Abridgment

AASHTO Red Book Application: Economic Analysis of Third Columbia River Bridge

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The economic analysis portion of the Columbia River Bridge Feasibility Study, required by the U.S. Congress, is described. The study to assess the feasibility of a third bridge between Vancouver, Washington, and Portland, Oregon, had four components: (a) interviews with state and local officials, (b) a review of reports to assess the demand for travel between the two cities and the capacity of existing and proposed transportation facilities for serving that demand, (c) an economic analysis of a third bridge, and (d) a review of funding available for its construction. The economic analysis followed the procedures outlined in the 1977 American Association of State Highway and Transportation Officials Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. This paper treats the estimation of traffic for this analysis in detail.

This economic analysis was to give scale to the economic feasibility of an additional highway bridge across the Columbia River (1). As such, it did not attempt to distinguish the relative economic efficiency among several possible building alternatives, and consequently it considered only one such alternative for comparison with the alternative of not building a bridge. The analysis followed the procedures outlined in the American Association of State Highway and Transportation Officials (AASHTO) Manual on User Benefit Analysis of Highway and Bus-Transit Improvements (2). The approach was to determine the annual road-user benefits, or the difference in user costs for each of three vehicle types between the alternatives of building or not building over the anticipated life of the facility. The stream of annual user benefits and the proposal's residual value were reduced to their present values and compared with the present values of the costs to construct, operate, and maintain the facility.

TRAFFIC DATA

The traffic data, taken from a Washington State Legislative Transportation Committee study report, included 1977 and 2000 average-weekday-traffic (AWD) estimates for the alternative of not building and the eight alternatives of building, including the location selected for analysis for the congressional study. The third river crossing was assumed to be open to traffic in 1995 and to have a service life of 50 years. Since traffic estimates were not available for after 2000, basic traffic growth assumptions were required for the period 2000-2045.

For the alternative of not building, traffic was assumed to increase at the annual compound rate, 1.75 percent, until the capacity (120 000) of the I-5 bridge would be reached in 2002. From 2002 to 2045 the rate, 0.75 percent, was assumed.

For the alternative of building, traffic was assumed to increase at the annual compound rate, 2.00 percent, but for this study's alternative of building this rate of growth was continued until the combined capacity (200 000) of the existing and proposed bridges would be reached in 2025. From 2025 until 2045 the rate, 0.75 percent, was again assumed for the remainder of the study period. Traffic estimates for the alternative to build represented the total traffic on both bridges, and since each bridge was assumed to have the same ratio of volume to capacity, their total volume and total capacity were used in analyzing the alternative to build. These traffic-growth and capacity assumptions resulted in the AWD estimates for each year shown in Figure 1.

The AASHTO manual uses the volume-to-capacity (V/C) ratio as the primary factor in determining roadway-user costs. The daily traffic volumes were assigned to two periods--peak and off-peak--for this analysis. V/C ratios were computed for the two alternatives, the two daily traffic periods, and the four analysis years (1995, 2002, 2025, and 2045), which correspond to the discontinuities in the traffic projections in Figure 1.

By defining peak-period traffic as K(AWD), where K is the ratio of peak-period traffic to daily traffic, and by assuming that all daily traffic occurred in 18 h of the day, the off-peak-period hourly traffic would be [(1 - 2K)(AWD)]/16. All peak-period traffic was assumed to occur uniformly across 1 h for each period until it exceeded the hourly capacity. Consequently, the traffic volume would remain at capacity but the excess peak-period traffic would spread to each side of the peak hour. The duration (D) of one peak period for this case was calculated based on equivalent areas (Figure 2). That is, by definition, as follows:

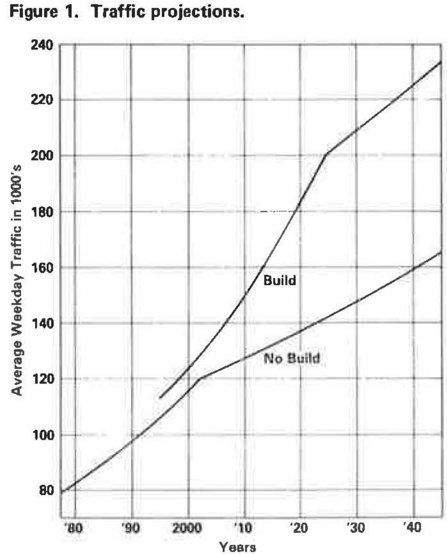
$$1 \times K(AWD) - (1 - 2K)(AWD)/16 = D \times \text{hourly capacity} - (1 - 2K)(AWD)/16 \quad (1)$$

Therefore,

$$D = [K(AWD) - (1 - 2K)(AWD)/16] / [\text{hourly capacity} - (1 - 2K)(AWD)/16] \quad (2)$$

Consequently, the duration of the two peak periods is 2D and the duration of the off-peak traffic periods is 18 - 2D. Table 1 summarizes the volume of hourly traffic, the duration of peak and off-peak periods, and the ratios of volume to capacity.

Figure 1. Traffic projections.



ANALYSIS PARAMETERS

The AASHTO analysis procedure requires the parameters given below:

1. Discount rates: 5, 10, and 15 percent
2. Travel-time costs
   a. Automobiles, $3.98/vehicle-h
   b. Single-unit truck,$9.91/vehicle-h
   c. Truck combinations, $11.33/vehicle-h
3. Analysis period: 1995-2045 (50 years)
4. Analysis intervals: 1995-2002, 2002-2025, 2025-2045
5. Construction cost
   a. Bridge, $46 118 750
   b. Connections, $19 101 000
   c. Total, $65 219 750
6. Net increase in
   a. Annual operating cost, $25 000
   b. Maintenance cost, $28 700
7. Residual value: $48 913 812
8. Project length: 5.8 km

For the analysis, the travel-time values were taken from the manual and adjusted upward for automobile occupancy and inflation. Construction and maintenance cost estimates were based on unit costs available in Federal Highway Administration (FHWA) headquarters. The increase in facility operating cost was based on the assumption that two person-years would be needed. The residual value was estimated by using percentages of the initial costs for the structure, right-of-way, pavement, and engineering. [These cost estimates are detailed in the section on benefits and costs (2).] All dollar values were adjusted to reflect 1979 prices.

USER COSTS

Basic Section Cost

The AASHTO manual (2) provides user costs attributable to a highway section based on vehicle type. To take advantage of this, the traffic stream was split among the vehicle types: automobiles, pickup trucks, and small vans (Auto), 93 percent; single-unit trucks that have dual wheels (SUT), 3 percent; and combination trucks (CT), 4 percent. This was based on a total truck factor of 7 percent and a 41-59 percent split between single-unit and combination trucks.

The basic section cost has four components: tangent-running cost, travel-time cost, speed-change cost, and added-curve cost. The following parameters and assumptions were used in developing these costs:

1. Tangent-running costs were developed for each vehicle type by using curves established for six-lane freeways that have a 90-km/h speed limit on level grade.
2. Travel time was developed by using the same parameters as those for the tangent-running cost and was converted to travel-time cost in dollars by the travel-time cost values previously determined.
3. The lower curve for speed-change cost was used from the AASHTO manual until the V/C ratio reached 1. Then both curves were read, one for just before the traffic would break down (level of service E) and one for just after traffic would break down (level of service F). The E-value was used for the end year of the analysis interval and the F-value was used for the beginning year of the next analysis interval.
4. Running cost on curves was neglected.

Accident Costs

Accident costs for urban expressways used in this analysis were derived from the AASHTO manual. Under this approach, accident rates per million vehicle kilometers by accident type (fatal, injury, and property-damage-only) and costs per accident type were applied to total vehicle kilometers.

Total (Highway) User Costs

Two additional categories of costs--transition cost and intersection-delay cost--would normally be included in an analysis of this type, but these were neglected for this analysis. Once the individual cost components had been determined, the unit highway user costs (HU) for operating on the entire section were determined by applying Equation 3:

$$HU = (B + A)L + T + D \qquad (3)$$

where

HU = total unit highway user operating cost for section,
B = basic section cost,
A = accident costs,
L = section length (5.8 km),
T = section transition cost = 0, and

Figure 2. Peak spreading.

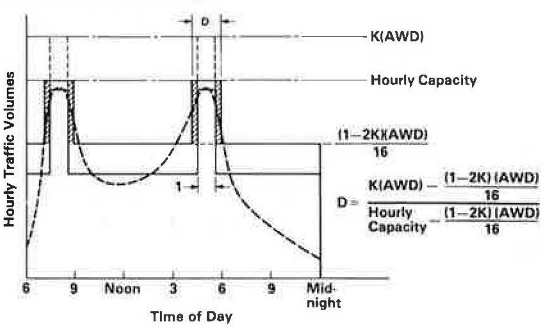
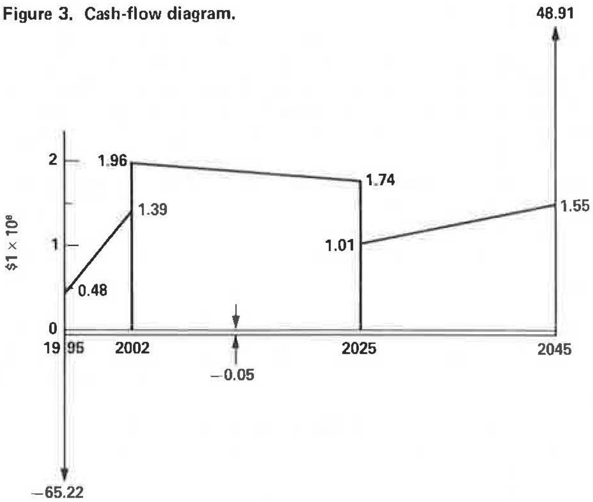


Table 1. Traffic data.

Year	Alternative of Not Building						Alternative of Building					
	Peak Period			Off-Peak Period			Peak Period			Off-Peak Period		
	Hourly Volume (000s)	D	Ratio, V/C	Hourly Volume (000s)	18-2D	Ratio, V/C	Hourly Volume (000s)	D	Ratio, V/C	Hourly Volume (000s)	18-2D	Ratio, V/C
1995	10.6	2.0	0.9	5.3	16	0.44	11.3	2	0.6	5.65	16	0.3
2002	12	2.0	1.0	6.0	16	0.5	12.8	2	0.6	6.4	16	0.3
2025	12	3.0	1.0	7.15	15	6.0	20.0	2	1.0	10.05	16	0.5
2045	12	4.4	1.0	8.25	11.6	6.9	20.0	2.8	1.0	11.65	15.2	0.6

Figure 3. Cash-flow diagram.



D = intersection delay cost = 0.

BENEFITS AND NONUSER COSTS

User Benefits

Annual user benefits for each vehicle type within each traffic period for each analysis year were determined by using Equation 1 in the AASHTO manual. This formula is restated as Equation 4:

$$\text{User benefits} = H_{TP}(U_{NB} - U_B)(V_{NB} + V_B)/2000 \quad (4)$$

where

H_{TP} = number of hours in year for given traffic period,
U_{NB} = user cost per 1000 vehicles under alternative of not building,
U_B = user cost per 1000 vehicles under alternative of building,
V_{NB} = traffic volume under alternative of not building, and
V_B = traffic volume under alternative of building.

To calculate the annual user benefits for the study years 2025 and 2045, an additional traffic period was required, since the peak period for the alternative of not building was longer than the one for building. For this intermediate period, peak-period traffic volumes and costs were used for the alternative of not building and off-peak-period traffic volumes and costs were used for the alternative of building.

Construction Cost

The bridge was assumed to have a 120-m lift span that cost $5 000 000, a remaining length of 1934 m, a width of 22.5 m, and a unit cost of $1060/m². This gives a total cost for the bridge of $46 126 000. The connections had an assumed length of 3.7 km and a unit cost of $5 160 473/km for a cost of $19 093 750. The total construction cost was $65 219 750.

Residual Value

This analysis assumed that the project had 75 percent of its original value at the end of its life in 50 years. The bridge itself would retain approximately three-fourths of its original value. Right-of-way, which was estimated as roughly 15 percent of total cost, was expected to maintain its value; pavement and engineering, which together were roughly 7 percent of the total cost, would have no value. Therefore, the residual value would be $48 914 812.

Annual Operating and Maintenance Costs

The annual operating and maintenance costs of the alternative of building were expected to exceed the costs for the alternative of not building by an amount equal to these costs for the new bridge and connections. The total of these costs was $53 700. The cash-flow diagram (Figure 3) represents the expected stream of benefits and expenditures over the life of the project.

PRESENT VALUES AND ECONOMIC DESIRABILITY

The benefits shown in Figure 3 along with the costs were reduced to their present value in 1979 dollars by assuming that the user benefits are increasing or decreasing gradients for the appropriate interval and by applying the appropriate discount factors. The costs and residual value were similarly reduced to their present values for various discount rates and appropriate time periods. Rather than select a specific discount rate, rates of 5, 10, and 15 percent were used to observe how sensitive the analysis was to the discount rate.

Based strictly on an economic analysis, a third bridge across the Columbia River was not feasible. The net present values at the discount rates of 5, 10, and 15 percent were $-35 512 506, $-52 124 552, and $-57 555 828, respectively.

REFERENCES

1. Columbia River Bridge Feasibility Study. FHWA, U.S. Department of Transportation, Jan. 1980.
2. Manual on User Benefit Analysis of Highway and Bus-Transit Improvements. American Association of State Highway and Transportation Officials, Washington, DC, 1977.

Publication of this paper sponsored by Task Force on Economic Analysis.