Life-Cycle Cost Analysis: A Practitioner’s Approach

Nathaniel D. Coley Jr.

FHWA Office of Performance Management
Topics

- Fundamentals of Economic Analysis
- Tools and resources
- What to do now
By the end of this workshop you should:

• Be familiar with economic analysis concepts, methods and tools

• Where to get help
We consider a short list of alternatives for bridge at a project level:

• Replacement
• Rehabilitation
• Painting
• Seismic retrofit
• Systematic preventive maintenance
• Installation of scour countermeasures
Life-Cycle Comparisons of Alternatives

Typical Life-Cycle Profile

Initial Capital Cost

Dollars

Year

Benefits
Costs

Example Direct Benefits
• Reduced Accident Costs
• Reductions in Delay Costs
• Reduced Life-Cycle Costs

Example Indirect Benefits
• Land use impacts
• Employment
• Non-user benefits

Example Direct Benefits
• Reduced Accident Costs
• Reductions in Delay Costs
• Reduced Life-Cycle Costs
When will the future deterioration countermeasures be required?
The Role of Economic Analysis

• Mechanism for monetizing, evaluating and comparing long-term costs and benefits of alternatives

• Economic analysis results
  – Help structure project and program level tradeoffs to ensure that resources are allocated efficiently to achieve the maximum ROI (Allocative Efficiency)
  – Quantify & Qualify costs and benefits to the agency and to roadway users
  – Support repeatable and transparent project justification and prioritization

• Does not provide THE decision. It provides a logical framework to support decisions

Adam Smith
Dollar Now vs. Dollar Later

Two separate and distinct factors account for why the value of a dollar, as seen from the present, diminishes over time:

- Inflation
- Time value of a dollar (Discounting)
Calculate Present Values of Costs and Benefits

What is the present value of future sums?
Guidance on Discount Rates

- Real discount rate of 3% with a sensitivity analysis ranging from 2% to 5% (More on “Sensitivity Analysis” later)
- States may select higher or lower rates, but rate should be justified. (e.g. borrowing or bond rates)
- Do not adjust discount rate for risk because the risk that society places on forgoing consumption is already built in. This is different from risk of returns in bond or stock markets
For public agencies benefit-cost analysis benefit-cost analysis is essentially ROI. Traditional benefit cost analysis and ROI analysis for transportation includes user benefits (time, cost, safety) for travelers and select environmental effects (air, quality, noise) along with capital, operations, and maintenance (O&M) costs.
Life-Cycle Cost Analysis is a **process** for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user, reconstruction, rehabilitation, restoring, and resurfacing costs, over the life of the project segment.

*Source: Transportation Equity Act for the 21st Century*
Cost Effectiveness Analysis (OMB Circular A-94)

- CEA compares alternatives on the basis of the ratio of their costs and a single quantified but not monetized effectiveness measure (e.g. dollars per lives saved). Programs that cost less per life saved are more cost-effective than other programs.
- It is a measure of technical efficiency and is not necessarily a good measure of allocative efficiency.
  - **Allocative efficiency** - are funds directed to activities which will produce the greatest gains. (MAX ROI)
  - **Technical efficiency** - once resources are allocated, are they being combined to produce the greatest output (Spread The Butter Thin)
The Process

1. Characterize bridge and its elements
2. Define planning horizon, analysis scenario(s), and base case
3. Define alternative bridge management strategies
4. Specify/select appropriate deterioration models and parameters
5. Estimate costs
   - Agency, routine maintenance
   - User, work related, other
   - Vulnerability, agency & user
6. Calculate net present values
7. Review results
8. Modify management strategies if unacceptable
9. Select preferred strategy
10. End
**Method**

**BCA Formula**

- BCA is done using the basic multi-year discounting formula:

\[
PV = \sum_{t=0}^{N} \left( \frac{1}{(1+r)^t} \right) (Benefit_t - Cost_t)
\]
### Retain 29 year old bridge (BR-08232), constructed 1982, with deteriorated timber substructure (SR-11 7.10 2/99) versus replacement

**PV = (1+r^t)/(1+t)**

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<th>Widening</th>
<th>New Rail</th>
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# Rail cost included in widening costs

Total Present Worth = $2,835,212

### Replace with New Bridge, Bridge No. 18628

**Annual Maintenance**

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<th>PW Factor</th>
<th>Capital Cost</th>
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Total Present Value = $2,594,548

**Recommendation:** The present value and comparative analysis, widen and maintain the bridge versus replace. Therefore, recommend the preservation of the deteriorated timber substructure and implement the Dynamic Design Enhancements.
Benefit and Cost Elements

- **Agency Cost/Benefit**
  - Design and Engineering
  - Land Acquisition
  - Construction
  - Reconstruction/Rehabilitation
  - Preservation/Routine Maintenance
  - Remaining Asset Value (end of analysis period)

- **User Cost/Benefit**
  - Delay/Time Saving
  - Crashes/Avoided Crashes
  - Vehicle Operating Costs

- **Externalities**
Roadway User Costs Components

**Definition**
Costs to highway users over the life of a Highway Project

**Components**

- **Delay Costs** – Costs associated with an increase (or decrease) in the amount of time it takes for a user to travel from point A to B. (In our case, navigating through or around a work zone)

- **Vehicle Operating Costs** – Costs attributable to the operation or maintenance of a vehicle (brake wear, idling, fuel consumption, tire ware, etc.)

- **Crash costs** – Cost resulting from property damage, injuries, or loss of life
• Each construction/WZ strategy involves tradeoffs
  • Agency vs. user costs
  • Initial vs. long-term costs
• An analysis of roadway user costs permits comparison of cost tradeoffs
1. Existing Costs on construction Route (Pre-WZ)
2. Additional Costs from WZ

1. Existing cost on detour route (Pre-WZ)
2. Additional Costs of detoured traffic on Detour Route
Conceptual Work-Zone impact on travel speed

Free Flow Speed

Free-Flow Speed

Discharge

Work-Zone

End of Work-Zone

Beginning of Queue

$\$$

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Comparing Benefits To Costs

Different BCA Measures

• Net Present Value (NPV)
• Other measures include:
  Equivalent Uniform Annual Value (EUAV)
  Internal Rate of Return (IRR)
The value of potential service remaining at the end of the analysis period

- Accounts for end-of-analysis period “differences” between alternatives
- Removes economic bias between alternatives
Salvage Value

The value of recovered or recyclable materials

• Assumes material is removed from service at the end the analysis period
• Salvage value is only realized when materials are actually reclaimed
• Inputs are defined by their range of values and probability of occurrence (probability distribution)

• Through simulation, outputs are expressed as ranges of values with probabilities of occurrence
Simulation Results: Histogram

Net Present Value (NPV), $Millions

Best Case

Most Likely

Worst Case

Range = 0.4
## Comparing BCA and EIA Metrics

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<th>Metric</th>
<th>BCA/LCCA</th>
<th>EIA(NEPA)</th>
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Economic Analysis Tools

Tools to assist organizations with economic analysis

- **BLCCA 2** (NCHRP 483 Software Revamped)
- **NBIAs**: network level pavement needs assessment tool
- **FHWA Division Bridge Engineer**: Simple spread sheet in their Bridge Manual
Transportation Performance Management:
- States will manage Their Networks so that no more than 10% bridges by deck are structurally deficient
- Risk Based Asset Management Plan
- Performance Targets
- Progress Assessment Reports
- States & MPOs

Element Inspections
Management Systems
Value Engineering (LCCA Required for Bridges)
National Bridge Investment Analysis System (NBIAS)

NBIAS: Element Transition Probabilities

Database: NBIAS 3.5 2009 SCREENED SOLSPAC

Element:
- Concrete Deck: Unprotected w/ AC Overlay
- Concrete Deck: Protected w/ AC Overlay
- Concrete Deck: Protected w/ Thin Overlay
- Concrete Deck: Protected w/ Rigid Overlay
- Concrete Deck: Protected w/ Coated Base
- Concrete Deck: Protected w/ Cathodic System
- Steel Deck: Open Grid
- Steel Deck: Concrete Filled Grid
- Steel Deck: Corrugated/Orthotropic/El.
- Timber Deck: Base
- Timber Deck: w/ AC Overlay

Cost Model:
- Cost coefficients: Agency: 1.000, User: 1.000
- Discount Rate: 4
- Equivalent Factor: 0.861538

Transition Probabilities:

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<th>Action 2</th>
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Failure Probability: 12.34

Optimization Results:

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<tr>
<th>CS</th>
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Figure 2: Deck area percentage of structurally deficient bridges

Legend:
- Red: All the money in the world
- Green: $290 mil Annual budget
- Purple: $400 mil year 1 $210 after
- Blue: $150 mil 2% annual increase
Thank You

Nathaniel D. Coley Jr.

FHWA

Washington, DC
NColey@dot.gov
202-366-2171

http://www.fhwa.dot.gov/infrastructure/asstmgmt/economic.cfm