“Guidelines for Upgrading of Existing Bridgerails/ Approach Rail Transitions in Alberta”

INTRODUCTION

During the year 2000, Alberta Transportation (AT), adopted new standard bridgerail and approach rail transition designs meeting the requirements of “CAN/CSA-S6-00 Canadian Highway Bridge Design Code (CHBDC)” for new construction. For the assessment of existing bridgerails, the report titled “Guidelines for Upgrading of Existing Bridgerails/ Approach Rail Transitions in Alberta” was finalized in May 2003.

For the existing bridge inventory, there is a considerable mileage of existing bridgerails and approach guardrails that does not meet all the new code requirements. However, these existing bridgerails represent a significant capital expenditure that was invested with the expectations of a long service life. It is not reasonable to render all of them obsolete without justification from the potential to realize significant benefits. Transportation is only one of many competing societal needs that demand a share of government funding. Therefore a decision to upgrade or replace an existing bridgerail should be based on cost-benefit considerations to ensure the efficient use of limited funds. For example, if the traffic is of very low volume and the potential of a collision with the bridgerail is nearly non-existent, then there will be no benefit to spending the money on upgrading a bridgerail.

The main factors considered in the development of the cost-benefit procedure include:

- the frequency of a bridgerail or approach rail transition collision;
• the severity (societal cost) of a bridgerail or approach rail transition collision; and
the life cycle costs of bridgerail and/or approach rail transition upgrading.

The frequency of collisions (collisions/year) is affected by:

• the length of the bridgerail or transition
• the basic encroachment rate for the ADT and appropriate highway type (Table B.1)
• the highway curvature (Table B.2)
• the highway grade (Table B.3)
• the lateral encroachment probabilities based on shoulder width and design speed
  (Table B.4)
• the number of lanes (Table B.5)

The annualized societal costs or severity of the collision of an existing rail or upgrade
is affected by:

• the frequency of collisions
• the severity index based on bridgerail/transition type and design speed (Table B.7 and Figures)
• the height and/or type of occupancy under the bridge structure (Table B.6)
• the present worth conversion factors based on the design life and discount rate
  (Table B.8)

In Alberta, there are no inventory and accident database of sufficient detail, accuracy
and precision that one could use to evaluate the field performance of specific
bridgerail designs. To create such a database would be extremely time consuming
and costly. Therefore the procedure uses analysis modules contained in Appendix A
of the 1996 AASHTO Roadside Design Guide, the 2002 AASHTO Roadside Design
Guide, and the 1989 AASHTO Guide Specifications for Bridge Railings. It is
primarily based on the same concepts used by the 2000 CHBCD. The resulting
guidelines have been calibrated based on engineering judgement and practicality, and
are not intended to be academically rigorous.
The most effective upgrading alternative, including the do nothing option, can be determined by comparing the summation of the present worth of accident costs (PWAC) and the corresponding present worth of different upgrading alternatives. The alternative with the lowest total present worth will be the best alternative.

The analysis can also be used for prioritizing different bridge sites eligible for upgrading by ranking their benefit/cost ratios. The benefit will be the reduction in PWAC effected by the upgrade and the cost will be the cost of the selected upgrading alternative. When determining the upgrading costs, considerations should be given to other associated costs such as traffic accommodation, curb and deck repair, approach guardrail lengthening, side-slope improvements, additional right of way, etc.

The self-contained ‘Technical Summary’, from Appendix B of the UMA report, summarizes the benefit/cost analysis procedure and provides design examples. It is reproduced here for quick access on the Internet. The full report is available from Bob Readner of the Business Management Branch (Tel. 780-415-1068).

Contact:

Questions or further information on this guideline may be directed to Raymond Yu, P.Eng., Structural Standards Engineer, Alberta Transportation, (780) 415-1016.
The need to upgrade an existing bridgerail/approach rail transition is determined from a life cycle cost-benefit analysis procedure. This Technical Summary outlines the analysis procedure to be used for determining the need to upgrade Alberta Transportation’s standard bridgerails/approach rail transitions. Three design examples are presented to explain the procedure.

The steps to be followed in carrying out the life cycle cost-benefit analysis procedure are as follows:

1. Select the bridgerail/approach rail transition upgrading alternatives to be considered. Figures B.1 to B.4 show Alberta Transportation's existing standard bridgerails/approach rail transitions as well as recommended upgrading concepts for these bridgerails/approach rail transitions. Other bridgerail/approach rail transition upgrades may be used if justified by site specific requirements. The upgrading alternatives considered should include the “do nothing” alternative.

2. Determine the severity indices for each existing bridgerail/approach rail transition and upgrading alternative being considered. Severity indices are shown on Figures B.1 to B.4.

3. Determine the “present worth” of the collision costs for each bridgerail/approach rail transition upgrading alternative being considered using the following equation:

\[ \text{PWAC} = R \times k_c \times k_g \times P \times k_m \times k_s \times AC \times L \times KC / 1000 \]

Where:
PWAC = present worth of the collision costs
R = basic encroachment rate (Table B.1)
k_c = highway curvature factor (Table B.2)
k_g = highway grade factor (Table B.3)
P = lateral encroachment probability (Table B.4)
k_m = highway multi-lane factor (Table B.5)
k_s = bridge height and occupancy factor (Table B.6)
AC = cost per collision for severity index (Table B.7)
L = length of bridgerail for which collision costs are being determined (m)

= length of approach rail transition shown on Figure B.2. Use same length for all alternatives being considered. Collision costs determined are for the approach rail transition at one corner of the bridge only.

KC = converts annual accident costs to present worth for discount rates of 4 and 6% (Table B.8). The project life used to determine KC should not exceed 20 years.

4. Determine the bridgerail/approach rail transition upgrading costs including any deck and curb upgrading costs, approach roadway widening/side slope improvements costs, increased length of guardrail costs and right-of-way costs.

5. Determine the “present worth” of each bridgerail/approach rail transition upgrading alternative being considered by adding the bridgerail/approach rail transition upgrading cost (if any) to the “present worth” of the annual collision costs. Select the upgrading alternative with the lowest “present worth” at discount rates of 4% to 6%. If an upgrading alternative has the lowest “present worth” at a discount rate of 4% but not 6% the need for upgrading is left to the user’s discretion.
6. Alternatively, determine the “benefit/cost” ratio of each bridgerail/approach rail transition upgrading alternative being considered by dividing the reduction in “present worth” of the collision costs by the bridgerail/approach rail transition upgrading costs. Select the upgrading alternative with the highest “benefit/cost” ratio at discount rates of 4% and 6%. Assume that the “do nothing” alternative has a “benefit/cost” ratio of 1.0. If an upgrading alternative has the highest “benefit/cost” ratio at a discount rate of 4% but not 6%, the need for upgrading is left to the user’s discretion.

Table B.1: Basic Encroachment Rates (R)

<table>
<thead>
<tr>
<th>Traffic Volume (AADT)</th>
<th>Basic Encroachment Rate - Undivided Highways (encroachments/ km/yr)</th>
<th>Basic Encroachment Rate - Divided Highways (encroachments/ km/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1000</td>
<td>0.34</td>
<td>0.13</td>
</tr>
<tr>
<td>2000</td>
<td>0.61</td>
<td>0.23</td>
</tr>
<tr>
<td>3000</td>
<td>0.80</td>
<td>0.30</td>
</tr>
<tr>
<td>4000</td>
<td>0.91</td>
<td>0.36</td>
</tr>
<tr>
<td>5000</td>
<td>0.97</td>
<td>0.38</td>
</tr>
<tr>
<td>6000</td>
<td>0.92</td>
<td>0.38</td>
</tr>
<tr>
<td>7000</td>
<td>0.76</td>
<td>0.41</td>
</tr>
<tr>
<td>8000</td>
<td>0.66</td>
<td>0.43</td>
</tr>
<tr>
<td>9000</td>
<td>0.66</td>
<td>0.45</td>
</tr>
<tr>
<td>10,000</td>
<td>0.67</td>
<td>0.48</td>
</tr>
<tr>
<td>11,000</td>
<td>0.70</td>
<td>0.50</td>
</tr>
<tr>
<td>12,000</td>
<td>0.72</td>
<td>0.53</td>
</tr>
<tr>
<td>13,000</td>
<td>0.74</td>
<td>0.56</td>
</tr>
<tr>
<td>14,000</td>
<td>0.76</td>
<td>0.59</td>
</tr>
<tr>
<td>15,000</td>
<td>0.79</td>
<td>0.62</td>
</tr>
<tr>
<td>16,000</td>
<td>0.81</td>
<td>0.66</td>
</tr>
<tr>
<td>17,000</td>
<td>0.83</td>
<td>0.69</td>
</tr>
<tr>
<td>18,000</td>
<td>0.86</td>
<td>0.72</td>
</tr>
<tr>
<td>19,000</td>
<td>0.88</td>
<td>0.75</td>
</tr>
<tr>
<td>20,000</td>
<td>0.91</td>
<td>0.79</td>
</tr>
<tr>
<td>21,000</td>
<td>0.93</td>
<td>0.83</td>
</tr>
<tr>
<td>22,000</td>
<td>0.95</td>
<td>0.87</td>
</tr>
<tr>
<td>23,000</td>
<td>0.98</td>
<td>0.91</td>
</tr>
<tr>
<td>24,000</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td>25,000</td>
<td>1.02</td>
<td>0.99</td>
</tr>
</tbody>
</table>

NOTE: Basic Encroachment Rates are the encroachment rates on one side of the highway from the adjacent traffic lane only.
### Table B.2: Highway Curvature Factors ($k_c$)

<table>
<thead>
<tr>
<th>Radius of Curve (m)</th>
<th>Bridgerail/Approach Rail Transition on Outside of Curve</th>
<th>Bridgerail/Approach Rail Transition on Inside of Curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 300</td>
<td>4.00</td>
<td>2.00</td>
</tr>
<tr>
<td>350</td>
<td>3.00</td>
<td>1.65</td>
</tr>
<tr>
<td>400</td>
<td>2.40</td>
<td>1.45</td>
</tr>
<tr>
<td>450</td>
<td>1.90</td>
<td>1.30</td>
</tr>
<tr>
<td>500</td>
<td>1.50</td>
<td>1.15</td>
</tr>
<tr>
<td>550</td>
<td>1.20</td>
<td>1.05</td>
</tr>
<tr>
<td>&gt; 600</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Table B.3: Highway Grade Factors ($k_g$)

<table>
<thead>
<tr>
<th>Grade*</th>
<th>Highway Grade Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;-2</td>
<td>1.00</td>
</tr>
<tr>
<td>-3</td>
<td>1.25</td>
</tr>
<tr>
<td>-4</td>
<td>1.50</td>
</tr>
<tr>
<td>-5</td>
<td>1.75</td>
</tr>
<tr>
<td>&lt;-6</td>
<td>2.00</td>
</tr>
</tbody>
</table>

* Positive grade increases in the direction that traffic is travelling.

### Table B.4: Lateral Encroachment Probabilities (P)

<table>
<thead>
<tr>
<th>Shoulder Width (m)</th>
<th>Design Speed (kph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
</tr>
<tr>
<td>0.00</td>
<td>1.0000</td>
</tr>
<tr>
<td>0.50</td>
<td>0.6798</td>
</tr>
<tr>
<td>1.00</td>
<td>0.5203</td>
</tr>
<tr>
<td>1.50</td>
<td>0.4132</td>
</tr>
<tr>
<td>2.00</td>
<td>0.3319</td>
</tr>
<tr>
<td>2.50</td>
<td>0.2698</td>
</tr>
<tr>
<td>3.00</td>
<td>0.2209</td>
</tr>
<tr>
<td>3.50</td>
<td>0.1822</td>
</tr>
<tr>
<td>4.00</td>
<td>0.1506</td>
</tr>
<tr>
<td>4.50</td>
<td>0.1248</td>
</tr>
<tr>
<td>5.00</td>
<td>0.1035</td>
</tr>
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</table>
Table B.5: Highway Multi-Lane Factors ($k_m$)

<table>
<thead>
<tr>
<th>Design Speed (kph)</th>
<th>Highway Multi-Lane Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1.20</td>
</tr>
<tr>
<td>60</td>
<td>1.30</td>
</tr>
<tr>
<td>80</td>
<td>1.45</td>
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<td>100</td>
<td>1.60</td>
</tr>
<tr>
<td>110</td>
<td>1.65</td>
</tr>
<tr>
<td>120</td>
<td>1.70</td>
</tr>
</tbody>
</table>

Table B.6: Bridge Height and Occupancy Factors ($k_o$)

<table>
<thead>
<tr>
<th>Bridge Height Above Ground (m)</th>
<th>Bridge Height and Occupancy Factor</th>
<th>Bridge Height Above Ground (m)</th>
<th>Bridge Height and Occupancy Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Occupancy Land Use</td>
<td>High Occupancy Land Use¹</td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>0.70</td>
<td>0.70</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>0.70</td>
<td>0.80</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>0.70</td>
<td>0.90</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>0.70</td>
<td>1.00</td>
<td>17</td>
</tr>
<tr>
<td>9</td>
<td>0.80</td>
<td>1.15</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>0.95</td>
<td>1.25</td>
<td>19</td>
</tr>
<tr>
<td>11</td>
<td>1.05</td>
<td>1.35</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>1.20</td>
<td>1.50</td>
<td>&gt;24</td>
</tr>
<tr>
<td>13</td>
<td>1.30</td>
<td>1.60</td>
<td></td>
</tr>
</tbody>
</table>

¹ High Occupancy Land Use includes highways or railways beneath bridges. It also includes water deeper than 3 metres.

Table B.7: Severity Index – Cost per Collision Relationship

<table>
<thead>
<tr>
<th>Severity Index</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$20,448</td>
</tr>
<tr>
<td>2</td>
<td>$37,520</td>
</tr>
<tr>
<td>3</td>
<td>$74,560</td>
</tr>
<tr>
<td>4</td>
<td>$110,800</td>
</tr>
<tr>
<td>5</td>
<td>$186,000</td>
</tr>
<tr>
<td>6</td>
<td>$317,040</td>
</tr>
<tr>
<td>7</td>
<td>$470,240</td>
</tr>
<tr>
<td>8</td>
<td>$720,000</td>
</tr>
<tr>
<td>9</td>
<td>$1,030,000</td>
</tr>
<tr>
<td>10</td>
<td>$1,340,000</td>
</tr>
</tbody>
</table>
### Table B.8: Present Worth Conversion Factors (KC)

<table>
<thead>
<tr>
<th>Project Life (years)</th>
<th>4% Discount Rate KC</th>
<th>6% Discount Rate KC</th>
<th>Project Life (years)</th>
<th>4% Discount Rate KC</th>
<th>6% Discount Rate KC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.971</td>
<td>0.953</td>
<td>11</td>
<td>9.712</td>
<td>8.711</td>
</tr>
<tr>
<td>2</td>
<td>1.924</td>
<td>1.870</td>
<td>12</td>
<td>10.496</td>
<td>9.335</td>
</tr>
<tr>
<td>3</td>
<td>2.858</td>
<td>2.752</td>
<td>13</td>
<td>11.266</td>
<td>9.936</td>
</tr>
<tr>
<td>4</td>
<td>3.774</td>
<td>3.601</td>
<td>14</td>
<td>12.020</td>
<td>10.513</td>
</tr>
<tr>
<td>5</td>
<td>4.672</td>
<td>4.418</td>
<td>15</td>
<td>12.76</td>
<td>11.069</td>
</tr>
<tr>
<td>6</td>
<td>5.554</td>
<td>5.204</td>
<td>16</td>
<td>13.486</td>
<td>11.605</td>
</tr>
<tr>
<td>7</td>
<td>6.418</td>
<td>5.960</td>
<td>17</td>
<td>14.198</td>
<td>12.119</td>
</tr>
<tr>
<td>8</td>
<td>7.266</td>
<td>6.688</td>
<td>18</td>
<td>14.896</td>
<td>12.615</td>
</tr>
<tr>
<td>9</td>
<td>8.097</td>
<td>7.388</td>
<td>19</td>
<td>15.580</td>
<td>13.092</td>
</tr>
<tr>
<td>10</td>
<td>8.912</td>
<td>8.062</td>
<td>20</td>
<td>16.252</td>
<td>13.550</td>
</tr>
</tbody>
</table>
EXAMPLE 1 - RED DEER RIVER BRIDGE ON HWY 36 (BF7461)

BACKGROUND INFORMATION

- highway is a two lane undivided highway;
- highway design speed is 100 kph;
- highway is on tangent horizontal alignment;
- highway is on a vertical curve with a maximum grade less than 2%;
- bridge deck is 13.0 metres above stream bed (water depth less than 3.0 metres);
- bridge shoulder width is 0.9 metres;
- existing bridgerail is a 450 metre long horizontal rail bridgerail on safety curb;
- existing approach rail transition is deep-beam guardrail unconnected to bridgerail;
- AADT is 1700; and
- remaining life of bridge deck and curbs is a minimum of 20 years.

BRIDGERAIL UPGRADING

Alternative 1 “Do-Nothing”

Input Variables

- \( R = 0.53 \) (see Table B.1)
- \( k_c = 1.0 \) (see Table B.2)
- \( k_g = 1.0 \) (see Table B.3)
- \( P = 0.7848 \) (interpolated from Table B.4)
- \( k_m = 1.60 \) (see Table B.5)
- \( k_s = 1.30 \) (see Table B.6)
- \( SI = 3.6 \) (see Figure B.1(a))
- \( AC = $96,300 \) (see Table B.7)
- \( KC = 16.252 \) (4% discount rate) (see Table B.8)
- \( KC = 13.550 \) (6% discount rate) (see Table B.8)
- \( L = 450 \text{ m} \)
Present Worth of Accident Costs (PWAC)

\[
PWAC = 0.53 \times 1.0 \times 1.0 \times 0.7848 \times 1.60 \times 1.30 \times 96,300 \times 450 \text{ m} \times 16.252/1000 = 609,320 \text{ (4\% discount rate)}
\]

\[
PWAC = 0.53 \times 1.0 \times 1.0 \times 0.7848 \times 1.60 \times 1.30 \times 96,300 \times 450 \text{ m} \times 13.550/1000 = 508,010 \text{ (6\% discount rate)}
\]

Present Worth of Upgrading Costs (PWUC)

PWUC = $0

Total Present Worth (TPW)

\[
TPW = 609,320 + 0 = 609,320 \text{ (4\% discount rate)}
\]

\[
TPW = 508,010 + 0 = 508,010 \text{ (6\% discount rate)}
\]

**Alternative 2 “Upgrade Existing Bridgerail Based on Figure B.3a”**

Input Variables

- R = 0.53 (see Table B.1)
- \( k_c = 1.0 \) (see Table B.2)
- \( k_g = 1.0 \) (see Table B.3)
- \( P = 0.7848 \) (interpolated from Table B.4)
- \( k_m = 1.60 \) (see Table B.5)
- \( k_s = 1.30 \) (see Table B.6)
- SI = 3.3 (see Figure B.3(a))
- AC = $85,430 (see Table B.7)
- KC = 16.252 (4\% discount rate) (see Table B.8)
- KC = 13.550 (6\% discount rate) (see Table B.8)
- L = 450 m
Present Worth of Accident Costs (PWAC)

\[
PWAC = 0.53 \times 1.0 \times 1.0 \times 0.7848 \times 1.60 \times 1.30 \times \$85,430 \times 450 \text{ m} \times 16.252/1000 = \$540,540 \text{ (4\% discount rate)}
\]

\[
PWAC = 0.53 \times 1.0 \times 1.0 \times 0.7848 \times 1.60 \times 1.30 \times \$85,430 \times 450 \text{ m} \times 13.550/1000 = \$450,670 \text{ (6\% discount rate)}
\]

Present Worth of Upgrading Costs (PWUC)

\[
PWUC = 450 \text{ m} \times \$250/\text{ m} = \$112,500
\]

Total Present Worth (TPW)

\[
TPW = \$540,540 + \$112,500 = \$653,040 \text{ (4\% discount rate)}
\]

\[
TPW = \$450,670 + \$112,500 = \$563,170 \text{ (6\% discount rate)}
\]

The “Do-Nothing” alternative has the lowest present worth at discount rates of 4\% and 6\% and is therefore the recommended alternative.

**APPROACH RAIL TRANSITION UPGRADING**

**Alternative 1 “Do-Nothing”**

Input Variables

- R = 0.53 (see Table B.1)
- \( k_c = 1.0 \) (see Table B.2)
- \( k_y = 1.0 \) (see Table B.3)
- P = 0.7848 (interpolated from Table B.4)
- \( k_m = 1.60 \) (see Table B.5)
- \( k_s = 1.30 \) (see Table B.6)
- SI = 5.6 (see Figure B.2(a))
- AC = $264,620 (see Table B.7)
o KC = 16.252 (4% discount rate) (see Table B.8)
o KC = 13.550 (6% discount rate) (see Table B.8)
o L = 8.5 m (see Figure B.2(a)

Present Worth of Accident Costs (PWAC)

\[
PWAC = 0.53 \times 1.0 \times 1.0 \times 0.7848 \times 1.60 \times 1.30 \times 264,620 \times 8.5 \times 16.252 / 1000
= 31,630 \text{ (4\% discount rate)}
\]

\[
PWAC = 0.53 \times 1.0 \times 1.0 \times 0.7848 \times 1.60 \times 1.30 \times 264,620 \times 8.5 \times 13.550 / 1000
= 26,370 \text{ (6\% discount rate)}
\]

Present Worth of Upgrading Costs (PWUC)

PWUC = $0

Total Present Worth (TPW)

\[
TPW = 31,630 + 0 = 31,630 \text{ (4\% discount rate)}
\]

\[
TPW = 26,370 + 0 = 26,370 \text{ (6\% discount rate)}
\]

**Alternative 2 “Upgrade Existing Approach Rail Transition Based on Figure B.4a”**

Input Variables

o R = 0.53 (see Table B.1)
o \(k_c = 1.0\) (see Table B.2)
o \(k_g = 1.0\) (see Table B.3)
o P = 0.7848 (interpolated from Table B.4)
o \(k_m = 1.60\) (see Table B.5)
o \(k_s = 1.30\) (see Table B.6)
o SI = 3.3 (see Figure B.4(a))
o AC = $85,430 (see Table B.7)
- KC = 16.252 (4% discount rate) (see Table B.8)
- KC = 13.550 (6% discount rate) (see Table B.8)
- L = 8.5 m (see Figure B.2(a))

Present Worth of Accident Costs (PWAC)

$$PWAC = 0.53 \times 1.0 \times 1.0 \times 0.7848 \times 1.60 \times 1.30 \times $85,430 \times 8.5 \times 16.252/1000 = $10,210 \text{ (4% discount rate)}$$

$$PWAC = 0.53 \times 1.0 \times 1.0 \times 0.7848 \times 1.60 \times 1.30 \times $85,430 \times 8.5 \times 13.550/1000 = $8,510 \text{ (6% discount rate)}$$

Present Worth of Upgrading Costs (PWUC)

$$PWUC = $8,000/\text{corner} = $8,000$$

Total Present Worth (TPW)

$$TPW = $10,210 + $8,000 = $18,210 \text{ (4% discount rate)}$$
$$TPW = $8,510 + $8,000 = $16,510 \text{ (6% discount rate)}$$

The “Upgrade Existing Approach Rail Transition” alternative has the lowest present worth at discount rates of 4% and 6% and is therefore the recommended alternative.

**SUMMARY**

Recommended that the existing approach rail transitions be upgraded but not the existing bridgerails.
EXAMPLE 2 - WANDERING RIVER BRIDGE ON HWY 63 (BF76185)

BACKGROUND INFORMATION

- highway is a two lane undivided highway;
- highway design speed is 100 kph;
- highway is on tangent horizontal alignment;
- highway is on a vertical grade of 0.8%;
- bridge deck is 7.5 metres above stream bed (water depth less than 3.0 metres);
- bridge shoulder width is 1.8 metres;
- existing bridgerail is an 110 metre long single layer deep-beam bridgerail on safety curb;
- existing approach rail transition is deep-beam guardrail unconnected to bridgerail;
- AADT is 2500; and
- remaining life of bridge deck and curbs is a minimum of 20 years.

BRIDGERAIL UPGRADING

Alternative 1 “Do-Nothing”

Input Variables

- $R = 0.70$ (see Table B.1)
- $k_c = 1.0$ (see Table B.2)
- $k_g = 1.0$ (see Table B.3)
- $P = 0.6351$ (interpolated from Table B.4)
- $k_m = 1.60$ (see Table B.5)
- $k_s = 0.70$ (see Table B.6)
- $SI = 3.8$ (see Figure B.1(c)
- $AC = 103,550$ (see Table B.7)
- $KC = 16.252$ (4% discount rate) (see Table B.8)
- $KC = 13.550$ (6% discount rate) (see Table B.8)
- $L = 110$ m
Present Worth of Accident Costs (PWAC)

PWAC  = 0.70 x 1.0 x 1.0 x 0.6351 x 1.60 x 0.70 x $103,550 x 110 m x 16.252/1000
= $92,170 (4% discount rate)

PWAC  = 0.70 x 1.0 x 1.0 x 0.6351 x 1.60 x 0.70 x $103,550 x 110 m x 13.550/1000
= $76,850 (6% discount rate)

Present Worth of Upgrading Costs (PWUC)

PWUC = $0

Total Present Worth (TPW)

TPW = $92,170 + $0 = $92,170 (4% discount rate)
TPW = $76,850 + $0 = $76,850 (6% discount rate)

Alternative 2 “Upgrade Existing Bridgerail Based on Figure B.3g”

Input Variables

- R = 0.70 (see Table B.1)
- k_c = 1.0 (see Table B.2)
- k_g = 1.0 (see Table B.3)
- P = 0.6351 (interpolated from Table B.4)
- k_m = 1.60 (see Table B.5)
- k_s = 0.70 (see Table B.6)
- SI = 3.3 (see Figure B.3(g))
- AC = $85,432 (see Table B.7)
- KC = 16.252 (4% discount rate) (see Table B.8)
- KC = 13.550 (6% discount rate) (see Table B.8)
- L = 110 m
Present Worth of Accident Costs (PWAC)

\[
PWAC = 0.70 \times 1.0 \times 1.0 \times 0.6351 \times 1.60 \times 0.70 \times 85,432 \times 110 \times 16.252/1000 = 76,050 \text{ (4\% discount rate)}
\]

\[
PWAC = 0.70 \times 1.0 \times 1.0 \times 0.6351 \times 1.60 \times 0.70 \times 85,432 \times 110 \times 13.550/1000 = 63,400 \text{ (6\% discount rate)}
\]

Present Worth of Upgrading Costs (PWUC)

\[
PWUC = 110 \times 250/1000 = 27,000
\]

Total Present Worth (TPW)

\[
TPW = 76,050 + 27,000 = 103,050 \text{ (4\% discount rate)}
\]

\[
TPW = 63,400 + 27,000 = 90,400 \text{ (6\% discount rate)}
\]

The “Do Nothing” alternative has the lowest present worth at discount rates of 4\% and 6\% and is therefore the recommended alternative.

**APPROACH RAIL TRANSITION UPGRADING**

**Alternative 1 “Do-Nothing”**

Input Variables

- \( R = 0.70 \) (see Table B.1)
- \( k_c = 1.0 \) (see Table B.2)
- \( k_g = 1.0 \) (see Table B.3)
- \( P = 0.6351 \) (interpolated from Table B.4)
- \( k_m = 1.60 \) (see Table B.5)
- \( k_s = 0.70 \) (see Table B.6)
- \( SI = 5.6 \) (see Figure B.2(c))
- \( AC = 264,620 \) (see Table B.7)
\[ KC = 16.252 \text{ (4\% discount rate)} \text{ (see Table B.8)} \]
\[ KC = 13.550 \text{ (6\% discount rate)} \text{ (see Table B.8)} \]
\[ L = 8.5 \text{ m} \text{ (see Figure B.2(c))} \]

**Present Worth of Accident Costs (PWAC)**

\[
\text{PWAC} = 0.70 \times 1.0 \times 1.0 \times 0.6351 \times 1.60 \times 0.70 \times 264,620 \times 8.5 \times 16.252 / 1000 \\
= 18,200 \text{ (4\% discount rate)}
\]

\[
\text{PWAC} = 0.70 \times 1.0 \times 1.0 \times 0.6351 \times 1.60 \times 0.70 \times 264,620 \times 8.5 \times 13.550 / 1000 \\
= 15,180 \text{ (6\% discount rate)}
\]

**Present Worth of Upgrading Costs (PWUC)**

\[ \text{PWUC} = 0 \]

**Total Present Worth (TPW)**

\[
\text{TPW} = 18,200 + 0 = 18,200 \text{ (4\% discount rate)}
\]
\[
\text{TPW} = 15,180 + 0 = 15,180 \text{ (6\% discount rate)}
\]

**Alternative 2 “Upgrade Existing Approach Rail Transition Based on Figure B.4g”**

Input Variables

\[ R = 0.70 \text{ (see Table B.1)} \]
\[ k_c = 1.0 \text{ (see Table B.2)} \]
\[ k_g = 1.0 \text{ (see Table B.3)} \]
\[ P = 0.6351 \text{ (interpolated from Table B.4)} \]
\[ k_m = 1.60 \text{ (see Table B.5)} \]
\[ k_s = 0.70 \text{ (see Table B.6)} \]
\[ SI = 3.3 \text{ (see Figure B.4(g))} \]
\[ AC = 85,430 \text{ (see Table B.7)} \]
\( KC = 16.252 \) (4% discount rate) (see Table B.8)
\( KC = 13.550 \) (6% discount rate) (see Table B.8)
\( L = 8.5 \text{ m} \) (see Figure B.2(c))

Present Worth of Accident Costs (PWAC)

\[
PWAC = 0.70 \times 1.0 \times 1.0 \times 0.6351 \times 1.60 \times 0.70 \times \$85,430 \times 8.5 \text{ m} \times 16.252/1000 = \$5,880 \text{ (4% discount rate)}
\]

\[
PWAC = 0.70 \times 1.0 \times 1.0 \times 0.6351 \times 1.60 \times 0.70 \times \$85,430 \times 8.5 \text{ m} \times 13.550/1000 = \$4,900 \text{ (6% discount rate)}
\]

Present Worth of Upgrading Costs (PWUC)

\[ PWUC = \$8,000/\text{corner} = \$8,000 \]

Total Present Worth (TPW)

\[
TPW = \$5,880 + \$8,000 = \$13,880 \text{ (4% discount rate)}
\]

\[
TPW = \$4,900 + \$8,000 = \$12,900 \text{ (6% discount rate)}
\]

The “Upgrade Existing Approach Rail Transition” alternative has the lowest present worth at discount rates of 4% and 6% and is therefore the recommended alternative.

**SUMMARY**

Recommended that the existing approach rail transitions be upgraded but not the existing bridgerails.
EXAMPLE 3 - HIGHWOOD RIVER BRIDGE ON HWY 2 (BF74458N)

BACKGROUND INFORMATION

- highway is a four lane divided highway;
- highway design speed is 110 kph;
- highway is on tangent horizontal alignment;
- highway is on a vertical curve with a maximum grade less than 2%;
- bridge deck is 9.5 metres above stream bed (water depth less than 3.0 metres);
- bridge shoulder width is 2.5 metres (average of left and right shoulders);
- existing bridgerail is a 200 metre long horizontal rail bridgerail on safety curb;
- existing approach rail transition is deep-beam guardrail connected to bridgerail;
- AADT is 9900; and
- remaining life of bridge deck and curbs is a minimum of 20 years.

BRIDGERAIL UPGRADING

Alternative 1 “Do-Nothing”

Input Variables

- \( R = 0.48 \) (see Table B.1)
- \( k_c = 1.0 \) (see Table B.2)
- \( k_g = 1.0 \) (see Table B.3)
- \( P = 0.5849 \) (see Table B.4)
- \( k_m = 1.65 \) (see Table B.5)
- \( k_s = 0.88 \) (see Table B.6)
- \( SI = 4.0 \) (see Figure B.1(f))
- \( AC = \$110,800 \) (see Table B.7)
- \( KC = 16.252 \) (4% discount rate) (see Table B.8)
- \( KC = 13.550 \) (6% discount rate) (see Table B.8)
- \( L = 200 \text{ m} \)
Present Worth of Accident Costs (PWAC)

\[ \text{PWAC} = 0.48 \times 1.0 \times 1.0 \times 0.5849 \times 1.65 \times 0.88 \times 110,800 \times 200 \text{ m} \times 16.252/1000 \]
\[ = $146,810 \text{ (4% discount rate)} \]

\[ \text{PWAC} = 0.48 \times 1.0 \times 1.0 \times 0.5849 \times 1.65 \times 0.88 \times 110,800 \times 200 \text{ m} \times 13.550/1000 \]
\[ = $122,400 \text{ (6% discount rate)} \]

Present Worth of Upgrading Costs (PWUC)

\[ \text{PWUC} = 0 \]

Total Present Worth (TPW)

\[ \text{TPW} = 146,810 + 0 = 146,810 \text{ (4% discount rate)} \]
\[ \text{TPW} = 122,400 + 0 = 122,400 \text{ (6% discount rate)} \]

**Alternative 2 “Upgrade Existing Bridgerail Based on Figure B.3l”**

Input Variables

- R = 0.48 (see Table B.1)
- \( k_c \) = 1.0 (see Table B.2)
- \( k_g \) = 1.0 (see Table B.3)
- P = 0.5849 (see Table B.4)
- \( k_m \) = 1.65 (see Table B.5)
- \( k_s \) = 0.88 (see Table B.6)
- SI = 3.3 (see Figure B.3(l))
- AC = $85,430 (see Table B.7)
- KC = 16.252 (4% discount rate) (see Table B.8)
- KC = 13.550 (6% discount rate) (see Table B.8)
- L = 200 m
Present Worth of Accident Costs (PWAC)

PWAC = 0.48 x 1.0 x 1.0 x 0.5849 x 1.65 x 0.88 x $85,430 x 200 m x 16.252/1000 = $113,190 (4% discount rate)

PWAC = 0.48 x 1.0 x 1.0 x 0.5849 x 1.65 x 0.88 x $85,430 x 200 m x 13.550/1000 = $94,300 (6% discount rate)

Present Worth of Upgrading Costs (PWUC)

PWUC = 200 m x $300/m = $60,000

Total Present Worth (TPW)

TPW = $113,190 + $60,000 = $173,190 (4% discount rate)
TPW = $94,300 + $60,000 = $154,300 (6% discount rate)

The “Do Nothing” has the lowest present worth at discount rates of 4% and 6% and is therefore the recommended alternative.

APPROACH RAIL TRANSITION UPGRADING

Alternative 1 “Do-Nothing”

Input Variables

- R = 0.48 (see Table B.1)
- k_c = 1.0 (see Table B.2)
- k_g = 1.0 (see Table B.3)
- P = 0.5849 (interpolated from Table B.4)
- k_m = 1.65 (see Table B.5)
- k_s = 0.88 (see Table B.6)
- SI = 5.0 (see Figure B.2(f))
- AC = $186,000 (see Table B.7)
**Present Worth of Accident Costs (PWAC)**

\[
PWAC = 0.48 \times 1.0 \times 1.0 \times 0.5849 \times 1.65 \times 0.88 \times $186,000 \times 5.0 \times 16.252/1000
\]

\[= $6,160 \text{ (4% discount rate)}
\]

\[
PWAC = 0.48 \times 1.0 \times 1.0 \times 0.5849 \times 1.65 \times 0.88 \times $186,000 \times 5.0 \times 13.550/1000
\]

\[= $5,140 \text{ (6% discount rate)}
\]

**Present Worth of Upgrading Costs (PWUC)**

\[PWUC = $0
\]

**Total Present Worth (TPW)**

\[TPW = $6,160 + $0 = $6,160 \text{ (4% discount rate)}
\]

\[TPW = $5,140 + $0 = $5,140 \text{ (6% discount rate)}
\]

**Alternative 2 “Upgrade Existing Approach Rail Transition Based on Figure B.4n”**

**Input Variables**

- KC = 16.252 (4% discount rate) (see Table B.8)
- KC = 13.550 (6% discount rate) (see Table B.8)
- L = 5.0 m (see Figure B.2(f))

**Present Worth of Accident Costs (PWAC)**

\[
PWAC = 0.48 \times 1.0 \times 1.0 \times 0.5849 \times 1.65 \times 0.88 \times $186,000 \times 5.0 \times 16.252/1000
\]

\[= $6,160 \text{ (4% discount rate)}
\]

\[
PWAC = 0.48 \times 1.0 \times 1.0 \times 0.5849 \times 1.65 \times 0.88 \times $186,000 \times 5.0 \times 13.550/1000
\]

\[= $5,140 \text{ (6% discount rate)}
\]
o $KC = 16.252$ (4% discount rate) (see Table B.8)
o $KC = 13.550$ (6% discount rate) (see Table B.8)
o $L = 5.0 \text{ m}$ (see Figure B.2(f))

Present Worth of Accident Costs (PWAC)

\[
\text{PWAC} = 0.48 \times 1.0 \times 1.0 \times 0.5849 \times 1.65 \times 0.88 \times \$96,300 \times 5.0 \text{ m} \times 16.252/1000 = \$3,190 \text{ (4% discount rate)}
\]

\[
\text{PWAC} = 0.48 \times 1.0 \times 1.0 \times 0.5849 \times 1.65 \times 0.88 \times \$96,300 \times 5.0 \text{ m} \times 13.550/1000 = \$2,660 \text{ (6% discount rate)}
\]

Present Worth of Upgrading Costs (PWUC)

\[
\text{PWUC} = \$8,000/\text{corner} = \$8,000
\]

Total Present Worth (TPW)

\[
\text{TPW} = \$3,190 + \$6,000 = \$9,190 \text{ (4% discount rate)}
\]

\[
\text{TPW} = \$2,660 + \$6,000 = \$8,660 \text{ (6% discount rate)}
\]

The “Do Nothing” alternative has the lowest present worth at discount rates of 4% and 6% and is therefore the recommended alternative.

**SUMMARY**

Recommended that the existing bridgerails and approach rail transitions not be upgraded.

**FIGURES:**
(c) SINGLE LAYER / DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION

(DETAILS SHOWN ARE BASED ON D-300, S-350, SPERR-B AND 5-400468)

EXISTING ALBERTA TRANSPORTATION APPROACH RAIL TRANSITIONS

FIGURE B.2 page 2 of 4
(e) DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION

DETAILS SHOWN ARE BASED ON AHS, S-4423 AND S-4437

(f) DOUBLE TUBE BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION

DETAILS SHOWN ARE BASED ON AHS, S-4606-89 AND S-474-48

EXISTING ALBERTA TRANSPORTATION APPROACH RAIL TRANSITIONS

FIGURE B.2

page 3 of 4
DOUBLE TUBE BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION

[SPECIFICATIONS SHOWN ARE BASED ON DRIVES 54-1402 AND 5-1402]

SINGLE TUBE BRIDGERAIL ON PARTICIPATING CURB

[SPECIFICATIONS SHOWN ARE BASED ON DRIVES 54-1402 AND 5-1402]

EXISTING ALBERTA TRANSPORTATION APPROACH RAIL TRANSITIONS

FIGURE B.2

page 4 of 4
SINGLE LAYER/DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON SAFETY CURB PL-1 UPGRADE WITH HSS BRIDGERAIL

SINGLE LAYER/DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON SAFETY CURB PL-1 UPGRADE WITH SINGLE LAYER DEEP-BEAM BRIDGERAIL

(SHORT BRIDGES ONLY)

DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON PARTICIPATING CURB PL-2 UPGRADE WITH HSS BRIDGERAIL

DOUBLE TUBE BRIDGERAIL ON SAFETY CURB PL-2 UPGRADE WITH HSS BRIDGERAIL

DOUBLE TUBE BRIDGERAIL ON PARTICIPATING CURB PL-2 UPGRADE WITH HSS BRIDGERAIL

SINGLE TUBE BRIDGERAIL ON PARTICIPATING CURB PL-2 UPGRADE WITH HSS BRIDGERAIL

RECOMMENDED BRIDGERAIL UPGRADING CONCEPTS

FIGURE B.3
HORIZONTAL RAIL BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH NO BRIDGERAIL UPGRADE

HORIZONTAL RAIL BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH HSS BRIDGERAIL UPGRADE

APPROACH RAIL TRANSITION
RECOMMENDED UPGRADE CONCEPTS

FIGURE B.4
(c) HORIZONTAL RAIL BRIDGE RAIL ON SAFETY CURB APPROACH RAIL TRANSITION PL-2 UPGRADE WITH HSS BRIDGE RAIL UPGRADE

MOTU:
1. FOR DOWNSTREAM ENDS OF BRIDGES ON DIVIDED HIGHWAYS WHERE APPROACH GUARDRAILS ARE ELIMINATED, ATTACH END GUARDRAILS DIRECTLY TO CONCRETE CURB MOULDING AND OEMERGENT CURB; BE SURE TO ATTACH GUARDRAIL TO CURB MOULDING WITH INSIDE END OF GUARDRAIL AT CURB MOULDING ADJUSTMENT TO BRIDGE WITH REMAINING POST SPACINGS AT 3000MM.
2. FOR UPSTREAM ENDS OF BRIDGES ON DIVIDED HIGHWAYS WHERE THE APPROACH RAIL TRANSITIONS TO A GUARDRAIL WITH THE GUARDRAIL ATTACHED BACK TO THE FACE OF THE BRIDGE, PROVIDE GUARDRAILS THAT ARE ATTACHED TO THE CURB MOULDING WITH A FULL STRENGTH CONNECTION.

(d) VERTICAL RAIL BRIDGE RAIL ON SAFETY CURB APPROACH RAIL TRANSITION PL-1 UPGRADE WITH NO BRIDGE RAIL UPGRADE

APPROACH RAIL TRANSITION
RECOMMENDED UPGRADE CONCEPTS

FIGURE B.4
page 2 of 10
(e) VERTICAL RAIL BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH HSS BRIDGERAIL UPGRADE

(f) VERTICAL RAIL BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION
PL-2 UPGRADE WITH HSS BRIDGERAIL UPGRADE

APPROACH RAIL TRANSITION
RECOMMENDED UPGRADING CONCEPTS

FIGURE B.4
page 3 of 10
(g) SINGLE LAYER / DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH NO BRIDGERAIL UPGRADE

(h) SINGLE LAYER / DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH HSS BRIDGERAIL UPGRADE
(i) SINGLE LAYER / DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION
PL-2 UPGRADE WITH HSS BRIDGERAIL UPGRADE

(ii) SINGLE LAYER DEEP-BEAM BRIDGERAIL, ON PARTICIPATING CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH NO BRIDGERAIL UPGRADE

APPROACH RAIL TRANSITION
RECOMMENDED UPGRAADING CONCEPTS

FIGURE B.4
page 5 of 10
(k) SINGLE LAYER DEEP-BEAM BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION
PL-2 UPGRADE WITH HSS BRIDGERAIL UPGRADE

(l) DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH NO BRIDGERAIL UPGRADE
(m) DOUBLE LAYER DEEP-BEAM BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION
PL-2 UPGRADE WITH HSS BRIDGERAIL UPGRADE

(n) DOUBLE TUBE BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH NO BRIDGERAIL UPGRADE

FIGURE B.4
RECOMMENDED UPGRADING CONCEPTS

page 7 of 10
DOUBLE TUBE BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION PL-2 UPGRADE WITH NO BRIDGERAIL UPGRADE

DOUBLE TUBE BRIDGERAIL ON SAFETY CURB APPROACH RAIL TRANSITION PL-2 UPGRADE WITH RELOCATED DOUBLE TUBE BRIDGERAIL UPGRADE
DOUBLE TUBE BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH NO BRIDGERAIL UPGRADE

DOUBLE TUBE BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION
PL-2 UPGRADE WITH RELOCATED DOUBLE TUBE BRIDGERAIL UPGRADE
(e) SINGLE TUBE BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION
PL-1 UPGRADE WITH NO BRIDGERAIL UPGRADE

(l) SINGLE TUBE BRIDGERAIL ON PARTICIPATING CURB APPROACH RAIL TRANSITION
PL-2 UPGRADE WITH HSS BRIDGERAIL UPGRADE