Cost Effectiveness Analysis

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TOPICS

- Decision-making and cost effectiveness
- Methodology
- Example
- Theoretical foundations
- Elaboration of methodology
- Criticisms of cost effectiveness analysis

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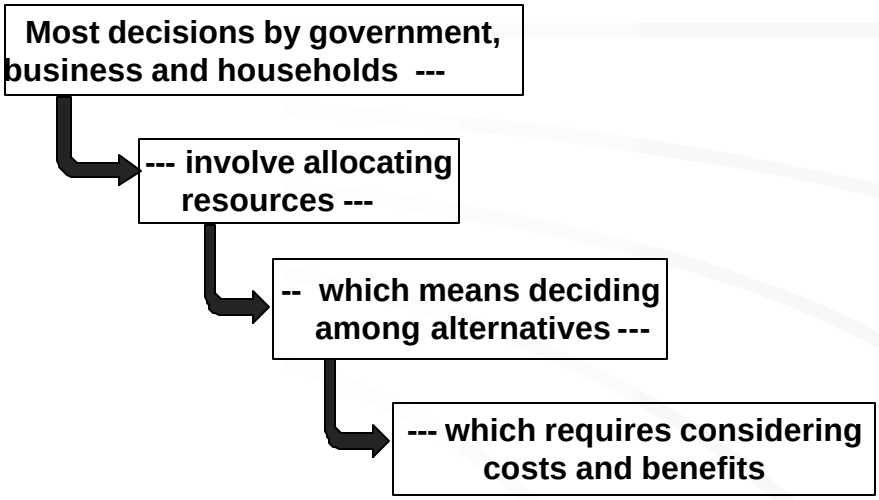
DECISION-MAKING



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COMMON DECISION-MAKING METHODS

- Judgments by officials and professionals
  - Captures corporate memory and institutional knowledge
    But decision makers often disagree
- Immersion in the facts
  - Stays in contact with reality
    But "what is" diverts attention from "what could be"
- Holistic approach ("Since judgment calls are required, let the practitioner decide")
  - People learn to do very well what they do every day
    But practitioners do not spend their days studying alternatives, costs and benefits

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ANOTHER METHOD: COST EFFECTIVENESS

- Deals with objective, alternatives, cost and benefits explicitly
- Does it quantitatively as much as possible

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SOME ODDS AND ENDS

- Cost effectiveness
  - is a methodology involving both; neither is an adjective
  - is sometimes called “systems analysis”
  - is related to profit maximization and cost–benefit analysis
  - in defense analysis, focuses on the peacetime cost of wartime capability

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COST EFFECTIVENESS METHODOLOGY

• Define Objectives	What do we want to do?
• Structure Alternatives	What are the ways to do it?
• Calculate Effectiveness	What do we gain?
• Estimate Costs	What do we lose?
• Choose a Criterion	Which alternative is best?

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THE CRUCIAL ISSUE

- Construct alternatives that "hold something constant"
  - Hold cost constant and maximize effectiveness

Or

  - Hold effectiveness constant and minimize cost
- Suppose this is impossible – stay tuned

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OTHER IMPORTANT ISSUES

- Don't carry out the steps sequentially
- Construct a "base case" using the most plausible inputs
- Conduct sensitivity analyses to cover uncertainties
- List omitted factors and indicate their likely effects
- Highlight critical issues requiring judgment calls
- Should the analyst make policy recommendations?

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APPLICATIONS

- Government
  - Buy new C-17s or stretch B-52s?
  - Extend subway to Dulles or widen the road?
- Industrial
  - What kind of plant to build?
- Medical
  - What diagnosis tools are best?
- Consumer
  - Toyota or Lexus?

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AN EXAMPLE: BUYING A NEW CAR

	Buy a Chevy	Buy a Honda	Buy a Chevy Rent a Mercedes for Inter-city Travel	Buy a Chevy Fly Between Cities
Unit Cost				
Procurement	$15,000	$20,000	$15,000	$15,000
Operating				
City	$0.14/mi	$0.12/mi	$0.14/mi	$0.14/mi
Country	$0.10/mi	$0.08/mi		
Rental			$0.40/mi	
Airlines				$0.20/mi
Salvage value	$5,000	$10,000	$6,000	$6,000
Unit Effectiveness				
Miles in city	10,000 mi/yr	10,000 mi/yr	10,000 mi/yr	10,000 mi/yr
Miles in country	5,000 mi/yr	5,000 mi/yr	5,000 mi/yr	5,000 mi/yr
Total 10-year cost	$29,000	$26,000	$43,000	$33,000
Total 10-year effectiveness				
City	100,000 mi	100,000 mi	100,000 mi	100,000 mi
Country	50,000 mi	50,000 mi	50,000 mi	50,000 mi

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WHY MUST COST ANALYSTS UNDERSTAND COST EFFECTIVENESS

- Cost analyses are usually (always?) done to support decision making
- The decision at hand affects the structure of the cost analysis
  - Which costs are relevant
  - What discount rate to use
  - How much accuracy is necessary?

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THEORETICAL FOUNDATIONS

Cost Effectiveness is a branch of microeconomics

	Benefit	Cost	Criterion
Private Sector	Revenue ($)	Cost ($)	Maximize profit ($)
Public Sector, Marketable Output	Benefit ($)	Cost ($)	Maximize the ratio
Public Sector, Non-marketable Output	Effectiveness	Cost ($)	Hold one constant, optimize the other

Cost effectiveness analysis

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- More on foundations of cost effectiveness in later lecture on "Economics in Cost Analysis"

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INSTITUTIONAL REQUIREMENTS

- Cost effectiveness analysis is
  - Required in the Department of Defense for large programs (COEA or AOA)
  - Recommended by OMB for non-defense programs

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FALLACIES AND ISSUES IN COST EFFECTIVENESS

- Objectives
- Alternatives
- Cost
- Effectiveness
- Criterion

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OBJECTIVES

- "Determine the system that has the highest effectiveness and the lowest cost"

  How can you do both?

- "Determine the least costly system for meeting the requirements"

  Requirements don't exist (except institutionally)

  The more we buy, the higher the effectiveness and the higher the cost

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OBJECTIVES (Continued)

- "You can't analyze all resource questions — some are really intractable"

  A polar position!

- "You can't analyze new technology options (basic research, exploratory development)"

  Make the alternatives menus of possibilities, rather than systems

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ALTERNATIVES

- "We should include *all* alternatives"
  - We can't

    Scenarios are uncertain
    Data are incomplete
    Models are imperfect
- One way to cope with these problems
  - Compare polar cases
    - *E.g., a sophisticated costly aircraft with a simpler but less costly one*

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COST

- Analyze historical data using statistical regression techniques to develop a Cost Estimating Relationship
- Results of regression

$$\text{Cost} = \alpha + \beta_1 (\text{input 1}) + \beta_2 (\text{input 2}) + \ldots$$

- Criteria of validity
  - Intuitive signs ("+" for resource variables)
  - Statistical significance (high t-statistics for all variables)
  - High predictability (high value of R^2)
  - What to do if t-statistics are high but R^2 is low

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TYPES OF COST

- Acquisition (non-recurring)
  - Development
  - Procurement
    - Land
    - Facilities
    - Equipment (depends on number of systems)
  - Salvage
- Operations and Support (recurring)
  - Operations and Maintenance
  - Personnel

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SUMMARY MEASURES

- 10-year system cost

  Development (~ no. of prototypes)
  + Procurement (unit proc. × no. of systems)
  + O&S (unit O&S × no. of systems × 10)
  – Salvage value (unit salvage × no. of systems)

- Life-cycle cost

  30 years of O&S

- Time-phased cost

  Total expenditures over next 10 (or 30) years

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- More specifics on cost models in the remaining lectures.

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ACCOUNTING FOR TIME

- A problem: $1 commands different resources in different years
- Why?
  - Inflation rate (general increase in prices)
  - Discount rate (banks pay interest)
  - Sunk costs
- Therefore, we must adjust!

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ADJUSTMENTS

- For inflation
  - Deflate future costs to constant (current) dollars
- For interest
  - Translate future costs to present values
- For sunk costs
  - Forget them!

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Calculating Constant Dollars and Present Values

- Assume 4% inflation and 6% real interest rate
  - Cost of widget purchased in 2003 =$100
  - Cost in 2002 dollars = $100/(1.04) = $96.15
  - Present value in 2002 dollars = $96.15/(1.06) = $90.71
- One step, using a *nominal* discount rate

1 + nominal r	= (1 + .06) x (1 + .04)
	= 1 + .06 + .04 + (.06)(.04)
	≅ 1 + .10
Present value in 2002 dollars	= $100/(1.10) = $90.91

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WARNING!

- OMB appropriation-specific deflators include *real* cost increases, in addition to inflation
- Therefore:
  - Use them for budgeting
  - But not for calculating costs in constant dollars

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- More on the rationale and use of discounting in “Economics in Cost Analysis,” “Cost Data,” and “Life-Cycle Costing”

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SUNK COSTS

- Quiz for the student:
  - Why ignore sunk costs?
- Answer:
  - They are not costs!

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FALLACIES

- "They're only 14 to 16 months away from coming up with a system. It would be a shame to throw away the investment in the program."
- "We're interested in how much money to put in the budget, so we should use the inflated costs for our cost effectiveness studies."
- "The DoD budget is relatively constant year-to-year, so there are no time tradeoffs, and costs should not be discounted."

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ACCOUNTING FOR LEARNING IN ESTIMATING PRODUCTION COSTS

People

Average cost = First unit cost x Slope $^{\log (\text{Quantity})}$

Example for 90% learning curve (0.90 slope)

Number of Systems Purchased	Average Cost	Total Cost
100	$ 100.0	$ 10,000
200	90.0	18,000
300	84.6	25,400
400	81.0	32,400
|		
|		

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- More on learning curves in “Cost Progress Curves”

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INDIRECT COSTS

- Reduction in reenlistment rates due to family separation
- Costs of Army defenses of deployed Air Force bases
- Reduction in mobilization base due to procurement cuts
- Imputed land cost of military bases
- Costs of environmental cleanup

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IF YOU CANNOT ESTIMATE ALL COSTS

- Estimate what you can. Something is better than nothing!

Cost of Cadillac	$31,000
Cost of Honda	– $19,000
What you are paying for improved comfort	$12,000

- The question becomes, “Is the softer ride worth $12,000?”

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THE COST ANALYST MUST INTERACT WITH OTHER TEAM MEMBERS

- Cost effectiveness analysis is an iterative process
- The cost analyst must ensure that:
  - The alternatives are cost-able
  - The effectiveness analysis focuses on what is costed
  - The criteria reflect cost as well as effectiveness

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EFFECTIVENESS MODELS

Type of Model	Inputs	Cost of Development	Accuracy of Results
Bottom-up engineering	Detailed theory Engineering data	High	High
Simulation (Combat model)	Operations analysis Operational data	High	High
Top -down regression	Major variables Historical data	Low	Medium
Expert systems	Personal experience	High	Medium
Back-of-the-envelope	General theory Casual empiricism	Lowest	Low

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LEVEL OF DETAIL

- Including too much detail
  - Increases the cost of doing the analysis
  - Risks "losing the bubble"
- Including too little detail
  - Loses the ability to discriminate among alternatives
  - Risks credibility

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LEVEL OF DETAIL
(Continued)

- Mount Everest approach to effectiveness modeling
  - "If it's there, put it in the model"
- "If the model does anything, it will do everything"
- Objections
  - "It will do nothing!"
  - "Roughly right" beats "precisely wrong"
    -- and costs less, besides

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SENSIBLE APPROACH TO MODELING

- Start with a back-of-the-envelope analysis
- Refine the model only where needed to discriminate among the alternatives

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"THE ANALYSIS IS NOT REALISTIC"

- We're analyzing alternatives, not making movies!
- All analysis involves abstraction from the real world
- The trick is to capture the effects that discriminate among the alternatives

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"DON'T COMPARE APPLES AND ORANGES"

- Cost Estimating Relationship for the Base Operating Support costs of 150 Navy facilities (1981 CNA Study)
  - Naval bases, hospitals, schools, labs, shipyards, etc.
- BOS cost =
  $.041\ (Mil)^{.034}(Civ)^{.248}\ (Area)^{.249}(Acre)^{.061}\ (BTU)^{.155}$
- $R^2 = .90$
  t-statistics: statistical significance better than 1%

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CRITERION

- Hold cost or effectiveness constant
- Keep ultimate goals in mind
  - In WW II convoying, reduce ships lost, not subs sunk
  - In setting speed limits, reduce lives lost, not number of accidents

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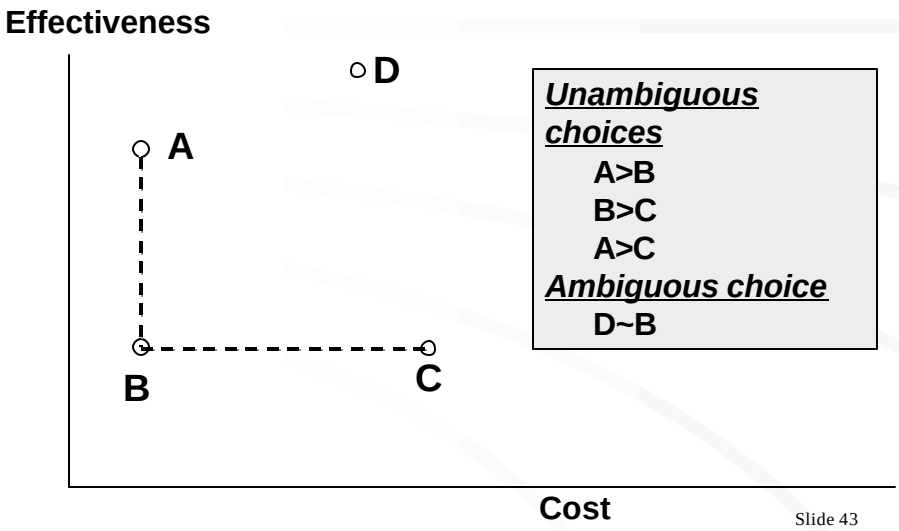
UNAMBIGUOUS CHOICES



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WHICH TO HOLD CONSTANT, COST OR EFFECTIVENESS?

- Theory doesn't care
- The sponsor may have preferences
- Consider analytical convenience

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HOLD ING SOMETHING CONSTANT MAKES DECISION-MAKING EASIER

Which choice is easier?

$18,000 Honda	vs	$30,000 Cadillac
$18,000 Honda and new $12,000 kitchen	vs	$30,000 Cadillac

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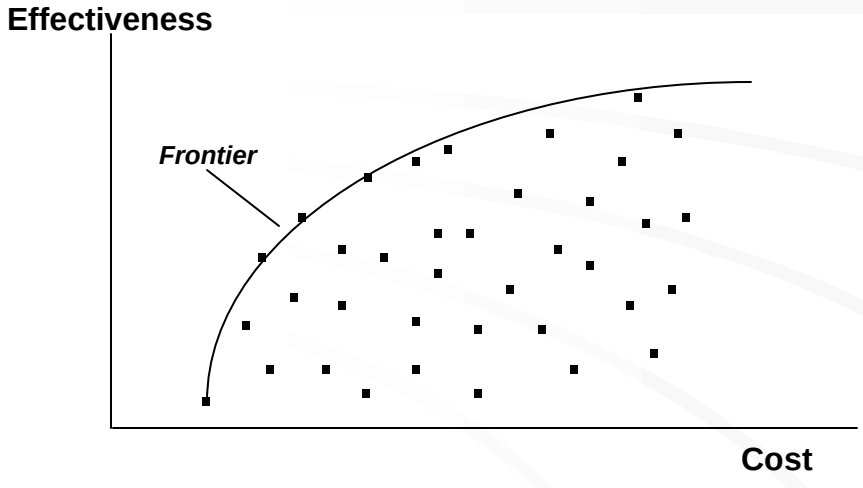
IF YOU CANNOT HOLD SOMETHING CONSTANT



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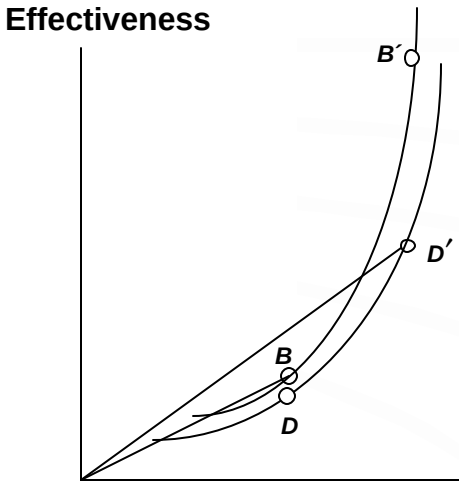
BEWARE OF COST EFFECTIVENESS RATIOS



Option D' has a better C/E ratio than option B

But B > D and B'>D' (B technology dominates D technology)

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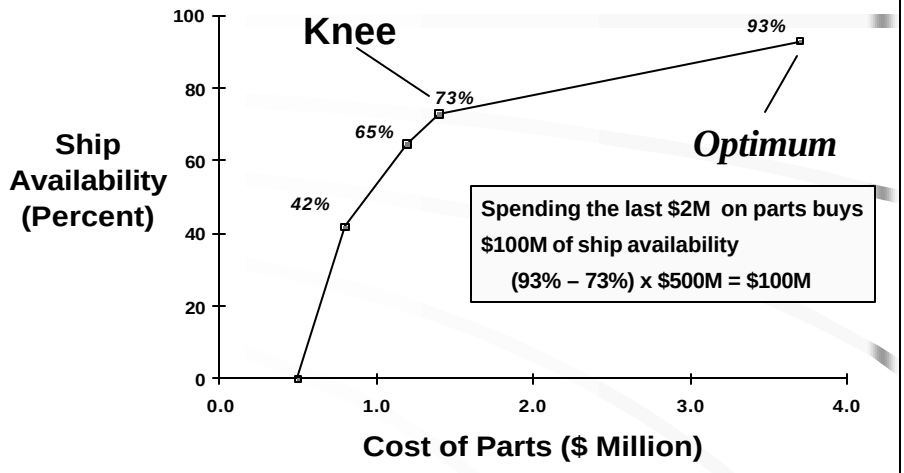
THE KNEE OF THE CURVE: FORGET THE KNEE, USE THE HEAD!



Spending the last $2M on parts buys $100M of ship availability
(93% – 73%) x $500M = $100M

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WHAT SHOULD YOU GIVE THE SPONSOR?

- Alternatives
  - What he *asks* for?
  - What he *really* wants?
  - What you think he *should* want?
- Strategic Basing Study, Late 1950s
  - Air Force question: Where in Europe should we station the strategic bombers?
  - RAND response: Station them in the U.S. and buy tankers!

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HANDLING RISK AND UNCERTAINTY

- Risk (probabilities are known)
  - Calculate expected value and variance of cost and effectiveness
- Uncertainty (probabilities are not known)
  - Give the decision maker information so he can apply his own intuition
- Show cross-over points
  - "Radar A > radar B if target range is over 100 miles"
- Show results for ranges of inputs

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CRITICISMS OF CURRENT C-E PRACTICE

- Does not identify who is helped, who is hurt
- Reduces comparisons to a single dimension, generally dollars and cents
- Conceals uncertainty of estimates

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C-E ANALYSIS CAN COMPLEMENT OTHER WAYS OF MAKING DECISIONS

- Helps to structure the problem
  - Offers a framework for analysis
  - Makes assumptions explicit
  - Identifies biases
- Helps advocates understand the strengths and weaknesses of their own positions
- Offers a neutral position for adjudicating disputes (elevating the quality of the debate)
- Incidentally, decision makers are free to reject our advice!!

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SUMMARY

- What is cost effectiveness?
- What does it apply to?
- What are its strong points?
- What are its failings?
- Even with its failings, can it help decision makers?

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