6.3 Benefit Cost Analysis

Project Description

Constructed in 1931, the Maine Kennebec Bridge (MKB) carries State Route 197 over the Kennebec River. MKB consists of 10 spans with a total length of 1239 feet, and is classified as Structurally Deficient by the Federal Highway Administration (FHWA). Five of its spans are also Fracture Critical, meaning that failure of certain steel tension members could result in catastrophic failure. A Feasibility Study completed in 2006 analyzed several options and found that replacement in approximately 10 years would be the lowest life cycle cost solution. In accordance with the findings of that Study, the proposed project is complete replacement with a high level, fixed span bridge estimated at $24.9 million. This application requests $10.81 million in TIGER funds to supplement $1.64 million in existing Federal funds to pay for 50% of the project.

A benefit cost analysis was conducted on replacing the Maine Kennebec Bridge. The analysis looks at the project from the standpoint of society as a whole, and accounts for the net benefits and net costs based on the criteria described in the TIGER Grant NOFA. The analysis seeks to answer the question, "Is society better off with the project or without the project?" The analysis presented here addresses travel time savings, vehicle operating costs, crash reduction, emission reduction, and livability enhancement.

Base Case Assumption

The life cycle cost analysis indicates that the lowest cost alternative is the high profile replacement. Consequently, the benefit cost analysis focuses on that option, and compares the replacement to the "no build' scenario, which is the base case assumption. This assumes that the existing bridge would be closed to traffic. Existing and future traffic would be diverted to alternate routes, thereby increasing travel time, mileage, and increased accidents. The benefits and crash reduction factors due to alignment & engineering changes of a replacement bridge would be forgone. Replacing the bridge avoids these future costs. The benefits that accrue to society from the Maine Kennebec River Bridge can be estimated by the avoided costs that would occur without the Bridge. The life cycle cost analysis includes only bridge construction costs in order to compare with the alternatives. The benefit cost analysis, on the other hand, includes all costs including preliminary engineering, construction engineering, and right-of-way, for total cost of $24.9 million.

Summary of Benefits and Costs

The annual benefits and costs values were discounted at 3% and 7% over a 50 year time horizon. Three percent is the most appropriate rate for the analysis because bridge has a very long life, and in addition, the alternate use of funds would be a public expenditure as opposed to a private investment. The full analysis can be found in spreadsheet linked to this application.[1] A summary of the results of this analysis are as follows.

[1] Maine Kennebec Bridge Benefit Cost Analysis.xls

- Total Benefits of $ 361.7 million
- Total Costs of $ 25.2 million
- Benefit-Cost ratio of 14.3

When discounted at 7%, the benefits and costs are lower. A larger discount rate implies that time preference for future amounts are preferentially discounted more severely. The amounts are show below.

- Total Benefits of $ 193.7 million
- Total Costs of $ 25.0 million
- Benefit-Cost ratio of 7.7

It is estimated that travel cost savings alone due to avoided VMT amount to $280.5 million. On an annual basis these costs savings represent over ¾ of the total annual benefits. These user costs savings are the key driver of the benefit-cost ratio. Even if all other benefits were ignored the benefit cost ratio would be a minimum of 6.0 at the larger, 7% discount rate. It must be noted, therefore that the assumptions on the other key criteria have a small influence on these results.

Project Benefits

Travel Costs

The Maine Kennebec Bridge is an important crossing on the Kennebec River. The nearest alternative crossings are bridges at Bath, Gardiner, and Augusta, which are 16.4 miles, 9.3 miles and 17.3 miles away respectively. The average annual daily traffic is on the Bridge is 3,340 vehicles, with approximately six percent of that being trucks. If the Bridge were closed and taken out of service, travelers would be forced to use these alternate crossing and traffic would shift to accommodate the loss. The total increase in vehicle-miles-traveled is estimated a 9.3 million miles annually. This number was developed using MaineDOT's Statewide Travel Demand Model, a transportation analysis tool, based on the TRIPS modeling software that can be used to evaluate the impact of major changes in the highway network. The Model relies on population demographics, employment, and economic activity in order to forecast VMT. The Model can be used to evaluate the travel time and distance benefits of a major new bridge or highway facility and can also be used to evaluate the travel costs (disbenefits) of closing a major facility.

For this analysis the Model was run twice, once with the bridge in place and operating and once with the bridge lost or removed from service. The Model run with the bridge in place represents existing conditions. The Model run with the bridge removed represents conditions in which the loss of the bridge forces bridge users to alternate river-crossing routes that longer in distance and time between the start and end points of their trips. The nearest alternate locations for crossing the Kennebec River are at Bath, Gardiner, and Augusta. Subtracting the existing conditions Model results from the closed conditions results provides an estimate of the increases in user costs from closure of the bridge. The increases in travel distances and travel times that are avoided by replacing the bridge, rather than allowing the crossing to be lost, represent the benefits of a replacement bridge. The table below summarizes the calculations.

	User Costs Due to Bridge Closure		
	VMT	VHT	Cost
Per Vehicle Detoured	7.6	0.56	$ 8.66
Year-Round Total	9,284,981[2]	686,543	$ 10,903,033[3]
Note.			
Costs per Vehicle-Mile-Traveled in $0.25based on AAA data. Hourly value of time is $12.50.			

Vehicle Operating Costs

An increase in vehicle operating costs would result from the additional VMT created by closing the bridge. The total annual vehicle operating costs is estimated at $2.4 million and is included in the total user costs presented above. This is based on $0.25 per mile average that has derived from American Automobile Association operating costs data for passenger cars. These operating costs are avoided by bridge replacement. This does not include the amount from heavy truck traffic.

Operating costs avoided by a bridge would enhance economic competitiveness in the region served by the project. In addition, a decrease in delay would result, because the existing bridge traffic is reduced to one-lane operation when trucks are traversing the bridge. The narrow deck, and also low clearance at the sides, can cause oncoming traffic to either slow, move over, or stop entirely. This delay has not been included here. Similarly the few delays caused by traffic stoppage during vessel passage are not estimated.

This analysis does not estimate user costs of delay during construction, as it will be minimized by utilizing parallel bridge construction techniques. MaineDOT experience with parallel construction of the Norridgewock Bridge, and also on the Penobscot Narrows Bridge bears out this fact.

Safety

An analysis of the recent crash history shows that there were three crashes in the 2008-2010 period. The cumulative critical rate factor was 0.95 and the percent of personal injury was 66.7. There were two non-incapacitating injury crashes and one property damage only crash. All three crashes occurred on the west approach segment located approximately 400 feet west of the bridge to the swing span. This segment is characterized by non-standard horizontal and vertical curves, nonstandard superelevation, and inadequate sight distance on the western bridge approach in addition to the narrow bridge. The annual costs for these crashes are estimated at average value of $21,228 using the maximum Abbreviated Injury Scale (AIS) method[4].

Additional crash history is available from an analysis that was done previously for the 2006 bridge replacement feasibility study. At that time crashes were examined for 2002 through 2004. Both analyses are consistent in the magnitude of injuries. A total of 7 crashes occurred during that period. All of the crashes were property damage only, low speed collisions. Of those crashes

---

[2] Travel Cost Spreadsheet, assignment summary tab, cell G24
[3] Travel Cost Spreadsheet, assignment summary tab, cell I24.
[4] Crash Costs per AIS for Past Crashes.xls, cell K19

71% occurred on the west approach segment. One occurred on the east approach segment. One crash occurred at the swing span section. These rates and costs are discussed here only as a historical context. They are not included in the BCA, since the bridge approaches are assumed absent in the closure scenario.

If the bridge is closed, additional travel would presumably increase crashes on alternate routes in transportation network. To prepare an accurate estimate of crash costs, a specific crash rate was developed for all Maine rural major collectors, which would be the likely alternate routes. The table below lists these crash factors and the resulting injury costs using the KABCO injury scale.

Crash Costs due to Increased VMT			
VMT (Annual)	9,284,981[5]		
HMVM (Annual)	0.09284981[6]		
		Injury Values	Estimated Costs
Crashes[7]	16.89876305		
Fatalities	0.137613403	$4,000,000	$550,453.61
Incapacitating Injuries	0.633510223	$201,100	$127,398.91
Evident Injuries	2.478669818	$50,400	$124,924.96
Possible Injuries	3.35972131	$24,400	$81,977.20
Vehicles involved (1.6/crash event)	27.03802088	$2,200	$59,483.65
		Total Annual Crash Cost	**$944,238.32**

The KABCO estimates are converted to AIS levels using the table of values on Page 50310 of the NOFA. The resulting costs are shown below.

KABCO-AIS Conversion[8]						
		KABCO Estimates		AIS Level & Severity		
Crashes	16.89876305					
Fatalities	0.137613403	$4,000,000	$550,453.61	$6,200,000	6	$853,203.10
Incapacitating Injuries	0.633510223	$201,100	$127,398.91	$1,649,200	4	$1,044,785.06
Evident Injuries	2.478669818	$50,400	$124,924.96	$292,400	2	$724,763.05
Possible Injuries	3.35972131	$24,400	$81,977.20	$18,600	1	$62,490.82
Vehicles involved (1.6/crash event)	27.03802088	$2,200	$59,483.65	$3,285	PDO	$88,819.90
		Total Crash Costs	**$944,238.32**			**$2,774,061.93**

[5] Travel Cost Spreadsheet.xls, assignment summary tab, cell G24
[6] Major Collector Crash Rates & Injuries.xls, cell B25
[7] Major Collector Crash Rates & Injuries.xls, cell B24:B28
[8] Major Collector Crash Costs.xls, cells A24:G30

The table shows that the conversion to AIS nearly triples the estimated costs. The total annual safety costs for alternate routes are almost \$2.8 million.

State of Good Repair

The existing bridge was built in 1931. It is 1239 feet long with ten spans. One span consists of a center bearing swing span. The deck is an open steel grid type. Due to the age of the bridge, ongoing maintenance and operations costs are significant. Estimated annual average M&O costs amount to \$103,500 for personnel, repairs, and materials. If the bridge were closed these costs are avoided. In this BCA the annual M&O costs are added to user benefits since they are avoided costs to society if a new bridge is constructed.

The existing bridge has a swing span to allow for boat traffic. Navigability on this section of the Kennebec River is extremely important, especially for the U.S. Coast Guard icebreakers. The USCG vessels are utilized during most winters to prevent ice jams that can cause flooding in many upstream areas, if they are not cleared from the river channel. The existing bridge shows some damage from ice impacts. If the structure was not removed after closure, and the moveable section becomes inoperable, USGC vessels could not pass under it. This is not a realistic possibility, since Federal protection on navigable channels would probably require removal of the obstruction. Structure removal costs are only a guess. A ballpark estimate is would be approximately \$5 million, based on estimated removal costs on other recent MaineDOT bridge replacement projects. This removal cost is not included in this analysis since it would occur in both the “no build” and build alternatives, therefore it becomes a wash.

Sustainability

The avoided air emissions are based on avoided VMT from closure of the bridge and the loss of this crossing location. The emission savings have been calculated for nitrogen oxides, volatile organics, and carbon dioxide. The calculations are based on factors that were applied to the avoided VMT resulting from closure of the bridge. Data is not available for sulfur dioxide or particulate emissions.

Air Quality Impact Analysis						
Increase in VMT						
Annual VMT	Emission Factors (g/mi)[1]			Emissions Increase (Metric Tons / Year)		
	VOC	NOx	CO2	VOC	NOx	CO2
9,284,981[9]	0.597[10]	0.962[11]	555.40[12]	6	9	5157
Increase in VHT through idling						
Annual VHT	Emission Factors (g/hour)[2]			Emissions Increase (Tons / Year)		
	VOC	NOx	CO2	VOC	NOx	CO2
686,543	10.669	4.282	1388.50	7	3	953
Total Emission Increases						
Annual VHT	Total Emission Increase (Metric Tons / Year)			Value of Emissions ($ / Metric Ton)		
	VOC	NOx	CO2	VOC	NOx	CO2
	13	12	6110	$1,700	$4,000	$22
NOTES						
[1]Composite emission factors for all vehicles types at 46 MPH.						

The social cost of carbon (SCC) has been estimated using values found in "Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866". The report states that, "… SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change." In conformity with this viewpoint, this analysis escalates the CO2 portion of the air emissions cost increases estimated on Table 5: "Changes in the Average Annual Growth Rates of SCC Estimates between 2010 and 2050" in the report. The net present value of air emissions costs is $6.5 million at 3% discount and $3.3 million at 7 % discount.

Livability

There are many dimensions of livability including choice in transportation options, community values, health benefits, and recreation values. This bridge project, by virtue of its nature and location can probably influence these factors. A shared use pedestrian and bicycle lane on the bridge would make walking and bicycling safer and more accessible. Some studies in the research literature have shown that increased walking and bicycling can be associated with environments that encourage pedestrian and bicycling features. At this bridge location, there are several factors, however, that limit pedestrian and bicycling in this area. One is that the bridge is located a distance away from nearest village center; another might be that the facility does not connect with another shared use pathway. In addition, the fact that Maine experiences severe winter weather probably limits walking & bicycling somewhat, especially on a rural bridge deck. It is not known what the induced demand will be for this river crossing.

---

[9]Travel Cost Spreadsheet.xls, assignment summary tab, cell G24
[10] Emissions Reduction- Richmond-Dresden Bridge.xls, cell B6
[11] Emissions Reduction- Richmond-Dresden Bridge.xls, cell B7
[12] Emissions Reduction- Richmond-Dresden Bridge.xls, cell B8

Nevertheless, an estimate of potential health and recreation benefits for pedestrian & bicyclists was developed, based on several assumptions. The analysis assumes that 2.1% of the population would use the shared use pathway a few times per year. It is assumed that 10% of the population participates in walking for recreation. Further assumptions are made on the portion of those who might choose a bridge route, depending on distance from the facility. The number of tourism crossings is also assumed. The total fitness and health benefit is estimated at around $7,500[13] per year. Other livability factors were not considered due to lack of a meaningful way to estimate them. Even if these estimates are off by a factor of 20, the benefit cost ratio would be changed by only 0.1.

Project Costs

Total Construction Costs

The life cycle cost analysis was updated from the analysis contained in the 2006 Feasibility Study[14]. The preferred alternative is the high profile replacement as shown in the LCCA. The life cycle cost analysis includes only bridge construction portion of total replacement costs, to preserve equal comparison of alternatives.

The benefit cost analysis, on the other hand, includes all costs including preliminary engineering, construction engineering, and right-of-way, for total cost of $24.9 million. Maintenance and operations costs for the high profile replacement bridge are considered negligible until the wearing surface is rehabilitated after 30 years, at a cost of $826,500.

[13] Value of Health Benefits.xls, cell I24
[14] Feasibility Study, Maine Kennebec Bridge, Bridge #2506, by MaineDOT and Erdman Anthony and Associates, July 2006, p.21