Decision Analysis II

Part 6

Decision Analysis II

What is Decision Analysis?

- A systematic quantitative approach for assessing the relative value of one or more different decision options

Why use Decision Analysis?

- Making real-world decisions often involves assessing the probability and value of multiple outcomes
- It is difficult to evaluate complex decisions
- Decision analysis allows for the incorporation of data from multiple sources, makes assumptions explicit, and quantifies the decision parameters

Judgment under Uncertainty: Heuristics and Biases

- Uncertainty: "I think that…"
- Sometimes expressed as probabilities
- How do people quantify uncertainty?
  - They rely on a limited number of heuristic principles
    - Representativeness
    - Availability
    - Adjustments and Anchoring
  - Can be useful, but can lead to errors

Tversky and Kahneman, Science 1974 185:1124

Heuristics: Representativeness

- Is A related to B? People evaluate how representative B is of A
- Example: "Steve is very shy and withdrawn, invariably helpful, but with little interest in people, or in the world of reality. A meek and tidy soul, he has a need for order and structure, and a passion for detail"
- What is his most likely profession?
  - Farmer, salesman, airline pilot, librarian, or physician

Heuristics: Representativeness

- Error I: **Insensitivity to prior probabilities**
- There are many more farmers than librarians. Does this revise your estimate?
- Experiments have shown that people utilize prior probabilities when given no other information, but will ignore this information if they are able to use representativeness

Heuristics: Representativeness

- Error II: **Insensitivity to sample size**
- People assume similarity of sample to population does not depend on the sample size
- Example: How likely is it that the average height of 10 men is over 6 ft.? Of 100? Of 1000?

Heuristics: Representativeness

- Error III: **Misconception of chance**
- People assume a sequence of outcomes will represent the essential characteristics of the process
- For a coin, is H-T-H-T-H-T or H-H-H-T-T-T more likely?
- "Gambler's fallacy": Black likely on roulette wheel after long run of red

Heuristics: Representativeness

- Error IV: **Insensitivity to predictability**
- People's evaluations (of current characteristics) are same as their predictions (of future characteristics)
- Example: Performance on a quiz gives "perfect" prediction of future performance

Heuristics: Representativeness

- Error V: **The illusion of validity**
- Validity of prediction is evaluated by consistency of inputs
- Example: Predict final GPA of student with all B's versus A's, B's, and C's.
- Redundancy of inputs decreases accuracy but increases confidence

Heuristics: Representativeness

- Error VI: **Misconceptions of regression**
- "Regression to the mean"
- Example: encouragement leads to poorer performance after a good performance, and punishment leads to improvement after a poor one
- Conclusion (erroneous): negative feedback more effective than positive feedback

Heuristics: Availability

- People assess frequency of an event based on ability to recall such events
- Error I: Biases due to retrievability (celebrity names)
- Error II: Effectiveness of a search set (letter “r” in words)
- Error III: Biases of imaginability
- Error IV: Illusory correlation (causation)

Heuristics: Adjustment and anchoring

- “Starting point bias”
- Conjunctive event: probability of a specific sequence of events (probability of success/failure)
- Usually overestimated when each event fairly likely -> project planning too optimistic

Heuristics: Adjustment and anchoring

- Disjunctive event: probability of one specific event in a sequence of events (evaluation of risk)
- Usually underestimated when each event fairly unlikely -> underestimate risk of failure of a complex system (e.g. nuclear reactor, human body)

Heuristics: Adjustment and anchoring

- Subjective probability distributions usually too narrow, i.e. uncertainty is underestimated because people tend to “anchor” toward their central estimate

Framing decisions

- A disease outbreak is expected to kill 600 people in the U.S. You need to choose an intervention:
- Program A: 200 people will be saved
- Program B: There is a 1/3 probability that 600 people will be saved, and a 2/3 probability that no people will be saved
- Which do you favor?

Tversky and Kahneman, Science 1981 211:453

Framing decisions

- A disease outbreak is expected to kill 600 people in the U.S. You need to choose an intervention:
- Program C: 400 people will die
- Program D: There is a 1/3 probability that no one will die, and a 2/3 probability that 600 people will die
- Which do you favor?
- Over 70% of students chose A, then D

Prospect theory

- Response to losses is greater than response to gains
- Low probabilities are overweighted
- Moderate and high probabilities are underweighted

In summary:

- People evaluate uncertainty
  - based on similarities
  - ability to recall examples
  - with starting-point bias
- Thus, utilizing decision analysis to make decisions under uncertainty explicit can help to avoid potential errors or misconceptions

When to use Decision Analysis

- There should be some uncertainty about the appropriate clinical strategy
  - Clinical trial may not include all outcomes
  - Different levels of risk have not been evaluated
- The interventions to be compared should have tradeoffs
  - Effectiveness vs. cost
  - Benefit vs. risk

Step 1: Identify and bound the problem

- What is the decision problem; what is the research question?
- What are the potential alternative actions?
- What are the events that follow the decision?

Example

- 15 new cases of measles are reported in a small urban area. This is the first report of measles in the area in several years. All of the cases are in children age 8-15 who previously had only 1 measles vaccination - the recommendation at the time, but it is now known not to confer lifetime immunity.

Example

- Problem: Should children vaccinated only once be re-vaccinated?
- Alternative: Do not revaccinate
- Events:
  - exposure to infectious measles
  - development of measles
  - death from measles

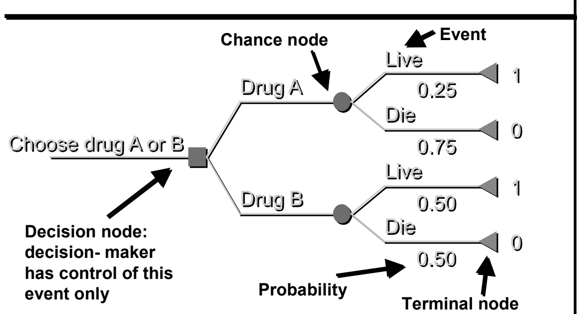
Step 2: Structure the problem

- Use a decision tree
- A decision tree depicts graphically the components of the decision problems and relates actions to consequences

Decision tree conventions

- Build left to right
- Nodes
  - decision nodes (squares)
  - chance nodes (circles)
- Event placed above "branch"
- Probability of event placed below "branch"

Decision tree



Decision tree

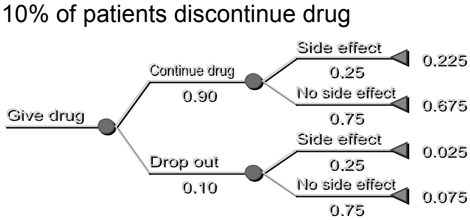
- Each event at a node must be mutually exclusive
- Thus, the sum of the event probabilities at a node must be 1.0

Probabilities

- Use **conditional probabilities** for "downstream" nodes
  - p(A)=0.10 prob. you're asleep
  - p(B)=0.25 prob. you understand DA
  - p(B|A)= prob. you understand DA given that you are asleep 1.0? 0.0?

Example

- 25% of patients started on a drug experience an adverse drug reaction
- 10% of patients discontinue drug

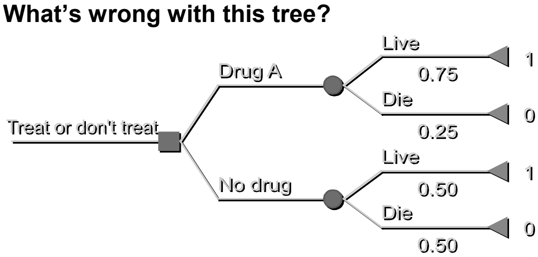


How complex should a model be?

- Key factors that impact cost-benefit must be included
- But an model that is unnecessarily complex may be ineffective for influencing decisions
- **Model structure is usually data driven**
- **Model building is an iterative process**

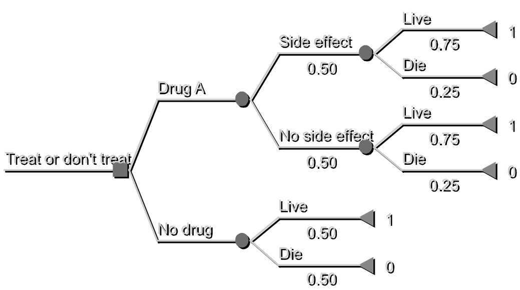
a) Tree should have ‘balance’

What’s wrong with this tree?



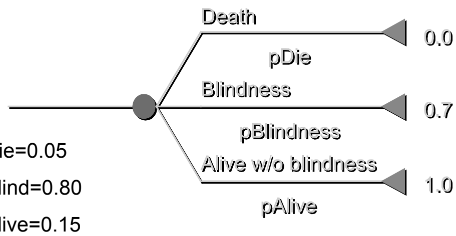
Detsky et al, Med Dec Making 1997 17:123

The “Drug A” branch had no risk



b) Only 2 branches per node

Why might this structure be a problem?

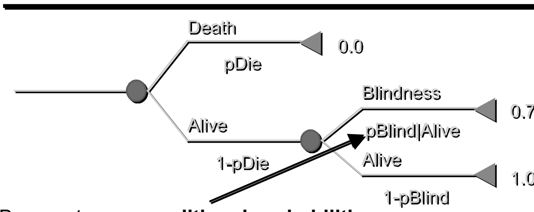


pDie=0.05

pBlind=0.80

pAlive=0.15

Solution



Be sure to use **conditional probabilities**

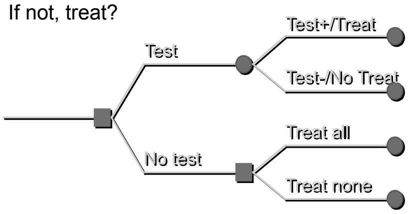
pBlind|Alive=pBlindness/(1-pDie)

=0.80/(1-0.05)=0.84

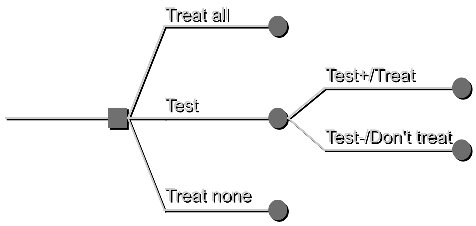
pDie=0.05
pBlind=0.80
pAlive=0.15

c) No embedded decision nodes

Use diagnostic test?
If not, treat?

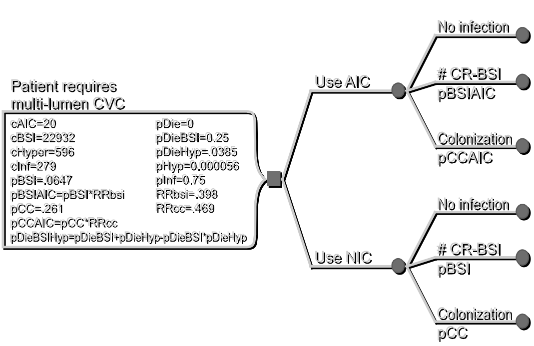


Present all options at first node



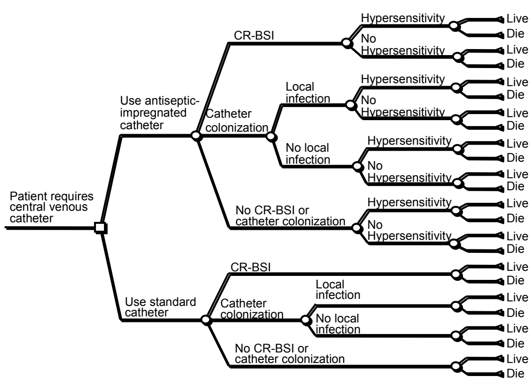
d) Link branches

- Linkage is the explicit relationship among probabilities or outcomes that ought to be related
- Linkage is achieved by designing for the two branches mathematical expressions that share common variables (e.g. prevalence, efficacy (relative risk))

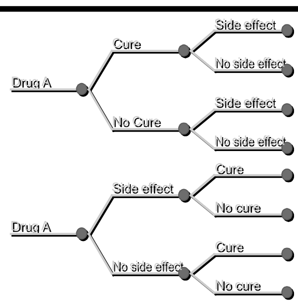


e) Tree should have symmetry

- Use same subtree structure throughout model when possible



f) Order of events not critical



Step 3: Gathering data

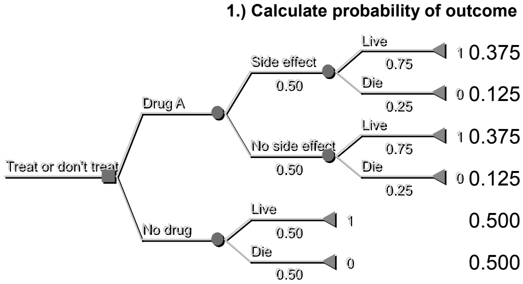
- Conduct systematic search where appropriate
- Can use RCT's, meta-analysis, expert opinion, etc.
- Use best estimate for "base-case" analysis
- Use 95% CI's or ranges for sensitivity analysis

Step 4: Analyzing the tree

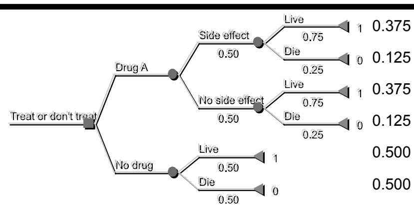
- Calculate expected value of each strategy
- Also referred to as "rolling back" or taking the average of the tree
- Start at terminal node and multiply probabilities as you trace tree to origin to get probability of outcome
- Sum weighted outcomes for each strategy

Analyzing tree

1.) Calculate probability of outcome



Analyzing tree



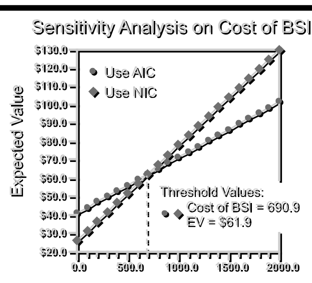
2) Multiply outcome value by outcome probability and sum

Drug A: 1(.375)+0(.125)+1(.375)+0(.125) = **0.75**
Drug B: 1(.5)+0(.5) = **0.5**

Step 5) Run sensitivity analyses

- Perform 1-way sensitivity analyses on **all** parameters to debug tree
- Vary probabilities from 0 to 1; response of model to changes should be logical
- Set all costs/outcomes to zero; strategies should have same expected value

1-way sensitivity analysis



Example

- In the context of an epidemic of measles in an inner-city population, experts estimate that 20 out of every 100 children age 8-15 will come in contact with an infectious case of measles each year. Literature review reveals that the probability of getting measles if exposed to an infectious case is 0.33 in a child who has had only one measles vaccination and 0.05 in a child who is re-vaccinated. The probability of getting measles (and of dying of measles) in children not exposed is 0. During the current epidemic, the probability of dying from measles if a child gets measles is 23 per 10,000 cases, or 0.0023.
  [Petitti, page 25]

Example

- Construct a decision tree comparing the outcomes of the re-vaccinate and don't re-vaccinate strategies
- Assign probabilities to nodes
- Calculate expected value of each strategy