CE 4401
Pavement Design

Introduction to Life Cycle Cost Analysis

LCCA Defined (FHWA)

"A process for evaluating the total economic worth of a useable project segment by analyzing initial costs and discounted future costs, such as maintenance, reconstruction, rehabilitation, restoring, and resurfacing costs, over the life of the project segment."

LCCA Policy Statement (9/96)

- FHWA philosophy ...
  - LCCA is a decision support tool
  - Results are not decisions
  - Results often less important than logical evaluation process

LCCA Policy Statement (9/96)

- LCCA is an important consideration in all highway investment decisions
- Level of detail commensurate with level of investment
- Long analysis periods
  - Pavements - min. 35 years
  - Bridges - min. 75 years

Policy Statement Con't ...

- All appropriate agency and user costs should be included
- All appropriate future costs should be discounted to their net present value (NPV) or present worth (PW)

Use of LCCA

- Compare two or more candidate alternatives on a rational, economic basis
- Results should be used to assist in the decision process, not to be the only deciding factor

Life Cycle Costs

- Highway Agency Costs
- Highway Users Costs

Agency Costs

- Design & engineering/contract administration, etc.
- Initial construction
- Future maintenance and rehabilitation
- Future salvage value
- Include on differential costs between alternatives

Salvage Value

- Value of asset (e.g., pavement) at the end of the analysis period
- Considered a negative cost (i.e., benefit)

User Costs

- User Delay
  - Costs associated with delay resulting from work zones
- Vehicle operating costs (VOC)
  - Extra costs due to increased roughness
- Crash costs

LCCA Approaches

- Deterministic
- Probabilistic

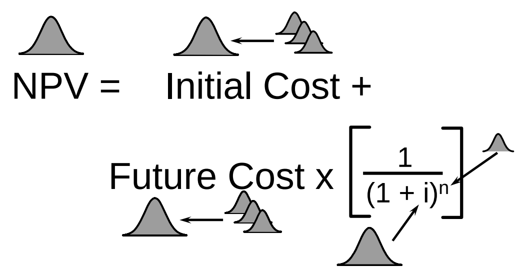
Deterministic Approach

- The application of LCCA procedures and techniques disregarding the variability of input factors
- Uses only mean values, or oftentimes, only best estimates
- Results in average present value

Probabilistic Approach

- A technique that identifies the variability associated with LCCA input factors and carries this variability through the computation process to generate results in the form of a probability distribution
- Uses means and standard deviations of input factors to mimic real-world variability

Probabilistic Approach



Economic Analysis Technique

- Types of Analyses
  - Cost-benefit analysis (CBA)
    - net present value (NPV)
    - equivalent uniform annual cost (EUAC)
    - internal rate of return (IRR)
    - benefit-cost ratio (B/C)
  - Cost-effectiveness analysis (CEA)
  - Multi-criteria analysis (MCA)
- Recommended by FHWA: NPV
  - MDOT uses EUAC

Net Present Value

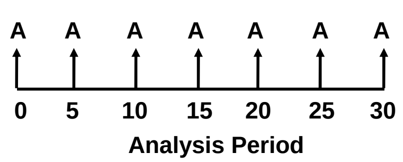
$$NPV = \text{Initial Cost} + \sum\{\text{Future Cost} * [1 / (1+i)^n]\}$$

Where: n is the number of years

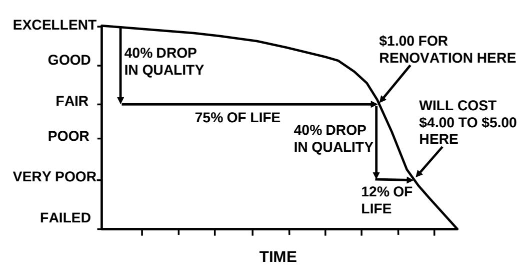
i is the discount rate

Equivalent Uniform Annual Cost (EUAC) Method

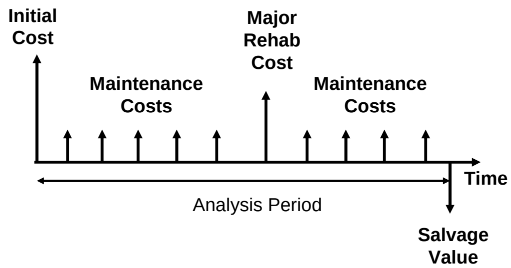
$$\mathbf{EUAC = NPV \frac{i\,(1+i)^n}{(1+i)^n - 1}}$$



Timing of Maintenance and Rehabilitation Activities



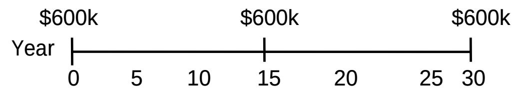
Cost Stream



Example Alternative A

Alternate A:

Expense

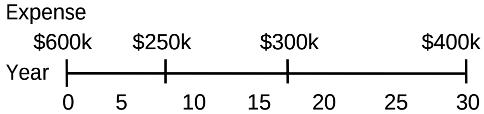


Total Additive Cost ....= $1,800,000
Present Worth ....= $1,118,280
Equivalent Uniform Annual Cost ...... = $64,637

Example Alternative B

Alternate B:

Expense



Total Additive Cost ....= $1,400,000
Present Worth ....= $975,400
Equivalent Uniform Annual Cost ...... = $56,378

Time Value of Money

- A dollar in hand today is worth more than it will be if received tomorrow
- Constant dollars vs. nominal dollars:
  - Constant – reflects the same or constant purchasing power of the dollar into the future (also called real dollars)
  - Nominal – includes an inflation premium on future costs (also called actual dollars)

Real versus Nominal Dollars

- Real versus nominal dollars
  - Real dollars--same or constant purchasing power over time
    - current price of patching = $100/yd²; use $100/yd² for estimating future-year patching costs
  - Nominal dollars--variable purchasing power over time
    - inflation rate = 4%; use $104/yd² for estimating patching costs 1 year from now
- Recommended: Real/constant dollars

Discount Rate

- Discount rate is very important
- Discount rate is function of interest rate and inflation rate

Exact relationship: $i_{dis} = [(1+i_{int}) / (1+ i_{inf})] - 1$

For practical purposes: $i_{dis} \approx i_{int} - i_{inf}$

Discount Rate (Continued)

- Interest rate is cost of borrowing money (i.e., earning power of money)
  - State municipal bond rates reasonable reflection of market interest rate
- Inflation rate is rate of increase in prices of goods and services (i.e., changes in purchasing power of money)
  - Producers Price Index (PPI) reasonable reflection of inflation rate

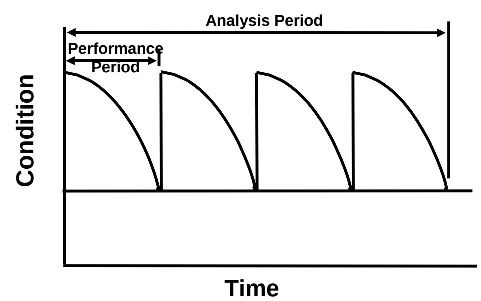
Discount Rate (Continued)

- Recent LCCA surveys indicate that most States use discount rates of 3 to 5 percent
- 5-year ('91 – '96) evaluation of U.S. Government Treasury Bill (10-year Treasury note) showed real rate of return between 3 and 5% (average ≈ 4%)
- Recommended: Use value between 3 and 5%, in conjunction with real/constant dollars
  - Is this reasonable when DOTs are relying on gas taxes for funding?

Analysis Period

- Recommended analysis periods
  - High-volume urban: 30 to 50 years
  - High-volume rural: 20 to 50 years
  - Low-volume paved: 15 to 25 years
- Should capture at least one major rehabilitation

Performance Period



Selection of the Preferred Design Alternative Based on LCCA

- Objective:
  - The selection of the preferred design alternative for a given alternative requires a systematic, step-by-step approach that considers all relevant factors

Key Considerations

- There is always more than one alternative (including "do nothing")
- Alternatives have associated costs, constructability, performance life, reliability, maintainability, and other unique characteristics
- The preferred alternative is the one that meets all engineering criteria and is the most cost effective

Typical Design Alternatives

- HMA surface with granular/ stabilized base
- Full-depth HMA
- JPCP with granular/stabilized base
- JRCP with granular/stabilized base
- CRCP with granular/stabilized base
- Many others

Value Engineering

- Design review committee
- Solicitations for intra-department or inter-department suggestions
- Solicitations for ideas from contractors, material suppliers, etc.
- Brainstorming
- Review of previous studies

Habitual Thinking

- Designer should make strong efforts to identify feasible alternatives
- Applying “standard designs” results in inefficient designs
- Customized engineering design and consideration of various alternatives are needed to ensure the best use of limited funds