Benefit-cost Analysis: General Approaches

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Session Goals

- Basic definitions and theory
- Why economic analysis is appropriate to NMHS?
- How can BCA be used in evaluating the usefulness of NMHS
- Discuss some "special issues" for BCA of NMHS products and services

Economic analysis and NMHS

- The goals of economic analysis of NMHS options depend on the intended use of such an analysis.
- Benefit-cost analysis is most commonly used for justifying program budgets to decision makers.

Resources

- **Handbook on Economic Analysis of Investment Operations**
  - World Bank guidebook for benefit cost analysis / project assessment
  - includes techniques for undertaking analysis in developing countries
  - tools and techniques for assessing the projects with non monetary benefits that integrate financial, economic, and fiscal analysis
  - assessment of projects in education, health, and transport sectors

http://www.preventionweb.net/files/1064_econanal.pdf

http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2007/06/25/000020439_20070625152441/Rendered/PDF/207330REVISED.pdf

Benefit-Cost Analysis overview

- Can we justify purchasing a new super computer for research to improve weather forecasts – with no change in forecast quality until 10 years from now.
- Is it a good idea to build a new observation system?
- Should we broadcast additional weather forecasts?
- Would we be better off spending additional money on modeling for weather forecasting?
- Should we spend the money on weather forecasting or education or crime control or health care?

Each of these **should** be addressed by doing a proper cost benefit analysis.

Definition

- Benefit-cost analysis (BCA) is a tool for determining how well, or how poorly, a planned action will turn out.
  - Determine whether significant programs should proceed.
  - Choose the most attractive alternative to achieve program goals.
  - Measures cost and benefits in monetary terms of a project to the community or economy
  - It finds, quantifies, and adds all the positive factors
    - **benefits**
  - It identifies, quantifies, and subtracts all the negatives
    - **costs**
  - The difference between the two indicates whether the planned action is advisable.

BCA Decision Criteria

- Net benefit = benefits minus costs
  - If benefits > costs → worth doing the program
  - If benefits < costs → not worth doing the program

- Benefit-cost ratio:
  - If benefits / costs > 1 → worth doing the program
  - If benefits / costs < 1 → not worth doing the program

- Internal rate of return (IRR)
  - Rate of interest in a net present analysis that makes the benefits equal to or greater than the costs.
  - If IRR > rate of discount → worth doing the program
  - If IRR < rate of discount → not worth doing the program

Techniques for project analysis

- Even without all information available, it's beneficial to go through BCA
- Alternative to BCA: cost-effective analysis
  - goals / outcomes are measured in some single non monetary units (e.g. number of forecasts delivered)
  - cost per unit of outcome is derived under different options
  - what is the most cost-effective way to achieve the outcome?

BCA in 3 steps

1. Identify, quantify (monetize), and add up all the benefits
2. Identify, quantify (monetize), and add up all the costs
3. Compare benefits and costs and apply one of the decision criteria

Issues:

- Identify
- Quantify
- Monetize
- Add up (across all people, places, time …)

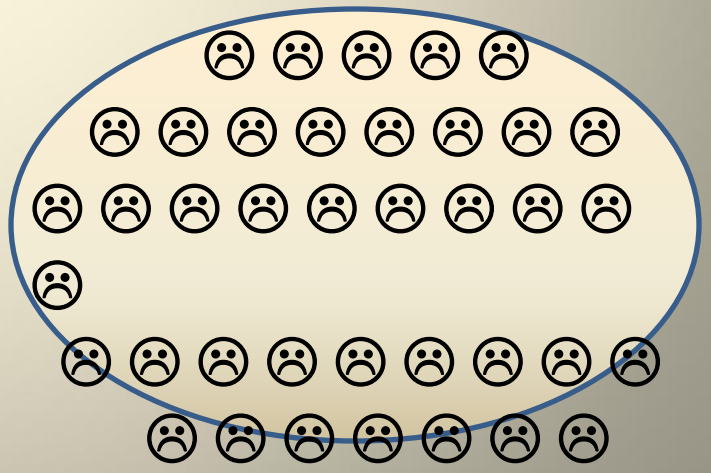
Special Topics
Distributional Issues

- BCA: Add up and compare all the benefits and costs to all people over all places over all time discounted appropriately to their present value
- Compare these sums
- Doesn't say anything in the end about who gets what, when, where ….

Special Topics
Distributional Issues

Project A:

Total benefits:	3,000,000
Total costs:	1,000,000
Net benefit	2,000,000



Special Topics
Distributional Issues

Distribution between:

- Different groups or individuals
  - one versus many
- Different geographic areas
  - countries
  - regions / states
- Gender
- Ethnicity
- Age groups
- Income groups

Special Topics
Distributional Issues

How does benefit cost analysis deal with distributional issues?

- Pareto principle: project is worthwhile if it makes one person off while making no-one else worse off
- Potential Pareto principle (Kaldor-Hicks Principle): ***could*** arrange sufficient compensation from those that are made better off to those that are made worse off so that all would end up no worse off than before.

How to do this "right" – be transparent and specific about distributional issues?

Special Topics
Uncertainty and risk

- Lack of information about the consequences of actions and the benefits and costs of these consequences often confounds the benefit-cost analysis
- Risk is the variation in potential outcomes to which an associated probability can be assigned
  - Outcome
  - Probability
  - Sum of all of the probabilities = 1.0
- Uncertainty is the lack of knowledge concerning
  - potential outcomes
  - probability distribution of outcomes
- Risk can be accommodated through the purchase of insurance or hedging.
- Uncertainty is harder to deal with behaviorally
  - uncertainty must be incorporated in cost-benefit analysis the decision process.

Special Topics
Uncertainty and risk

Suppose municipality is considering flash flood warning system.

- Analyst could hypothesize that the future would look very similar to the present:
  - population would remain stable
  - Incomes would remain constant relative to prices
  - historical weather patterns will not change
  - the dam uphill will not fail
  - the main road out of town for evacuation will not be closed.

  At least one, if not all, of these characteristics will change over the life flash flood warning system.

Special Topics
Uncertainty and risk

- How to treat uncertainty about key variables in cost benefit analysis?
  - Expert elicitation – ask relevant experts their assessment of the probabilities and potential outcomes and use the distribution of these estimates in the analysis
  - Sensitivity analysis – analyze uncertainty by changing input variables and observing the sensitivity of the result.
    - Does the decision change when certain parameters change within reasonable levels?

Special Topics
Value of statistical life

- Example: Government uses the benefit-cost analysis to decide whether to:
  - invest in a new radar observations
  - hire more forecasters to work 24/7
  - give everyone weather radios
- A value must be put on human life or the environment (often causing great controversy)
- Another example: Should a guardrail on a dangerous stretch of mountain road be installed?
  - Yes, if the dollar cost of doing so is less than the implicit dollar value of the injuries, deaths, and property damage thus prevented

Special Topics
Value of statistical life

- It is a statistical term, the cost of reducing the (average) number of deaths by one.
- Some people feel that putting an economic price tag on life is inhumane, because every life is "priceless".
- Since resources are finite, tradeoffs are inevitable, even regarding potential life-or-death decisions.
- With a limited supply of resources it is impossible to save every life, so some trade-off must be made.
- The assignment of a value to statistical life is an approach to make rational decisions about tradeoffs of probabilities of loss of life.

Special Topics
Value of statistical life

- Various methods are used to estimate the value of life
  - willingness to pay to avoid premature death
  - wage differential approaches
  - ”human capital” approach that estimates the present value of future earnings of an individual that would be lost because of premature mortality.
- All these measures might be problematic when estimating life value across countries.

Special Topics
Value of statistical life

- For example, a common value for a “statistical life” in the United States is now $3-5 million or more
- this is a function of income levels and willingness to pay to avoid change in probability of death
- cannot apply this same value to another country with a per capita income one-twentieth the size of that in the United States
- yet deflating the U.S. value by the relative difference in income levels has critical ethical dimensions
- In the absence of carefully done national studies of the value of a statistical life, it is often best to present mortality data in terms of the number of lives lost or saved – possibly in addition to a monetary value

Special Topics
Value of statistical life

- Example:
  - City with 1,000,000 adults
  - 10 people die each year at the intersection of State Highway and Main Street
  - Highway Improvement Program would reduce this to 9 people per year
  - Risk reduction from 10:1,000,000 to 9:1,000,000
    - 1 life per year
  - Citizens said they would pay average of $6 per year for Highway Improvement Program
  - 1,000,000 adults x $6 = $6,000,000
    - to reduce fatalities by 1 person per year
  - VSL = $6,000,000

Special Topics
Discounting and Time

- Projects generate costs and benefits over a period of time, with costs and benefits often occurring in different time periods.
  - a dollar of costs or benefits ten years from today not directly comparable to a dollar of costs or benefits today.
  - investor prefers to receive a payment of a fixed amount of money today, rather than an equal amount in the future
- Discounting is used to express all future costs and benefits in their present value equivalent.
- Costs and benefits are discounted in each future time period and summing them to arrive at a present value.
- Some costs that occur far into the future may be given too little weight in traditional cost-benefit analysis
  - e.g., climate change impacts

Special Topics: Discounting and Time

- PV Benefits = $\frac{B^t}{(1+r)^t}$
- PV Costs = $\frac{C^t}{(1+r)^t}$
- NPV = PV Benefits-PV Costs = $\frac{B^t - C^t}{(1+r)^t}$
- Total NPV = sum of all PV Benefits-PV Costs =

$$\sum_{t=0}^{t=T} \frac{B^t - C^t}{(1+r)^t}$$

Special Topics
Discounting and Time - example

	Discount rate= 0.0%		Discount rate = 3.0%		Discount rate= 7.0%	
Year	Benefits	Costs	PV Benefits	PV Costs	PV Benefits	PV Costs
0	0.00	100.00	0.00	100.00	0.00	100.00
1	25.00	50.00	24.27	48.54	22.68	45.37
2	50.00	10.00	47.13	9.43	41.16	8.23
3	50.00	10.00	45.76	9.15	37.35	7.47
4	50.00	10.00	44.42	8.88	33.89	6.78
5	50.00	10.00	43.13	8.63	30.75	6.15
Total PV	225.00	190.00	204.71	184.63	165.84	174.00
NPV		35.00		20.08		8.16

Summary

- Benefit-cost analysis
  - Benefits increase societal welfare
  - Costs decrease societal welfare
- Special topics
  - Distributional issues
  - Uncertainty and risk
  - Value of statistical life
  - Discounting and time

Steps to Conducting an Economic Analysis

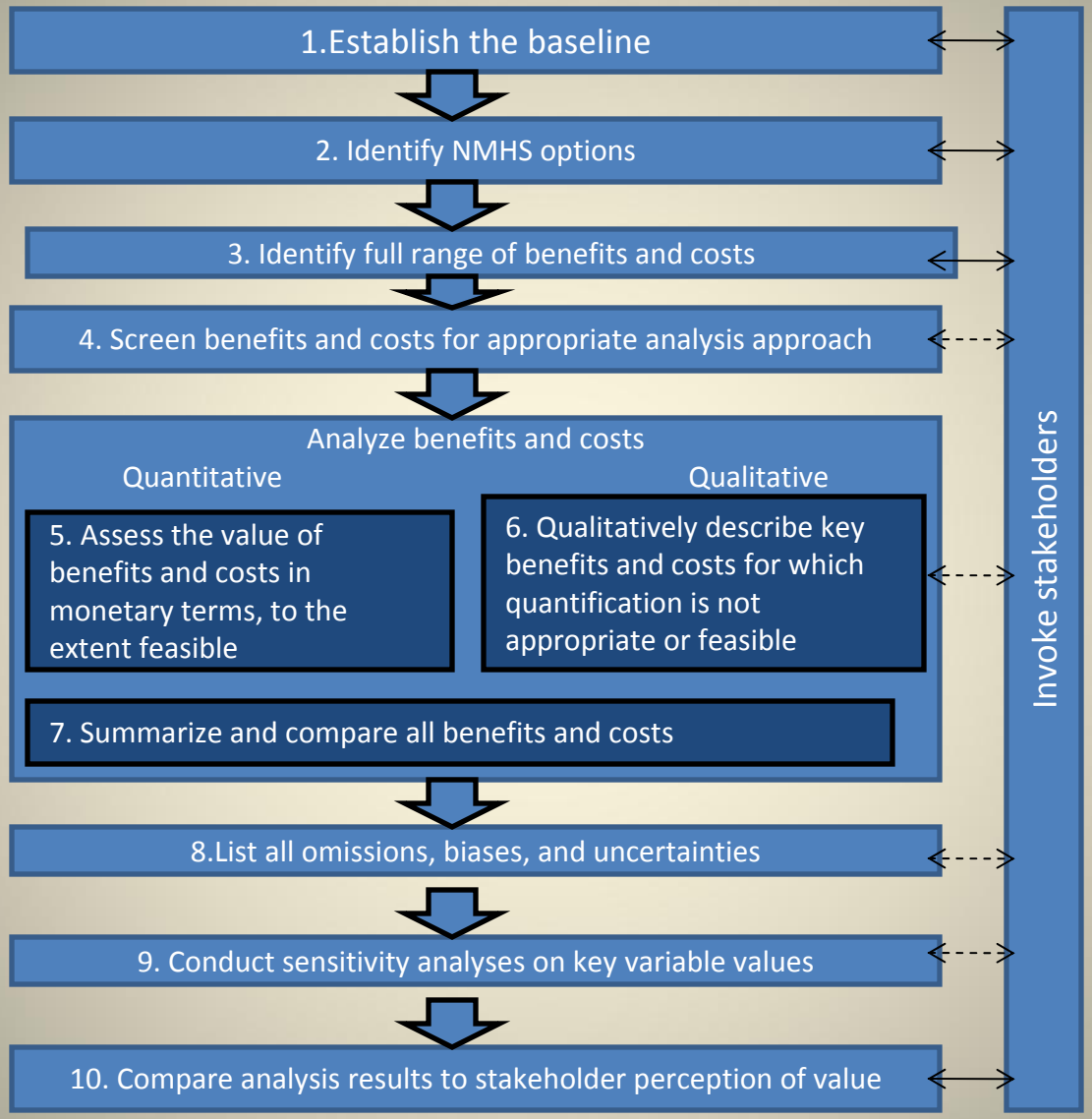
Learn the basic steps for conducting economic analysis

For some projects not all steps are

- feasible (depending on information available)
- necessary

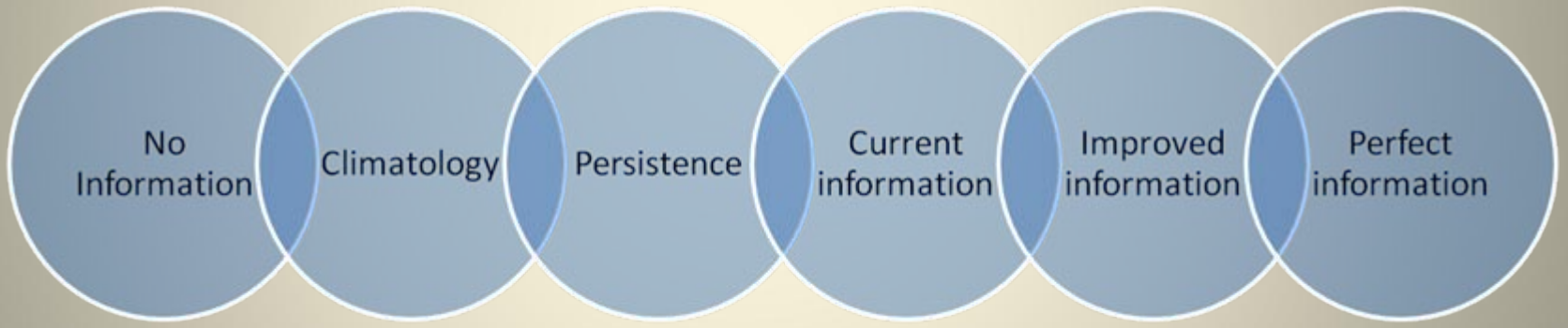
Which steps are not feasible/not necessary for your project?

Road map


1.Establish the baseline
2. Identify NMHS options
3. Identify full range of benefits and costs
4. Screen benefits and costs for appropriate analysis approach
Analyze benefits and costs
Quantitative
Qualitative
5. Assess the value of benefits and costs in monetary terms, to the extent feasible
6. Qualitatively describe key benefits and costs for which quantification is not appropriate or feasible
7. Summarize and compare all benefits and costs
8.List all omissions, biases, and uncertainties
9. Conduct sensitivity analyses on key variable values
10. Compare analysis results to stakeholder perception of value
Invoke stakeholders

Step 1: Establish the Baseline

- Define the outcomes associated with the “no action” status quo
  - What would happen without the forecasting option or options being considered?
- Define the scale and timing of the impacts of the baseline
- Articulate what problems the proposed program is intended to resolve
- Be explicit about assumptions.



- The baseline must specify what NMHS activities are being evaluated and to what they are being compared.
- In some cases the baseline information without the NMHS may be the information provided by another NMHS (e.g., from a neighboring country).

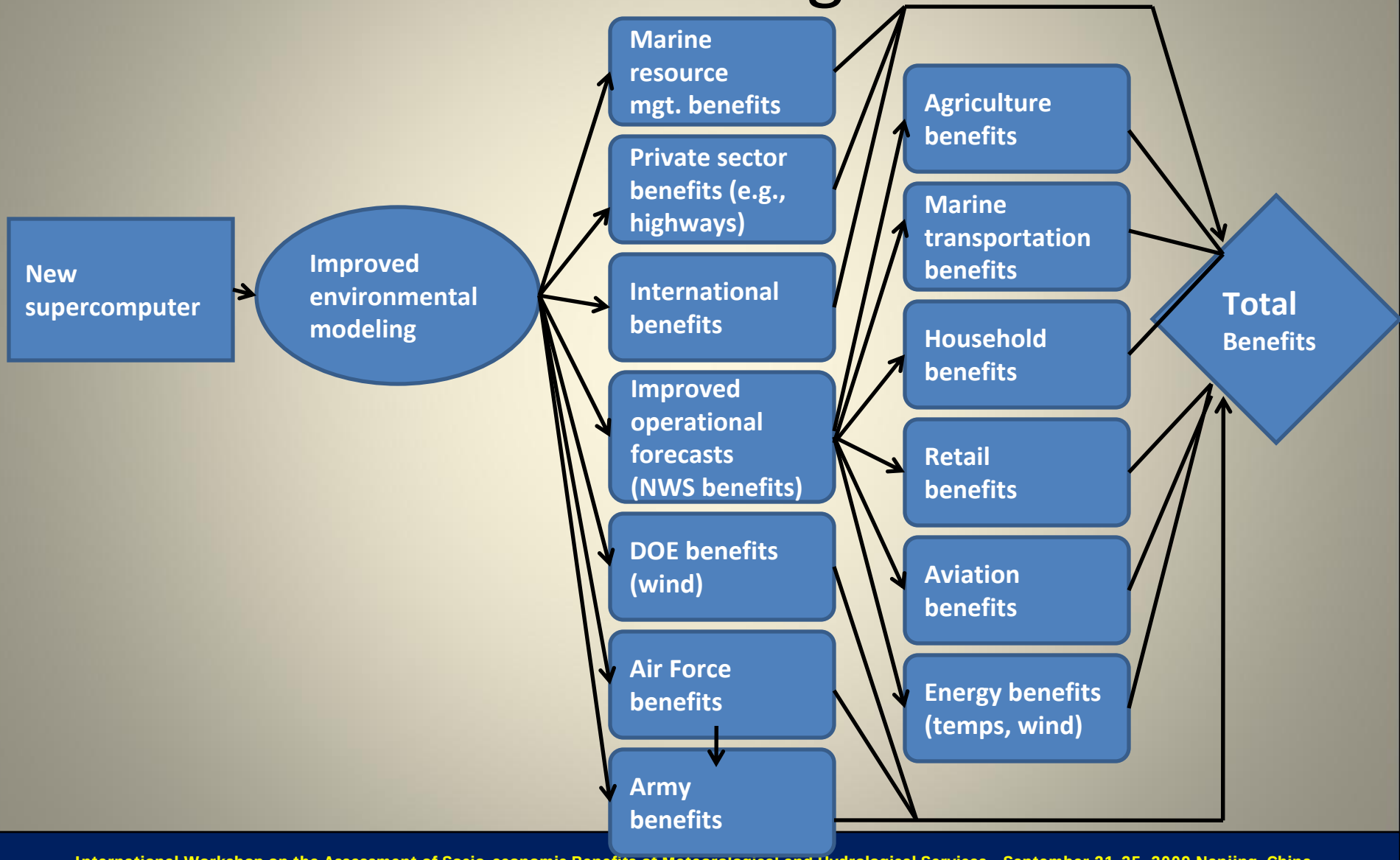
Step 2: Identify NMHS options

- Determine the primary and alternative options being considered in the analysis.
- Options often of interest to NMHS include changes or improvements in
  - Observation systems
  - Data assimilation
  - Forecasting models
  - Computer facilities and capacity
  - Forecast dissemination.
- Extending the traditional realm of many NMHS may involve improvements or implementation of new or better uses and responses to information, including:
  - Forecast communication
  - Development of decision support tools
  - Emergency response activities for severe weather or flood warnings.

Step 3: Identify full range of benefits and costs

- Costs and benefits should be included regardless of to whom they may accrue or where they might be realized.
  - All participants
  - Only citizens
  - Special group of citizens

Benefits of Improved Weather Modeling



Step 4: Screen Benefits and Costs for Appropriate Analysis Approach

- Determine which costs and benefits can and should be analyzed quantitatively and which should be described only qualitatively.
  - Costs and Benefits that are truly insignificant can be eliminated from further analysis.
- Analyze Benefits and Costs
  - For an NMHS program, costs are typically the initial and continuing monetary costs of funding the program.
  - The benefits of an NMHS program typically arise from information the program produces
    - characterize the information in terms of its potential users and what they use information for in decision making

Step 4: Screen Benefits and Costs for Appropriate Analysis Approach

- Following aspects of valuation problem need to be understood:
  - The type of information being valued (e.g. all hydrometeorological information or just high temperature information)
- The types of decisions being made using the information and how the information affects these decisions
- The beneficiaries of the value (e.g., the users of the information)
- The temporal and spatial scales of the values being generated.
- The hydrometeorological information process and the associated value chain:

Step 5: Assess the Value of Benefits and Costs in Monetary Terms

- Express the costs and benefits of a proposed NMHS program in monetary terms (quantitatively).
  - Costs are typically already in monetary terms
  - Expressing benefits in this way is the central challenge for NMHS programs

Step 6: Qualitatively Describe Key Benefits and Costs

- Non quantified benefits and costs need to be described in a meaningful, qualitative manner.
- One approach:
  - Use a simple scale that indicates the likely impact on net project benefits.
  - Qualitatively rank impacts on a 5-point scale, ranging from -2 to +2, to reflect relative outcomes that span from very negative to very positive
  - qualitative ratings should be accompanied by descriptions of the impact, and should be explicitly carried through the analysis.

Step 7: Summarize and Compare All Benefits and Costs

- If possible, discount quantitative benefit or cost projections over time (from Step 6) to PV at an appropriate discount rate.
- Summarize net monetized benefits and costs (either annual or present value) in one location, along with the listing and ranking of those benefits that can be described only qualitatively (from Step 6).
- Summary table must include:
  - the monetized benefits and costs
  - a listing and qualitative assessment of the non-quantified benefits and costs

Step 8: List All Omissions, Biases, and Uncertainties

- Explicitly document all omissions, biases, and uncertainties associated with the estimated benefits and costs.
- The impact that these may have on the final outcome of the analysis should be noted.
  - e.g., in terms of their likelihood of increasing or decreasing net benefits, or an uncertain direction of change in net benefits

Step 9: Conduct Sensitivity Analyses on Key Variable Values

- Conduct sensitivity analyses on key variables or benefit and cost estimates
  - with the aim of exploring and communicating the impact of assumptions, uncertainties, or natural variabilities.
- Sensitivity analyses is used to identify which assumptions or uncertainties have the largest impact on the outcome of the analysis
  - to identify which assumptions might change the net benefits of an option from positive to negative or to alter the ranking of options in terms of their relative net benefits.

Step 10: Compare Analysis Results to Stakeholder Perception of Value

- Compare the quantitative and qualitative values that result from the analysis and from the various sensitivity analyses with stakeholder expectations of values.
  - check on the reasonableness of the analysis results
  - process for working with stakeholders to help them realize (or at least better articulate) the values they obtain from the project.
- In the NMHS context, stakeholders are typically the users of the information that is to be produced by the program under consideration.

Summary

- Basic steps for conducting economic analysis
- For some projects not all steps are
  - feasible (depending on information available)
  - necessary

- For a given study . . .
  - which concepts, tools, and approaches this study will require
  - what data, economic models, etc. are needed to undertake this study
  - what type of expertise is needed to undertake this study and who will provide that expertise
  - how long such this study will take
  - how much this study will cost
- Explain what type of information will come out of the study
  - how will this information be used for decision making for this project
  - who will use this information for decision making for this project
  - what other information will affect their decision on this project