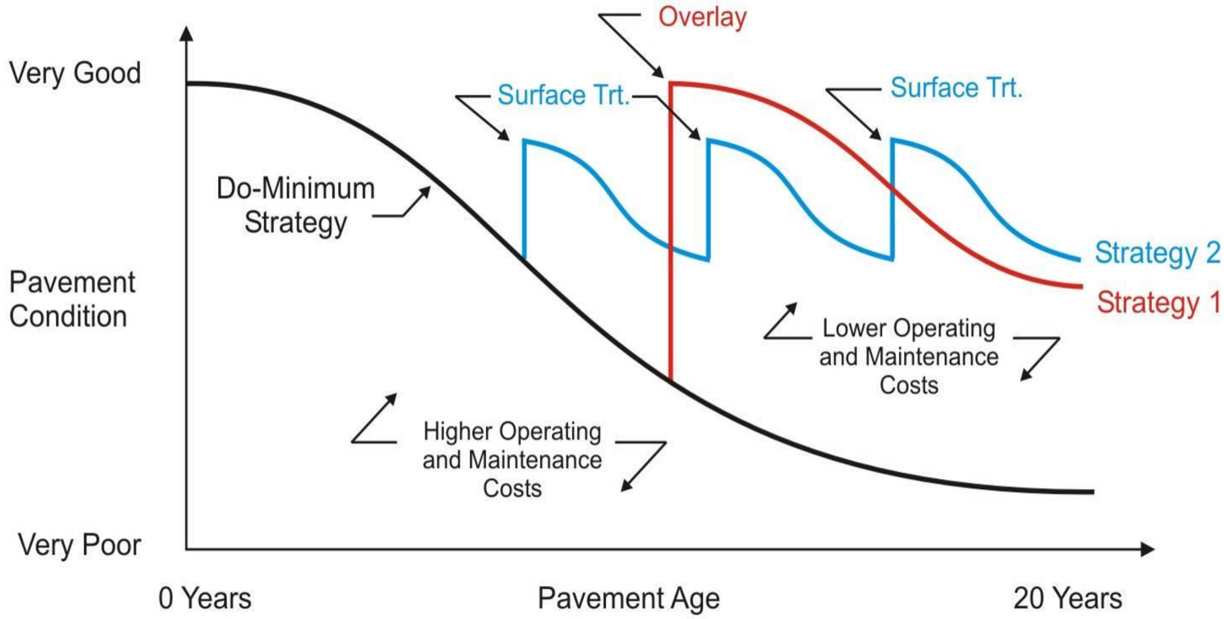


Figure 2: Example Life-Cycle Cost Strategies

There are three reasons for generating multiple strategies for each asset:

- A life-cycle cost analysis implies exploring alternative courses of action (strategies);
- In a constrained funding environment, the optimal strategy might not be financially possible; and
- Multiple strategies facilitate an optimization process whereby selecting strategies across asset types can be performed using an iterative algorithm that maximizes the net benefit across the asset types for any give set of budget constraints.

All life-cycle costs and benefits are compared in terms of Present Value at a specified discount rate.

Pavement Deterioration Prediction Models

Models for predicting PCI and BCI are based on pavement age and were available from BST and Pavement Management System reports (*3,4*). Locally calibrated versions of HDM 4 (Highway Development and Management) framework based performance models were also used to predict All Structural Crack Area (ACA) and IRI indices (*6*). The calibration factors have been developed based on data collected in Western Canada over the past 20 years. The prediction of

IRI forms the basis for the development of the VOC and hence the environmental and direct user costs.

Bridge Performance Models

The bridge performance modelling consists of two components. The first is a condition rating against time and the second is a Probability of Unsatisfactory Performance (PUP) against time. Figure shows an example of two performance curves for a bridge deck on the Smith River Bridge.

A PUP was established by an experienced bridge engineer for each condition rating of each primary structural component of each bridge. Condition ratings of 6 or 5 correspond to essentially zero probability of bridge closure, whereas a condition rating of 1 corresponds to approximately 50% probability of bridge closure in a given year (e.g. critically inadequate).

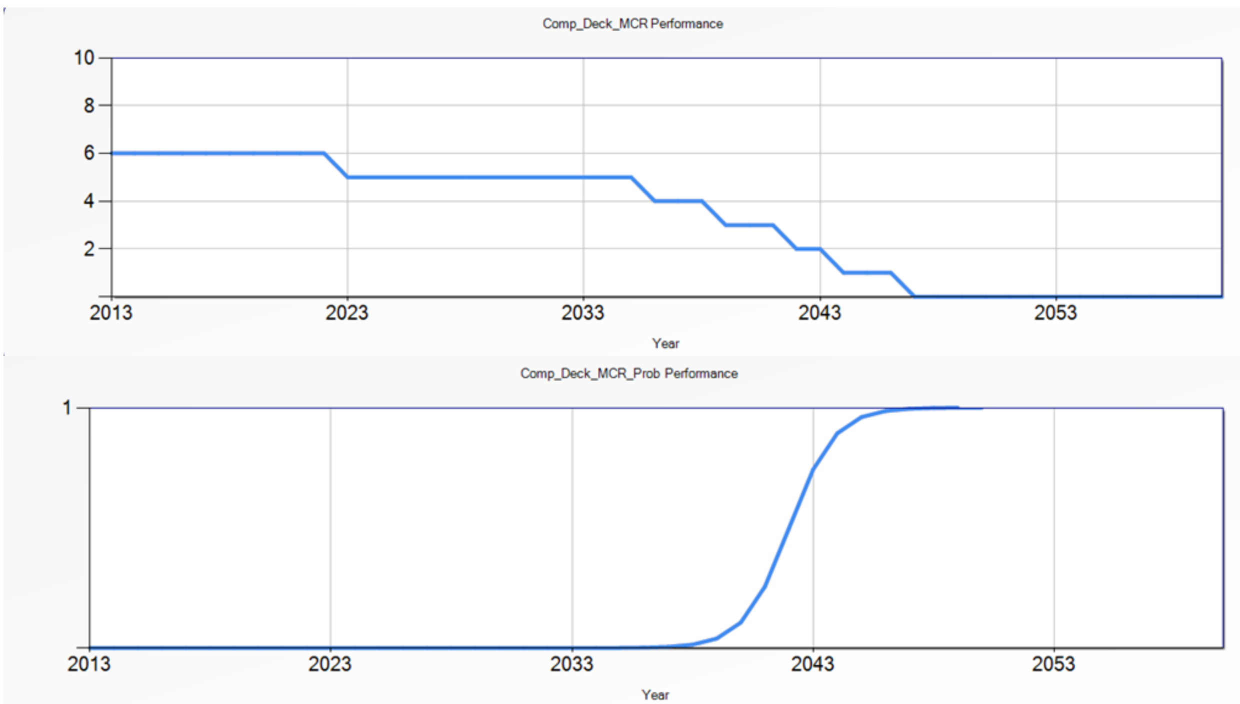


Figure 3: Deck Condition Rating and Probability of Unsatisfactory Performance (PUP) for the Smith River Bridge

The time for a structure's components to move from condition rating states (e.g. 5 to 4, 4 to 3) was determined based on the ages and ratings of structures and components in the latest bridge inspection reports and the judgement of a senior bridge engineer.

Treatments Definition and Cost

A set of maintenance and rehabilitation treatments was established as described below:

- 50 mm overlay of existing ACP: Used to correct minor pavement deficiencies ($30/m^2);
- Major Rehabilitation of existing ACP (Reclaim and Overlay): Removal of defective material from the driving lanes and replacement with new ACP ($50/m^2);
- Conversion of BST surface to AC surface: This strategy is used for Class 3 BSTs when traffic volumes warrant ($400,000 /km);
- Reconstruction of roadway to Geometric Standard (RAU-100): This strategy is used for sections that are not RAU-100 (Class 1 and Class 2 BSTs). Unit reconstruction costs were available from the 2003 Strategic Plan Report (*7*) for the sections between km 550 and km 751. These costs were used in the development of the current plan with an inflation factor of 1.4;
- Ripup and ReBST of existing BST surface (varied from $60,000 /km to $70,000 /km depending on the BST Class);
- Maintenance: The maintenance treatment is defined for both ACP and BST surface and include annual minor repairs like crack sealing and patching. BST maintenance cost was a function of BCI, however, the ACP maintenance cost was calculated based on area with cracking at $14/m^2;
- Bridge and Culvert Components Rehabilitation: Three different levels of rehabilitation (level 1, 2 and 3) were assumed for each component related to the condition rating; and
- Bridge Replacement or New Bridge.

Bridge replacement was assumed to be in-kind. All replaced bridges were assumed to be 11 m wide. The bridge replacement cost was assumed to be $9,000/m^2 of deck area for each bridge, with the exception of Coal River Bridge (Arc) and Lower Liard Bridge (Suspension), where the replacement cost was assumed to be $12,000/m^2 of deck area. The total culvert replacement cost was derived based on an assumed replacement cost of $2,000/m^2, with the area calculated as the interior area of the culvert.

Treatment Triggers and Resets

A set of “triggers” was developed so that only feasible strategies are explored. A strategy is a collection of treatments over time that addresses the deficiency of the asset. For example, the Conversion of BST surface to AC surface cannot be directly applied to BST sections with low traffic (AADT< 500 vpd). The triggers are based on the pavement and bridge key performance indicators such as BCI, PCI and ACA for pavements and OCR and OFR for bridges.

The application of any given treatment will improve the performance of a road or bridge. For example, with a 50 mm overlay, ruts would be filled, cracking would be removed, roughness would decrease, and strength would increase. To predict performance over time and account for and compare possible interventions, the performance models have to adjust the individual condition data to reflect the application of the treatment. These changes to the value of the analysis variables as a result of the application of a treatment are called resets. An analysis variable is defined as a variable whose value changes, as a result of predictive modeling or as the result of a condition improvement intervention, over the course of an asset’s life cycle analysis. These variables track, among other things the forecasted values of the pavement conditions such as IRI and ACA, the Bridge conditions, the Key Performance Indicator (KPI) and life cycle costs. Some heavy rehabilitation treatments, such as Conversion of BST to ACP, might reset virtually all of the analysis variables. The HDM-4 deterioration models are calibrated and adjusted as the analysis variables are reset following a treatment.

User Costs

A key factor in order to be able to compare different and competing treatment alternatives for multiple assets such as pavements and bridges is to be able to quantify some KPI that is common to both assets. In this project, user costs were used as the KPI and more specifically the savings in user costs. This section briefly describes how the user costs were derived.

Pavements Preservation

The authors' company has extensively used the HDM methodology to calculate user costs of various pavement preservation strategies. HDM uses pavement roughness (or ride) in determining vehicle operating costs (VOC).

The VOC including fuel, tire and vehicle depreciation/consumption is a function of the International Roughness Index (IRI), Average Annual Daily Traffic (AADT) and Percent Commercial Traffic. In addition, the generated greenhouse gas emission (GHG) by the vehicles was calculated for these components of VOC.

The following equation shows the components that go into the VOC.

$$VOC = Tire + PandM + Deprec + Fuel + GHG$$

Where:

- Tire: Tire consumption for all vehicles
- PandM: annual vehicle parts and maintenance cost
- Deprec: Depreciation of vehicles
- Fuel: Annual additional fuel consumption
- GHG: The environmental cost of operating a vehicle on the Highway
  - GHG is f(Current Carbon Trading Rate, GHG_tire, GHG_deprec, GHG_fuel)
  - Where:
  - Current Carbon Trading Rate is about $30 per tonne of CO_2 in July 2012 (*12*)
  - GHG_tire =additional GHG due to additional Tire consumption
  - GHG_deprec = additional GHG due to the accelerated depreciation of vehicles
  - GHG _fuel =additional GHG due to additional fuel consumption

Geometric Improvements

Safety was identified as the key driver for geometric improvements, specifically the projected reduction in the number *and* severity of accidents anticipated by upgrading the non-standard portion of the highway to an RAU-100 standard.

The deficiencies considered were:

- Substandard vertical curves;
- Substandard horizontal curves; and
- Insufficient width or side slope.

The sub-standard portion was sub-divided into individual instances of sub-standard vertical and/or horizontal curve geometry. Segments of highway between these instances of sub-standard curve geometry were considered to be sub-standard in width only.

The AASHTO model (*8*) was used to predict total crash frequency for each segment. The model was calibrated based on historic collisions, engineering judgment and a previous study (*9*). The model is a function of geometric data (curve radius, road and shoulder width), length of segment and traffic. The accidents were assigned costs using the BC MicroBenCost guide (*10*).

User time savings were calculated to result from improved geometry. The user time quantifies the monetary cost of time savings for each segment. This is used to quantify the benefit of geometric improvements to the highway in terms of an increase in the posted speed limit. Improving the geometry to posted speed limit of 100 km/h versus an existing lower speed limit provides a measurable travel time saving. The user time saving of the section is a function of AADT, occupancy rate per vehicle and value of time for each type of vehicle. Values of road user time were estimated based on Alberta Transportation's standard (*11*).

The individual highway sections comprising the areas of sub-standard geometry were modelled for expected accident rates under two scenarios: retain existing geometry or improve geometry to RAU-100 standard. The user benefits in terms of reduced accident costs, reduced travel time and reduced VOC were calculated under both scenarios.

Bridges

A monetary consequence of bridge closure was calculated based on the traffic volume and increased driving length due to detour (increased travel time and VOC) for an estimated closure time for repair.

Since the majority of traffic that uses the Highway originates from the south end, Edmonton Alberta was assumed to be the trip origin. Two destinations were considered for the traffic, Fort Nelson and somewhere north of Fort Nelson. Therefore two detours were estimated to be used based on the two destinations mentioned and this is shown in Figure 4.

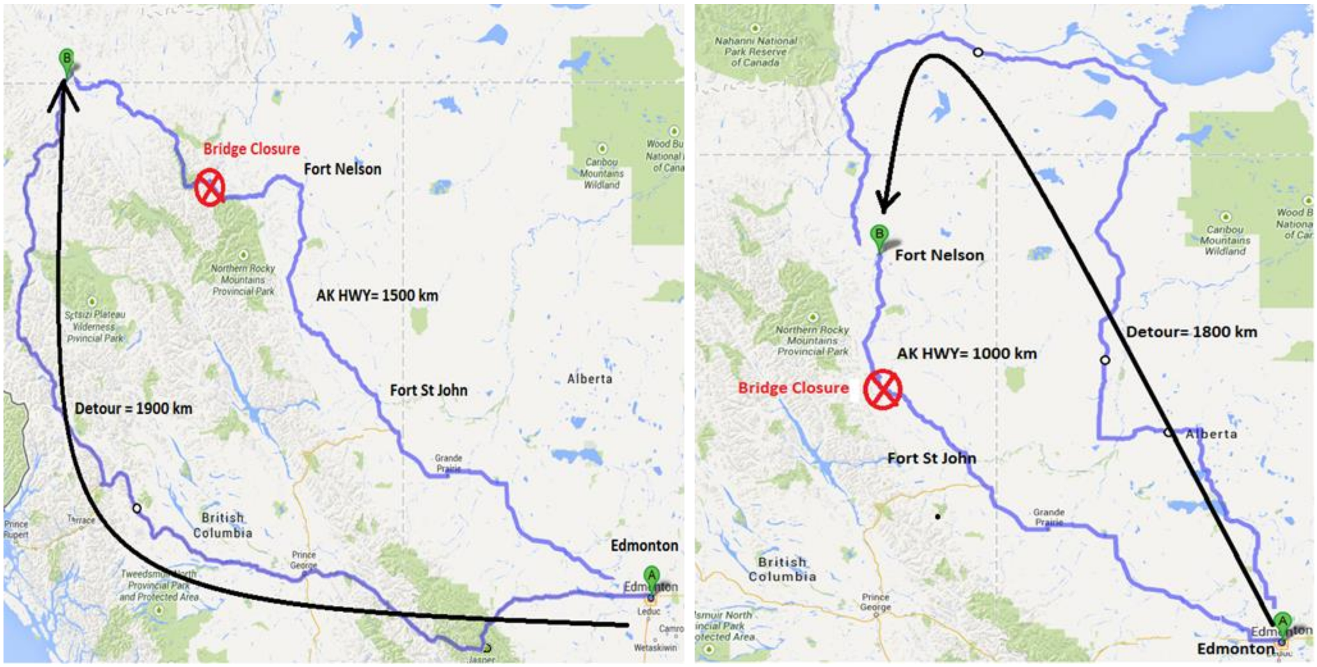


Figure 4: Two potential detour locations with length comparisons versus taking AK Hwy

The increased driving length due to potential detours caused by bridge closure in comparison to no detours was estimated to be 400 km (250 mi) for Northern bridges and 800 km (500 mi) for Southern bridges (refer to Figure 4). A bridge closure of one month and AADT of 500 vpd for each detour was also assumed. The VOC for a potential bridge closure then is the additional time and distance due to the detour for each vehicle.

Benefits

Pavements

Benefit can be calculated in terms of user cost based on the cumulative cost differences between do-nothing and any other strategy. Since user cost is proportional to pavement roughness, the IRI curve is used in the calculation. Figure shows an example of calculating the benefit based on this method, for an overlay strategy during the 50 year analysis period. Since all strategies have benefits (savings in users costs) and costs (PWGSC dollars) calculated in the same way, they can be compared relatively to one another in the optimization routine.

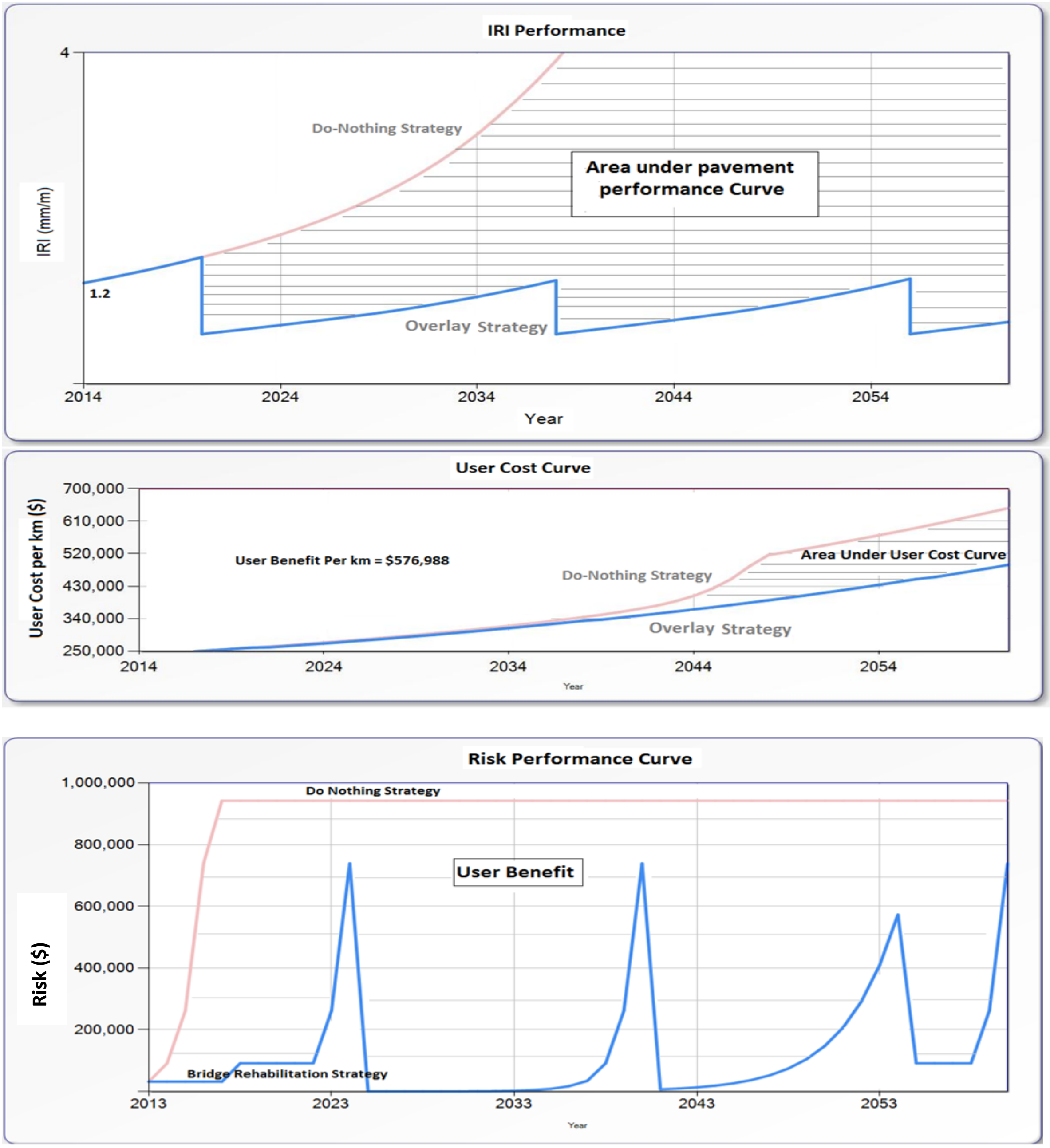


Figure 5: Examples of calculating the user benefit for an Overlay Strategy and for a Bridge Rehabilitation

Bridges

Risk was used as the benefit model for bridges. The risk is defined as the product of probability of bridge closure in any year multiplied by the monetary consequence of the closure. In the case of bridges, the benefit is the reduction in risk, calculated annually, as a monetary value. Figure shows an example to calculate user benefit for the Sikanni Bridge. In this figure, the Do-

Nothing strategy shows a bridge element in poor condition today and hence incurs a lot of risk early and over the life of the analysis since no treatment is done over the 50 year analysis period hence the probability of unsatisfactory performance continues to increase and by extension so does the risk. A strategy that includes treatments has much less risk since each treatment reduces the probability of unsatisfactory performance to acceptable levels. The bridge benefits are high due to the extraordinarily high detour lengths in this project.

PRIORITIZATION BASED ON LIFE CYCLE COST ANALYSIS (LCCA) RESULTS

In any public agency with a variety of assets, there are competing forces for a limited annual budget. This section describes the competing forces and discusses how they were quantified so that they can be compared against one another. The next section will discuss how a practical strategic plan for the entire highway is developed.

The main competing forces were:

- Conversion BST to ACP;
- Pavement Overlay on Existing ACP;
- Reconstruction (Geometric improvements); and
- Bridge Rehabilitation/Replacement.

For each of the first three of these items, the benefit of any strategy involved the reduction of Vehicle Operating Cost (VOC) as shown in Figure . Reconstruction also included an additional safety cost savings along with the VOC savings for its benefit model. VOC costs are based on an adaptation of the HDM (*6*) models as developed by New Zealand and assuming some cost escalation. In essence the reduction in roughness (IRI) contributes to a reduced VOC and hence quantifies the benefit of one rehabilitation strategy over another.

For a reconstruction option, a safety cost was included in the benefit. The safety cost consisted of two key components: a reduction in collision cost due to fewer accidents (recall, reconstruction was only considered on the highway for those sections that were not RAU-100 and hence had sub-standard geometric elements such as vertical and horizontal curves, width, side slope), and, a reduction in VOC due to decreased travel time (roughness and travel time are key components of VOC).

The following base model was used to predict total crash frequency:

$$N = AADT * L * 0.622 * 365 * 10-6 * e^{(-0.312)} * CMF \quad (8)$$

Where:

N = predicted total crash frequency for roadway segment (crashes per year)
L = total length of segment in km
CMF: Crash Modification Factors to account for curvature and road/shoulder width

= CMF (width) * CMF(curvature)
CMF (width) f(Lane width, Shoulder width)
CMF (curvature) (iterate through all horizontal and vertical curves in section) is f(Radius of horizontal curves, K factor for vertical curves)

A literature search indicated that by upgrading a section of highway from sub-standard to standard, not only is there a safety improvement due to a reduction in the number of collisions but the severity of the collisions is also reduced (*10*). This was taken into account in the reduction in the safety cost for a reconstruction.

As mentioned in the previous section and shown in Figure , the benefit of a bridge project was the reduction in risk due to a potential bridge closure. The exception to this was the three remaining truss bridges which were deemed to be functionally deficient and were handled separately.

A draft strategic plan was developed based on an optimization selecting the single strategy, for each asset across all asset types which had the largest net benefit. The draft plan selects projects independently of geographic location and proximity to adjacent assets. For example the roadway approach sections leading to a bridge slated for replacement would logically need to be improved at the time of bridge replacement. In addition, funding for both sets of improvements would need to be available at the same time. The draft plan therefore needs modification to make it practical to implement.

STRATEGIC PLAN RESULTS

This section outlines how the practical strategic plan was developed and shows the scheduling of the rehabilitation needs with limited budget as a constraint.

In addition to the LCCA priorities as described above, the following considerations were included to develop the practical strategic plans for the next 20 years. These considerations are all drivers that are additional to the pure economic benefits and strategy costs so far considered.

- Economic Constraints:
  - Annual capital budget of about $11 million was assumed in this plan ($220 million over next 20 years);
  - Required funding to convert all BST sections in the south end of the Highway (km 484) and complete all overlay projects on the existing pavements over 20 years is $67 Million and $48 Million respectively;
  - $90 Million over 20 years for the remaining reconstruction after some other PWGSC commitments are addressed.
- Operational Considerations:
  - Take into account both the practicality of actually performing the work by a contractor and the concerns of the travelling public;
  - The user benefit of reconstruction is based on time savings in increasing the speed limit from 80 km/h to 100 km/h;

  - Only long stretches in the order of 20 or 30 kilometres in length should be considered for RAU-100 upgrade;
  - It is not realistic to upgrade the geometry in isolated sections in different years; a practical plan needs to consider a more continuous upgrade to RAU-100;
  - Working the reconstruction from both ends of the sub-standard section and moving inwards extending already reconstructed sections is more practical than isolated sections of reconstruction. This was a key consideration and ultimately drove the development of the final plan;
  - The plan assumes a minimum length of about 10 km (6 mi) paving work to make economical tender packages for contactors;
- Other consideration - There are three truss bridges that have been flagged for replacement due to functional inadequacies.

Based on the LCCA results as well as the economic and other constraints, three reconstruction options that also considered bridge replacement were developed as shown in Figure :

- Option 1: Most reconstruction works within the first 20 years would be concentrated in the middle of the 221 km sub-standard corridor (km 624 and km 654) and in the north end of this corridor (km 729 to km 737) filling in a an 8 km gap between an already upgraded segment (constructed before development of this plan) and a segment that is currently under construction. This option includes two roadway improvements adjacent to two bridge replacement projects (MacDonald Creek Bridge and Racing River Bridge);
- Option 2: Most reconstruction works within the first 20 years would be concentrated on the south end of the sub-standard corridor (km 571 to km 612) and as in Option 1 working south from the north of the corridor (km 729 to km 737). This option includes one bridge replacement (Tetsa River Bridge #1) while deferring replacement of the MacDonald Creek and Racing river bridges;
- Option 3: Reconstruction works over the next 20 years would be distributed between the north end of the corridor (km 705 to km 737) and the south end of the corridor (km 571 to km 587). This option includes one bridge replacement (Tetsa River Bridge #1).

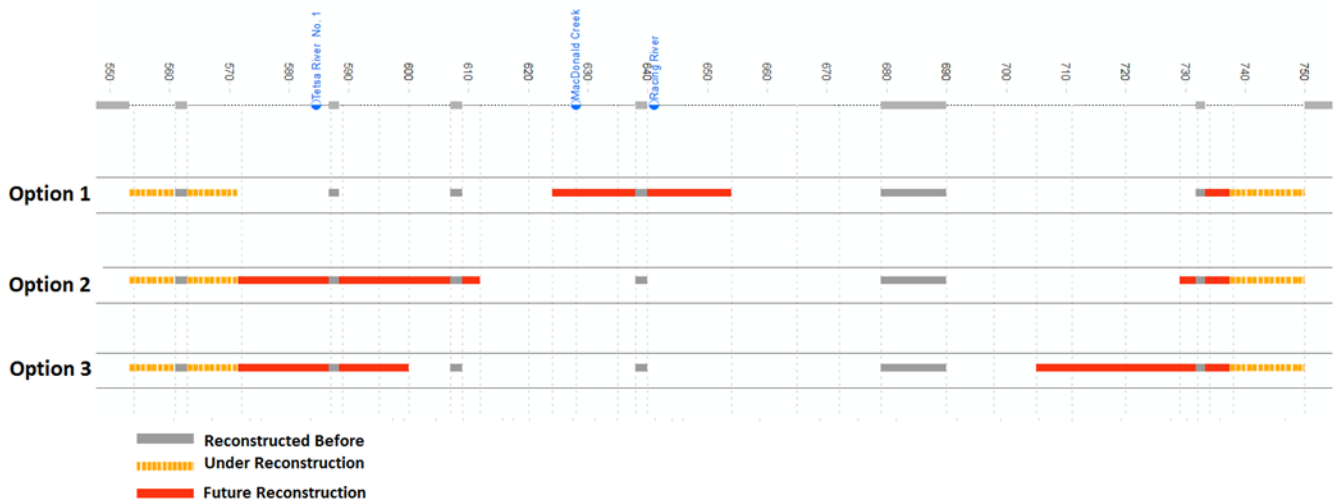


Figure 6: Practical reconstruction plans that were considered

The set of selected strategies, as defined by each of the three options, were evaluated against each other in terms of overall net benefit resulting in selection of the preferred “practical” strategic plan.

Option 3 was selected resulting in a strategic plan whereby all overlay projects and conversion of BST to ACP south of the geometrically sub-standard corridor together with 58 km of road reconstruction including the Tetsa River Bridge replacement could be completed within 20 years with the PWGSC budget of $11 Million annual capital. The remaining 2 functionally inadequate bridges are not replaced with this option and PWGSC will need to source additional funds to bring these up to standard. Figure shows the average condition plots for 50 years for the recommended road program. The figure shows that the current smoothness levels can be maintained at the existing road funding levels. Figure also shows average annual risk profile for 50 years for the recommended bridge program.

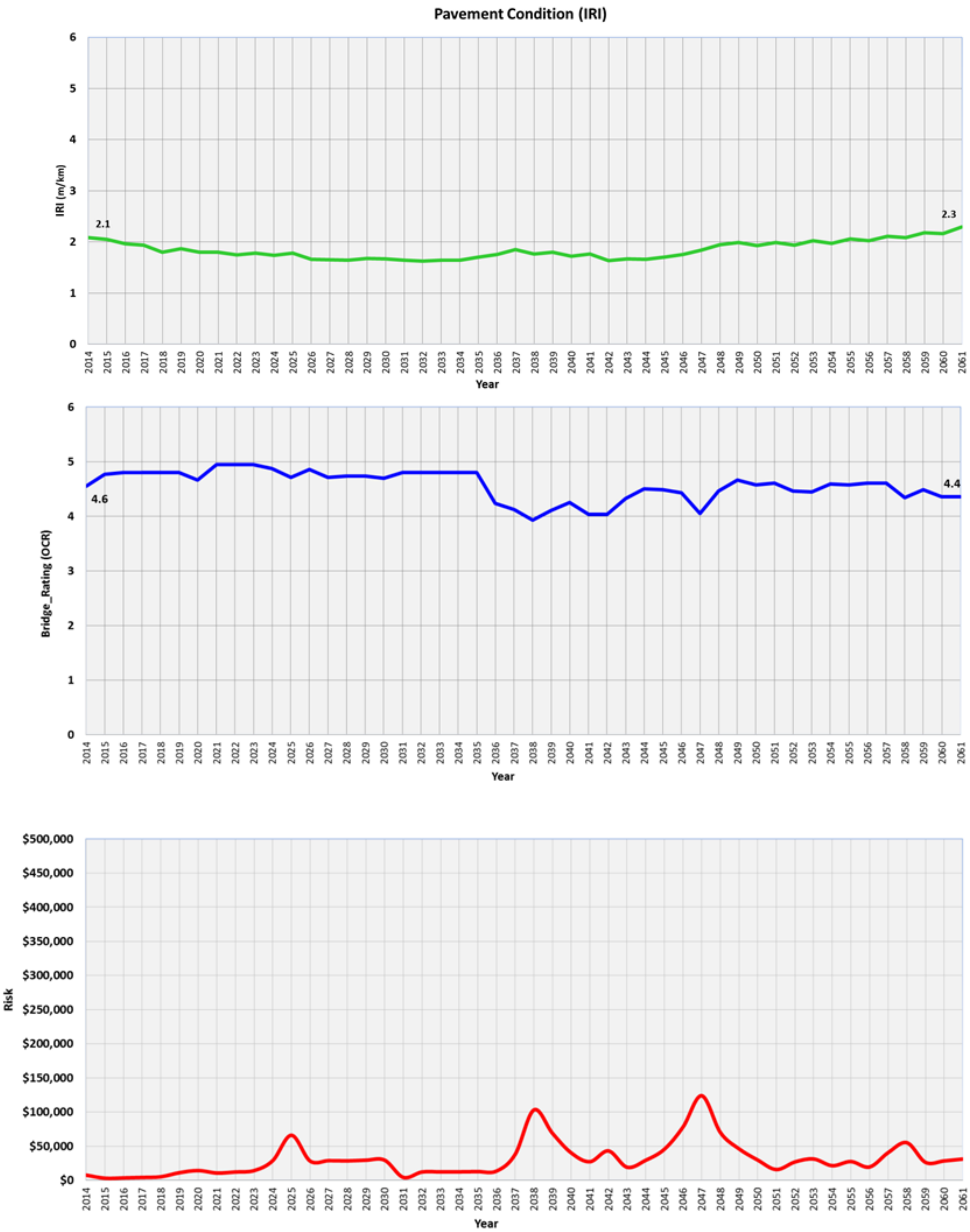


Figure 7: Summary Results – 50 Year Average IRI, 50 Year Bridge Rating and 50 Year Bridge Risk Profile

CONCLUSION

The work described in this paper represents a methodology for corridor or network wide cross asset optimization where the benefits of renewal or preservation of each asset class can be fairly compared in terms of the combined agency and road user financial benefits.

The methodology relied on the concept that financial value of reduction in risk for either traffic accidents or bridge closures could be directly compared to the financial savings arising out of good maintenance and preservation practices and reduced road user costs due to smoother road surfaces and improved geometry.

The resulting multi-year works plan closely matched that which was developed using the PWGSC's previous methodology of prioritizing the asset classes individually but the cross-asset management methodology has the added benefit of providing a reasonable and documented rationale to justify and obtain the required funding across the corridor.

Many agencies are faced with competing objectives for the assets they maintain and are questioning how to trade off one asset against another. This paper illustrates one such technique.

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