Public Sector Projects

- Benefit-cost analysis is often used to evaluate projects undertaken by the government
- Benefits and costs are evaluated on a monetary basis
- The choice of an appropriate interest rate is subject to much debate
- Social projects provide <u>public goods</u>
  - facilities or services available to all if available to one
- Public projects often provide <u>spillover benefits</u>
  - benefits to third parties not involved directly in the project
- Government project categories
  - protection
  - infrastructure development
  - cultural enhancement
  - resource management
- Government project characteristics
  - large and costly
  - long project life
  - multiple use
  - benefits often completely out of proportion to the financial support of individuals or groups
  - benefits (and disbenefits) affect many
  - public projects often not easily evaluated

Benefit-to-Cost Comparisons

- follow the same 8-step approach adopted in Chapter 4
- benefits, disbenefits, costs and savings must be quantified monetarily

Benefits - positive effects of a gov't investment
- desirable consequences for the public
- ignore benefits to any gov't body

Disbenefits - negative effects on the public
- exclude effects on gov't

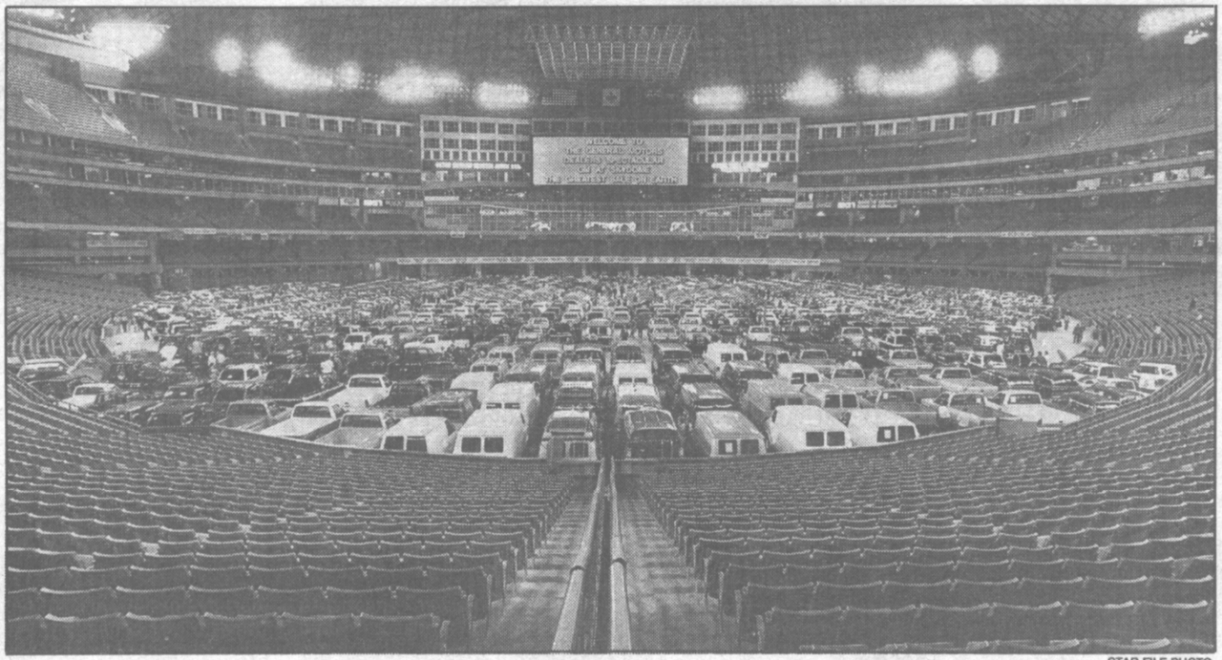
Costs - gov't expenditures over the planning period

Savings - income received by the gov't as a result of the project

Two Measures of Merit

- benefit-cost ratio (B/C)
- benefits less costs (B-C)

The Toronto Star -- Saturday, November 6, 1993



STAR FILE PHOTO

MONEY MACHINE: Non-sports events like this giant 1989 GM 'showroom' sale have broadened use.

Dome luring big bucks, study says

By Tony Van Alphen
TORONTO STAR

SkyDome, that signature landmark with the king-size public debt, is being held up as a big economic booster for Metro.

The impact of goods and services directly related to SkyDome and its hotel totals about $264.8 million in Metro and $351.9 million for the province annually, suggests a SkyDome-commissioned study on the downtown stadium.

"I thought it might have been $100 million for Metro but I was flabbergasted when the numbers came in," David Garrick, the stadium's vice-president of corporate affairs, said yesterday.

"Until this study, we had never been able to show how much SkyDome means to Toronto and the province."

The study by the Metropolitan Toronto Convention and Visitors Association does not include revenues and spending by the stadium's major tenants — the baseball Blue Jays and football Argonauts — or Dome Productions or development around the stadium such as restaurants and stores.

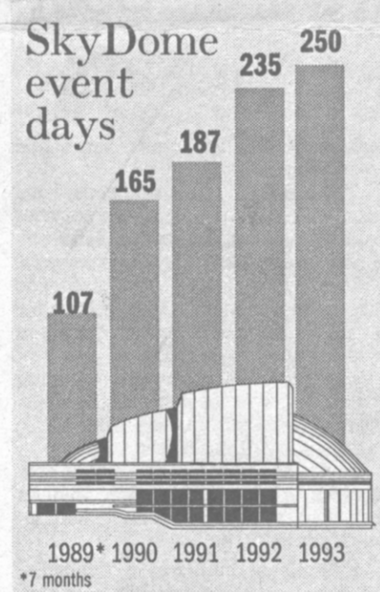
Garrick, who commissioned the study from the association, said SkyDome's economic impact should help answer criticism that the stadium's cost was far too high and taxpayers will never recoup their investment.

Metro and the provincial government contributed $60 million for the 50,000-seat stadium with the world's first workable retractable roof. But construction costs soared from an original $240 million contract to about $600 million, with taxpayers on the hook for more than $310 million.

SkyDome's popularity has helped a successful marketing drive that has significantly increased stadium days in use through such non-sports events as trade fairs, conventions, concerts and the like. Yet it has lost money every year — primarily because of interest payments on major borrowings to finance construction.

In the latest fiscal year ended Dec. 31, the stadium reported a net loss of $21.6

Please see SKYDOME, page C2



SOURCE: Stadium Corp. of Ontario

Benefits-to-Cost Comparisons

Benefit Cost Ratio

$$B/C = \frac{\text{Present Value of Benefits}}{\text{Present Value of Costs}}$$

or

$$= \frac{\text{Equivalent Annual Benefits}}{\text{Equivalent Annual Costs}}$$

<u>PV Approach</u>

Let B_{jt} = public benefits due to Project j in Year t

C_{jt} = gov't costs associated with Project j in Year t

and i = an appropriate interest rate

B/C:

$$B/C_j(i) = \frac{\sum_{t=1}^{n} B_{jt}(1+i)^{-t}}{\sum_{t=0}^{n} C_{jt}(1+i)^{-t}}$$

A project is "in the public interest" if B/C > 1.0.

(B-C): PV Net Benefits = PV(Benefits) - PV(Costs)

$$(B-C)_j(i) = \sum_{t=0}^{n} (B_{jt} - C_{jt})(1+i)^{-t}$$

Select public projects where (B-C) > 0.

Benefit-to-Cost Comparisons

- When comparing alternatives using a B/C ratio, use an incremental analysis

  i.e., ensure each increment of public expense returns sufficient benefits

- Order the alternatives from lowest to highest cost, then compare

$$\Delta(B/C)_{2-1}(i) = \frac{\Delta B_{2-1}(i)}{\Delta C_{2-1}(i)} = \frac{\sum_{t=1}^{n}(B_{2t} - B_{1t})(1+i)^{-t}}{\sum_{t=0}^{n}(C_{2t} - C_{1t})(1+i)^{-t}}$$

- Select the better of the two and then compare it with the next most costly alternative
- Continue the comparison of successive alternatives in pairs, until the "best" remains

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- For the $(B\text{-}C)_j$ method, calculate the value of $(B\text{-}C)_j$ for each Alternative j and then select the maximum

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(B-C) analysis appears straightforward but can be easily biased (knowingly or unknowingly) by the project evaluator.

Benefit-to-Cost Comparisons

- What perspective to use when comparing B to C?

Alternative	Equivalent Cost	Annual Flood Damage	Annual Benefit
I: No flood control	$ 0	$200,000	$ 0
II: Construct levees	40,000	130,000	70,000
III: Small reservoir	120,000	40,000	160,000
IV: Large reservoir	160,000	10,000	190,000

	TOTAL				INCREMENTAL			
Alternative	B	C	B/C	B-C	ΔB	ΔC	ΔB/ΔC	ΔB-ΔC
I:	$ 0	$ 0	0	$ 0				
					$70	$40	1.75	$30
II:	70	40	1.75	30				
					90	80	1.125	10
III:	160	120	1.33	40				
					30	40	0.75	-10
IV:	190	160	1.19	30				

Benefit-to-Cost Comparisons Cont'd

Decision Maker's Perspective Can Influence Outcome

1 Minimum investment: I
2 Maximum benefit: IV
3 Aspiration level (reduce flood damage by 75%): III
4 Annual cost threshold of $100,000: II
5 Maximum advantage of benefits over cost: III
6 Highest benefit to cost ratio: II
7 Largest investment having B/C > 1.0: IV
8 Largest investment having an incremental B/C > 1: III

Flood-Control Project

- Four tributaries originate in a national park and flow together to form a river
- Each year there is flooding, occasionally there is a major flood
- One or more dams would ease the flooding
- Dams on all four tributaries would eliminate major floods

<u>Benefits</u>

- reduce flood damage to private lands downstream
- reduce damage to fire/logging roads in the park
- recreational use of impounded water behind the dam
- water available for fire protection

<u>Costs</u>

- construction costs of the dam
- annual maintenance and operating costs

<u>Project Life</u>

- 40 years
- no salvage value for the dams

<u>Interest Rate</u>

- 4%
- low-risk project

Flood-Control Project

$$B/C \text{ ratio} = \frac{\text{annual flood \& fire savings} + \text{recreation benefits}}{\text{equiv. annual construction costs} + \text{maintenance}}$$

0.0505

Equivalent annual construction cost

= initial construction cost (A|P 4,40)

A study of the site has shown there are only four feasible combinations of dams:

Alternative	Dam Sites	Construction Costs	Equiv. Annual Constr. Cost
I.	1	\$1,200,000	\$60,600
II.	1 & 2	1,500,000	75,750
III.	1,2 & 3	2,700,000	136,350
IV.	1,2,3 & 4	3,500,000	176,750

Which of the four alternatives should be selected?

- Use incremental B/C ratios
- Do the additional benefits returned by an increment of cost justify that cost (B/C ratio > 1)?

Flood-Control Project

Annual Benefits & Costs

Dam Sites	Constr. Costs	Mtce & Op Costs	Flood Benefits	Fire Benefits	Recreation Benefits
1	60,600	20,000	200,000	20,000	30,000
1/2	75,750	35,000	190,000	40,000	30,000
1/2/3	136,350	50,000	280,000	60,000	60,000
1/2/3/4	176,750	60,000	300,000	70,000	70,000

Use Incremental Analysis

Dam Sites	Annual Benefits	Annual Cost	Incremental Benefit	Incremental Cost	Total B/C	Incremental B/C
1	250,000	80,600			3.1	
			10,000	30,150		0.3
1/2	260,000	110,750			2.3	
			140,000	75,600		1.4
1/2/3	400,000	186,350			2.1	
			40,000	50,400		0.8
1/2/3/4	440,000	236,750			1.9	

Flood Control Project

1 Dam Site 1 versus "do nothing":

$$B/C(I) = \frac{250{,}000}{80{,}600} = 3.1$$

2 Next increment meeting B/C > 1 is Dam Site 1/2/3:

$$\Delta B/C(III - I) = \frac{10{,}000 + 140{,}000}{30{,}150 + 75{,}600} = 1.4$$

3 Adding Dam 4 is unacceptable (B/C < 1):

$$\Delta B/C(IV - III) = \frac{40{,}000}{50{,}400} = 0.8$$

Flood-Control Project

The third alternative is preferred:

Dams at sites 1, 2 and 3

Dam Sites	B/C	Alternative
1	3.1	I
1/2	2.3	II
1/2/3	2.1	III
1/2/3/4	1.9	IV

If the incremental approach had not been used, the following improper choices may have been made:

Alternative I - choose the one with the highest B/C ratio (B/C = 3.1)

Alternative IV - Choose the one that has the highest annual benefits ($440,000) and a B/C $>$ 1 (B/C = 1.9).

Flood-Control Project

The selection is sensitive to changes in data.

1 At an interest rate of 8%, Alternative I would be selected. With (A|P 8,40) = 0.0839, the increased equivalent annual construction costs of Alternative III would no longer be justified.

2 If the spillover benefits were excluded from the analysis, Alternative I would have been selected.

$$\Delta B / C(III - I) = \frac{80,000}{30,150 + 75,600} = 0.8$$

Flood-Control Project

(B-C) method can also be used. (NPV Approach)

DAM SITES	CONSTRUCTION COSTS	ANNUAL COSTS	ANNUAL BENEFITS
1	1,200,000	20,000	250,000
1/2	1,500,000	35,000	260,000
1/2/3	2,700,000	50,000	400,000
1/2/3/4	3,500,000	60,000	440,000

$$(B-C)_j = \sum_{t=0}^{n} (B_{jt} - C_{jt})(1+i)^{-t}$$

19.7928

$$(B-C)_1 = -1{,}200{,}000 + (250{,}000 - 20{,}000)(\mathrm{P}\,|\,\mathrm{A}\ 4{,}40)$$

Alternative j	$(B\text{-}C)_j$ (\$000)	
I	3,352	
II	2,953	
III	**4,227**	**- preferred alternative**
IV	4,021	

NOTE: When using the (B-C) approach, incremental analysis need not be used.

Public Project Analysis: Point of View

- The point of view taken will affect the analysis of a public project:

1. An individual who will benefit or lose.
2. A particular governmental organization.
3. A local area such as a city or county.
4. A regional area such as a province.
5. The entire nation.

e.g. County Decision: Public versus Private Refuse Service

Cost to County	$25.00/tonne

but the county does not have to pay the taxes that a private contractor would:

Federal	$2.00/tonne
Provincial	1.00/tonne
Property Tax	1.50/tonne
	$4.50/tonne

- should the county adopt a
  - local
  - regional
  - national

  point of view?

A "local" decision can affect a much wider public.

Public Project Analysis: Interest Rate Selection

- The discount rate affects project ranking especially in long-term public projects **(i?)**
  1. Zero - tax monies are "free"
  2. Social time preference rate
     - as estimated by government
     - usually quite low (2-4%)
  3. Interest paid by government on borrowed money
     - Treasury Bills (T Bills) and long-term bonds
  4. Opportunity cost for those investments forgone by the private sector
     - rates of return higher in private sector
     - if not, companies would invest in risk-free gov't bonds
  5. Opportunity cost for investments foregone by gov't agencies due to budget constraints
     - increase the discount rate until only those projects that can be funded have positive NPV of (B-C)

  Treasury Board Social Discount Rate
- 10 year average of quarterly Treasury Bill rates

Public Project Analysis: Assessing B-C Factors

- Placing a value on “societal benefits” may be difficult

What factors are included in a study?

Internal Effects: Direct or indirect effects on the individuals or organizations with which the engineer is primarily concerned.
External Technological Effects: Effects which cause changes in physical opportunities for consumption or production.
e.g. water sport activity due to new dam.
Secondary Effects: Changes in the demand for goods and services arising from a public project.
e.g. New mine increases population in nearby towns.

Consider a flood control project
- $250,000 per year damage prevented

Disbenefits (which to include?)
- decrease in demand for post-flood restoration goods and services
- loss of agricultural land

Public Project Analysis: Over-counting

- A common problem when one is considering a large variety of effects is to over-count
- The benefits to society of some factors are unknowingly counted twice

Public Health Department Study

In order to increase awareness to reduce preventable disability in the workplace, the following data were presented:

Individual Income Loss:	
Number of workers affected	350,000
Average days per year lost due to preventable accidents	4
Average hourly wage	$12.50
Total individual loss per year	$17,500,000
Industry Loss:	
Loss due to disorganization, idle overhead & lessened productivity is 2 1/2 the wage lost	$43,750,000
TOTAL LOSS	$61,250,000

Loss to industry **only** its foregone earnings.

Public Project Analysis: Unequal Lives

- For one-shot public works projects having unequal lives, the planning period usually is the longest life

- With unequal lives, the discount rate chosen can affect project ranking

Government Discount Rate Example

Consider two one-shot projects that each have first costs of $200,000.

	Project A	Project B
Project Life	15 years	30 years
Costs (per annum)	$30,000	$30,000
Benefits (per annum)	$60,000	$52,808

- Consider the effects of the discount rate on the project with the longer life
- The project with the longer life is more sensitive to the discount rate chosen for project evaluation

Unequal Lives and the Discount Rate

NPV approach with i = 5%

Low interest rate reflects social time preference rate.

$(B\text{-}C)_A$ = 60,000(P|A 5,15) - 30,000(P|A 5,15) - 200,000
= \$111,400
$(B\text{-}C)_B$ = 52,800(P|A 5,30) - 30,000(P|A 5,30) - 200,000
= \$150,60

Project B is preferred.

NPV approach with i = 12%

Budget Constraint - Opportunity Cost of Public Project Investments Foregone = 12%

$(B\text{-}C)_A$ = 60,000(P|A 12,15) - 30,000(P|A 12,15) - 200,000
= 4,330
$(B\text{-}C)_B$ = 52,808(P|A 12,30) - 30,000(P|A 12,30) - 200,000
= -16,282

Project A is now preferred.

Public Project Analysis: User Fees

- Tolls, fees and user charges affect both benefits and costs
- Net benefits received are reduced by amount of payment
- Amount of payment also reduces government cost

B/C will change; (B-C) will remain constant

<u>Public Park</u>

- 10,000 visitors per year
- free admission
- park EUAC = \$20,000
- people, on average, receive recreational benefits of \$3.00:

$$B/C = \frac{\$3(10{,}000)}{\$20{,}000} = 1.5$$

(B-C) = \$3(10,000) - \$20,000 = \$10,000 per year

- To reduce public expense charge a \$1.75 fee:

Net benefit per person \$3.00-1.75 = \$1.25

Gov’t park revenue \$1.75(10,000) = \$17,500

$$(B/C) = \frac{\$30,000 - \$17,500}{\$20,000 - \$17,500} = 5$$

(B-C) = 30,000-17,500 - (20,000-17,500) = \$10,000 per year

Note B/C changed, (B-C) did not.

Public Project Analysis: User Fees

- user fees may affect the demand for services provided by a public project
- (B-C) may change if a user fee is imposed

Public Park

- 10,000 visitors per year each receiving on average $3 per person worth of benefits
- Actual break out is estimated to be:

# Persons	Recreational Benefits	Total
8,000	$ 1.45	$11,600
1,000	$ 3.00	3,000
1,000	$15.40	15,400
10,000		$30,000

- With a $1.75 fee only 2,000 visitors will patronize the park.

$$B/C = \frac{\$3(1000) + \$15.40(1000) - \$1.75(2000)}{\$20,000 - \$1.75(2000)} = 0.90$$

$$\begin{aligned}(B-C) &= [\$3(1000) + \$15.40(1000) - \$1.75(2000)] \\ &\quad -[\$20,000 - \$1.75(2000)] \\ &= \text{-}\$1,600\end{aligned}$$

Public Project Analysis: Multiple-Use Projects

- Multiple uses, and therefore multiple benefits, are often available at slight incremental costs
- Each increment of cost must result in a concomitant increase in benefits

<u>Irrigation & Flood Control</u>

- Dam and reservoir for irrigation provides benefits of \$25,000,000 and costs \$14,500,000
- Single-purpose flood control dam would cost \$9,000,000 and provide \$6,000,000 in benefits
- Modification to the irrigation dam will provide flood control benefits at a total cost of \$18,500,000
- Which public project should be undertaken?

$$\text{Irrigation:} \quad B/C = \frac{\$25{,}000{,}000}{\$14{,}500{,}000} = 1.72$$

$$\text{S/P Flood Control:} \quad B/C = \frac{\$6{,}000{,}000}{\$9{,}000{,}000} = 0.67$$

$$\begin{array}{l}\text{M/P Irrigation Plus} \\ \text{Flood Control:}\end{array} \quad \Delta B/\Delta C = \frac{\$6{,}000{,}000}{\$18{,}500{,}000 - \$14{,}500{,}000} = 1.5$$

$\therefore$ Build the multi-use facility.

Multi-purpose projects can pose a problem when costs of the project are “allocated” back to the beneficiaries.

Public Project Analysis: B/C Ratio Problems

1. Taking the project with the largest B/C ratio will often lead to errors in project selection.

$$B/C_{\text{Irrigation}} = \frac{25{,}000{,}000}{14{,}500{,}000} = 1.72$$

$$B/C_{\substack{\text{Irr+Flood}\\ \text{Control}}} = \frac{25{,}000{,}000 + 6{,}000{,}000}{18{,}500{,}000} = 1.68$$

Largest B/C ratio would cause us to select IRRIGATION only, <u>in error</u>.

2. Therefore use incremental analysis. Remember, proceed with incremental investment as long as $\Delta B/\Delta C > 1$.

$$B/C_{\text{Irrigation}} = \frac{25{,}000{,}000}{14{,}500{,}000} = 1.72$$

$$\Delta B/\Delta C_{\substack{\text{Irr+Flood}\\ \text{Control}}} = \frac{6{,}000{,}000}{18{,}500{,}000 - 14{,}500{,}000} = 1.5$$

Largest B/C ratio again would result in wrong selection.

Choose the IRRIGATION + FLOOD CONTROL project since $\Delta B/\Delta C > 1.0$. The additional cost of $4,000,000 is justified.

Public Project Analysis: B/C Ratio Problems

- Often difficult to decide whether an item is a benefit to the public or a cost savings to the government

  BENEFITS = $100,000 DISBENEFITS = $60,000

  COSTS = 5,000

<u>One View</u>

$$B/C = \frac{100{,}000 - 60{,}000}{5{,}000} = 8$$

$\therefore$ One analyst believes the project is outstanding.

<u>Other View</u>

Gov't will reimburse those damaged by project:

$$B/C = \frac{100{,}000 - 60{,}000 + 60{,}000}{5{,}000 + 60{,}000} = 1.54$$

- (B-C) stays the same with both viewpoints

  (B-C) = $35,000

- Advantages of (B-C)
  - eliminates inherent bias in B/C
  - does not require incremental approach where benefits and costs are known for each project
  - unlike B/C, highest (B-C) is best project
- Unfortunately, B/C ratio is the most popular

Cost-Effectiveness Analysis

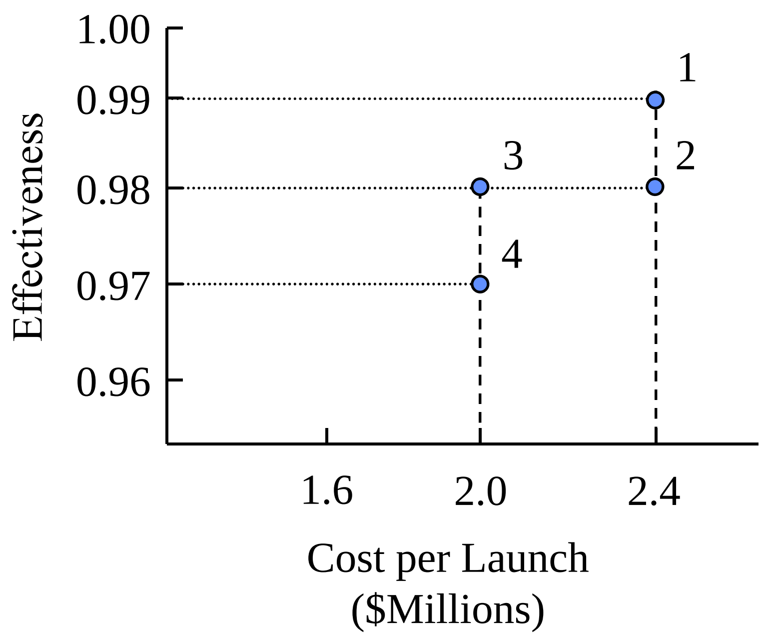
- Project outputs are measured quantitatively, but <u>not</u> in monetary terms
  - failure rate
  - system reliability
  - lives saved
- Project costs are in monetary terms
- Common goals are required to form basis for comparison

<u>Rocket Propulsion System</u>

(Cost per launch - $Millions)

SYSTEM	COST	RELIABILITY
1	2.4	0.99
2	2.4	0.98
3	2.0	0.98
4	2.0	0.97

Cost-Effectiveness Analysis



<u>1 versus 2</u>
- prefer System 1

<u>3 versus 4</u>
- prefer System 3

<u>2 versus 3</u>
- prefer System 3

∴ 1 dominates 2
3 dominates 2
3 dominates 4

Left with 1 versus 3.

Does an additional one %
of reliability justify $400K?

Assume total loss of payload if propulsion system fails.

Cost-Effectiveness Analysis

Does an additional one percent of reliability justify the incremental cost of $400,000?

(98% $\rightarrow$ 99% reliability)

i.e. expect, on average, 1 less failure per 100 launches

Additional cost per 100 launches:

$$\$400\text{K} \times 100 = \$40 \text{ million}$$

Is the payload, on average, valued at more than $40 million?