# Engineering Risk Benefit Analysis

## 1.155, 2.943, 3.577, 6.938, 10.816, 13.621, 16.862, 22.82, ESD.72

## CBA 5.  Evaluating Public Activities

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# General Welfare

- **The selection of public projects is not made on the basis of profit, but, rather, on the basis of maximization of the general (or, social) welfare of the citizens.**

- **What is general welfare?**

- *Pareto Improvement:* **At least one person is made better off by the project and no one is made worse off.**

- *Potential Pareto Improvement:* **Those who are better off could compensate those who are worse off and still be better off. This means that the *aggregate* benefits are bigger than the *aggregate* costs.**

- **No actual compensations need to occur.**

# Evaluating Public Activities

- **If all costs ("disbenefits") and benefits can be expressed in terms of money, then a decision criterion such as the Net Present Value (Present Worth) could be used.**

- **Discounting of cost and benefit flows should be applied, as appropriate.**

- ***Ethical* issues may arise.  Can the value of a park be measured in monetary terms?**

# Distributional Inequity

- **The risks and benefits do not usually accrue to the same individuals or to the same generation.**

- **Taxation is one way to remedy inequities.**

- ***Ethical* issues may arise. Can the impact of a project on future generations (e.g., waste disposal, climate change) be measured in monetary terms?**

- **Executive Order 12898 on *Environmental Justice*: No policy will result in disproportionately high adverse human health and environmental effects on low-income and minority populations compared to the general population in affected communities.**

# Public Activities: Ethical Issues (1)

- **How should risk transfer between generations be handled?**

- **How much should we spend now to protect future generations?**

- **Future generations should not be discriminated against.**

- **Risks imposed on future generations should not exceed current acceptable risk levels.**

# The Benefit-Cost Ratio

$$BC(i) = \frac{benefits \quad to \quad the \quad public}{cost \quad to \quad the \quad government}$$

- **Public:** (+) **advantages, receipts, savings**

   (-) **disadvantages, disbursements, losses**

- **Government:** (+) **disbursements, losses**

   (-) **savings, receipts**

- **Criterion:** **If $BC(i)_{Aj-Ak} > 1 \Rightarrow A_j \succ A_k$**

# Net Present Value (Present Worth)

$$\text{NPV}(i) \equiv \text{PW}(i) = \sum_t \frac{B_t}{(1+i)^t} - \sum_t \frac{C_t}{(1+i)^t}$$

**See slide 4, CBA 3.**

- **Criterion:** If $\text{NPV}(i)_{\text{Aj-Ak}} > 0 \Rightarrow A_j \succ A_k$

- **The following criteria are consistent when mutually exclusive alternatives are compared:**
  - ➤ *NPV(i) and AE(i) on total or incremental investment.*
  - ➤ *Rate of return on incremental investment.*
  - ➤ *BC(i) on incremental investment.*

# Multiple Alternatives (1)

**Example of slide 24, CBA 3**

| End of Year | A0 | A1 | A2 | A3 |
|---|---|---|---|---|
| 0 | 0 | -$5,000 | -8,000 | -10,000 |
| 1 – 10 | 0 | 1,400 | 1,900 | 2,500 |

**MARR = 15%**

# Multiple Alternatives (2)

**The present worth of the benefits for A1 is**

$$1,400 \frac{(1+0.15)^{10}-1}{0.15(1+0.15)^{10}} = 7,026$$

**Therefore,** $\quad BC(15)_{A1} = \dfrac{7,026}{5,000} = 1.41$

**Similarly:** $\quad BC(15)_{A2} = \dfrac{9,536}{8,000} = 1.19$

$$BC(15)_{A3} = \frac{12,547}{10,000} = 1.25$$

# Multiple Alternatives (3)

- **The "best" alternative (i.e., the one with the highest CB ratio) is A1.**

- **Recall (slide 28, CBA 3) that A3 was the best (PW analysis).**

- **Incremental Analysis**  $\mathbf{BC(15)_{A1-A0}} = \dfrac{\mathbf{7,026}}{\mathbf{5,000}} = \mathbf{1.41}$

$$\mathbf{BC(15)_{A2-A1}} = \mathbf{500(P/A,15,10)} = \frac{\mathbf{2,510}}{\mathbf{3,000}} = \mathbf{0.83}$$

$\Rightarrow$ **A1 remains the best.**

# Multiple Alternatives (4)

$$BC(15)_{A3-A1} = 1{,}100(P/A, 15, 10) = \frac{5{,}521}{5{,}000} = 1.10$$

$\Rightarrow$ **A3 becomes the final best alternative, just as before.**

# Public Policy (1)

- **Should a median barrier be added to a highway?**
- **<u>Current situation:</u>**

➢ **fatal accidents :**       **8 per $10^8$ vehicle miles**

➢ **non-fatal accidents:   35 per fatal accident**

➢ **damaging accidents: 240 per fatal accident**

➢ **vehicle density:       10,000 per day**

➢ **interest rate:       7%**

➢ **cost of fatality:       $900,000 per person**

➢ **cost of injury:       $10,000 per person**

➢ **cost of damage:       $1,800 per damaging accident**

# The Value of Life (1)

- **Essential in analyses and extremely difficult.**

➢ **"Willingness-to-Pay"**
  **-- how much is one willing to pay to decrease his/her probability of death or injury?**

➢ **"Human capital" (or "future earnings") with appropriate adjustments -- many ethical questions**

➢ **Inference from societal decisions**

# The Value of Life (2)

| Value of Life (2002 dollars) | Notes |
|---|---|
| **1,100,000** | **Derived from future earnings potential of "average man."** |
| **2,900,000** | **Derived from Swedish road safety data related to a willingness to pay to improve traffic risk.** |
| **7,000,000** | **Derived from mortality risks related to U.S. Government regulations.** |
| **1,100,000 to 9,700,000** | **Derived from "analysis of jobs with different wages and risks, …, and from direct questioning involving risk-money tradeoffs in constructed markets."** |

# Public Policy (2)

- **<u>Proposed barrier</u>**

➢New death rate:       4 per $10^8$ vehicle miles

➢Life:                30 years

➢Cost:                $1.5 \times 10^6$ per mile

➢Annual maintenance: $45,000 per mile

# Public Policy (3)

- **<u>Benefit-Cost Analysis</u>**

➤ **Aggregate cost per fatal accident =**

**900,000 + 35x10,000 + 240x1,800 = $1,682,000**

➤ **Annual benefit per mile to the public:**

$$\mathbf{AE(7)_B = \frac{(8-4)x10,000x365x1,682,000}{10^8} = \$242,572}$$

➤ **Annual cost per mile to the state:**

$$\mathbf{AE(7)_C = 1,500,000\frac{0.07x1.07^{30}}{1.07^{30}-1} + 45,000 = \$165,844}$$

# Public Policy (4)

- **Benefit-Cost Ratio:**

$$BC(7) = \frac{245{,}572}{165{,}844} = 1.48 > 1$$

- **The project should be accepted.**

- **OMB (1992): "It is a mistake to choose among mutually exclusive alternatives by selecting the alternative with the highest ratio of benefits to costs. An alternative with a lower benefit-cost ratio than another may have the higher net benefits."**

# Social Discount Rate

- **The US Federal Government uses a 7% real discount rate (Office of Management and Budget, 1992).**

- **This rate approximates the pre-tax rate of return on an investment in the private sector in "recent" years.**

- **For long periods of time, sensitivity studies are required.**

# Regulatory Analysis (1)

**Purpose:** **To determine whether there is adequate basis for imposing new requirements.**

- **Executive Order 12291 (President Reagan, 1981):**

  **No actions by federal agencies should be taken unless they result in a positive net value to society.**

# Regulatory Analysis (2)

- **Executive Order 12866 (President Clinton, 1993):**

➢ **EO 12991 is revoked.**

➢ **A regulatory analysis should be prepared for all "significant regulatory actions."**

➢ **These may result in a rule that may:**

   ✔ **have an annual effect on the economy exceeding $100 million**

   ✔ **adversely affect jobs, the environment, public health and safety**

   ✔ **seriously interfere with another agency's action**

   ✔ **raise novel legal or policy issues arising out of legal mandates, or the President's priorities.**

# Regulatory Analysis (3)

- **A regulatory analysis will not be required, if the regulatory action is necessary to ensure that the facility provides adequate protection to the health and safety of the public and is in accord with the common defense and security.**

# Value and Impact Evaluation

- **Values and impacts should be expressed on a common basis, e.g., constant dollars from a reference year.**

- **A <u>present-worth</u> basis is normally used to allow meaningful summations and comparisons.**

- **Health effects must be expressed in monetary terms.**

- **Other impacts, e.g., land contamination, are treated separately.**

# Discount Rates

- **The Office of Management and Budget (1992) recommends a rate of 7%.**

- **For sensitivity purposes, a calculation using a 3% rate is also recommended, because the NRC actions typically involve 30- to 60-year time horizons.**

# Decision Making

- **Selecting the alternative with the largest net present worth is consistent with obtaining the largest societal gain from among the alternatives.**

- **The benefit-cost ratio should be displayed but should not be the basis for the decision.**

- **OMB (1992): "It is a mistake to choose among mutually exclusive alternatives by selecting the alternative with the highest ratio of benefits to costs. An alternative with a lower benefit-cost ratio than another may have the higher net benefits."**