Decision Support for Leaders

Level III – DoD FM Certification

Defense Resources Management Institute
Naval Postgraduate School
Monterey, California
Why Decision Support?
Definitions of terms

• assessment – the output of an estimation or evaluation process (prediction)
• cues – items of information used as inputs to the assessment process (predictors)
• validity – strength of the relationship between a cue and event being assessed
• bias – a tendency to systematic error (i.e. the same type of error is reproduced)
Definition: long-run average match between assessment and reality (e.g. between prediction and predicted event)

Depends on:
- inherent predictability of the event
- cues used to make the prediction
- processing of the cues

Problems in any of these three areas reduce predictive accuracy.
Inherent Predictability

• We cannot increase inherent predictability – this is why we use the word “inherent”.
• Inherent predictability imposes an upper bound on (long-run) accuracy of predictions.
• The lower the inherent predictability the worse experts do at information gathering and processing.
True or False: Using more information always makes predictions (or decisions) better.
Amount of info. vs. Accuracy

- High inherent predictability

Adapted from TR Stewart, “The human forecaster: Components of judgmental skill” Jan.2007
Amount of info. vs. Accuracy

- Low inherent predictability

Adapted from TR Stewart, “The human forecaster: Components of judgmental skill” Jan.2007
Example: Heart patient triage

Decision: whether to send patient home, for observation, or check them into the hospital

Information available:

– Family history
– Medical history (diabetes, heart disease, etc.)
– Electrocardiogram (ECG) results
– Blood pressure, fever, pulse, weight, lung function, etc.
– Age, gender, race
Example: Heart patient triage

Statistical model based on four cues:

- Systolic blood pressure
- ECG results (4 parameters)
- Sound of fluid in lungs
- Chest pain

Cues not necessary: diastolic blood pressure, age, diabetes, prior heart disease, ...and everything else.
### Example: Heart patient triage

<table>
<thead>
<tr>
<th></th>
<th>Judgment</th>
<th>Model</th>
</tr>
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<tbody>
<tr>
<td>of patients with heart complications* how many were hospitalized</td>
<td>89%</td>
<td>94%</td>
</tr>
<tr>
<td>of patients who were hospitalized, how many who had complications</td>
<td>29%</td>
<td>36%</td>
</tr>
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</table>

* severe complications within 72 hours.

Pitfalls in information-gathering

- Collection of too many cues
- Inconsistent use of cues (changing cues)
- Use of non-valid cues
- Error (variability) in assessing cues
- Perceptual biases in collection and assessment of cues, including
  - Optimism
  - Confirmation bias
Definitions of terms

• Heuristic – a simple procedure for seeking a solution or making a decision
  
  Often called a “rule of thumb”

• Judgmental heuristic – a mental rule of thumb, which allows us to make a judgment quickly

• Bias – a tendency to systematic error (i.e. the same type of error is reproduced)
Exercise

Which kills more people in the US:
A. Shark attacks; or
B. Falling airplane parts

Which kills more people in the US:
A. Firearm Assault
B. Falling
Availability

Heuristic: events that are easy to imagine are more likely.

Bias: events that are recent, emotionally charged, or vivid are believed to be more likely than they really are.
Exercise

Which is more likely to have been generated by a fair coin?

• HTHTTHH
• HHHHTTT
Representativeness

Heuristic: things that resemble each other must be related.

Bias: events that are representative of their class seem more likely than they really are.
Which would you rather have:

1. A lottery ticket with a one in a thousand (0.1%) chance of winning a million dollars, or

2. The opportunity to flip ten coins. If all are heads, you win $1M.
Issues in Probabilities

Heuristic: multiple events lead to greater likelihood.

Bias: overestimating conjunctive probabilities (the probability of Event A AND Event B).
Exercise

Bill is 34 years old. He is intelligent but unimaginative. In school, he was strong in mathematics, but weak in social studies and humanities.

Which is more likely?
A. Bill is an accountant.
B. Bill plays jazz as a hobby.
C. Bill is an accountant who plays jazz as a hobby.

Reproduced from Tversky and Kahneman (1984)
Framing effect

Losses and gains are viewed differently.
Anchoring

Heuristic: start with a baseline estimate (‘anchor’) and adjust relative to this starting point.
Exercise

• For each of the following ten items, provide a low and high estimate such that you are 90 percent sure the correct answer falls between the two.

• The range (between high and low) should be neither too narrow (i.e., overconfident) nor too wide (i.e., underconfident).
Exercise

Adapted from Russo and Shoemaker
Exercise

• If you are well calibrated, how many will you get wrong (i.e. true value is outside your estimates)?

• Is it an advantage to know a lot about these items?

Answers
Overconfidence

Bias: humans are generally more confident in
- their relative abilities,
- future prospects, and
- judgments

than they should be.
Improving Intuition

“Experience is inevitable; Learning is not.”

Paul J. H. Shoemaker
Which of the following factors improve intuitive judgment?

- [x] Complex decision context
- [✓] Highly predictable environment
- [x] More information
- [x] Confidence
- [x] Experience
- [✓] Feedback
- [ ] Hearing this lecture
How to increase accuracy in repeated intuitive predictions

Systematize information gathering

- Choose cues systematically
- Use a small set of cues
- Test cues for validity
- Standardize the assessment of cues
- Provide systems (e.g. a checklist) for collection and use of cues
- Separate assessment of cues from prediction process
- Design systems to present cues to experts in most intuitive form
How to increase accuracy in repeated intuitive predictions

Create conditions for learning

- Systematic information gathering
- Task training: letting person making prediction know how valid cues are, how predictable context is
- Outcome feedback: measuring how well predictions match reality, and providing feedback
How to reduce errors
In one-time intuitive predictions

• Seek disconfirming evidence
• Require verbal justification of a prediction
• Combine *independent* judgments from more than one expert
• Break complex tasks into smaller pieces
How to reduce errors

Use formal models and analysis whenever appropriate (often!).
Analysis vs. intuition

Pros of Analysis
• More consistent
• More accurate*
• Can be automated
• Endures as personnel change
• Transparent

Cons of intuition
• Inconsistent
• Less accurate*
• Can be slower (reinventing the wheel)
• Expertise linked to the expert
• Harder to justify to others

* In many, many situations, even when experts do not believe this is possible.
Analysis vs. intuition

Cons of Analysis
• Some human perceptions cannot be reproduced
• Errors, though rarer, can be extreme
• Slower in a one-time decision
• Experts lose sense of control
• Transparent

Pros of Intuition
• Very good at certain kinds of pattern recognition
• Can be faster, especially in a one-time decision
• Experts feel more in control
• Not transparent
Distribution of Errors in Intuitive and Analytic Processes

Distribution of errors for intuitive process

Distribution of errors for analytic process

Intuitive judgment

Analytic judgment

Human beings are vulnerable to errors. What can we do about it?

- Be aware of these errors, and use techniques to combat them
- Monitor expert performance and find ways to support and enhance intuition.
- Systematize collection and use of information.
- Create conditions for learning with task training and feedback.
- When possible, use models and expert systems.
Decision Environment

Before
Informing a choice among alternatives
- acquisition
- policy
- process

After
Determining how well a chosen option is working
- acquisition
- policy
- program
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Analyses / Methodologies

Cross - Cutting
At the START

Before
Informing a choice among alternatives

After
Determining how well a chosen option is working

Cross – Cutting
At the END
Analysis
Formulation

• What is the **REAL** problem?

• What is the **RIGHT** question to ask?

• What is **RELEVANT** to consider?
  – What scope? Wide? Narrow?
  – What do we include?
  – What are the boundaries?
Pre-Decision Analysis

• The analysis you conduct to help you make choices among alternative courses of action

Cost - Estimating  Measuring Effectiveness  Risk
Risk
Benefits/Effectiveness
Risk
Cost Estimating
Additional Foci
Analysis of Alternatives

Cost Estimating

Benefits/Effectiveness

Risk

Additional Foci

Schedule

Sensitivity

Acquisition focus
Risk
Benefits/Effectiveness
Cost Estimating
Lease vs. Buy Analysis
Additional Foci
Assumes equal effectiveness
Affordability Analysis

Risk

Cost Estimating

Benefits/Effectiveness

Risk

Additional Foci

Scope

Portfolio Management
Affordability vs. Cost Estimating

Affordability Analysis ≠ Cost Estimates

Management Decision ≠ Best Estimate of Actual Costs
Robust Decision Analysis

Cost Estimating

Benefits/Effectiveness

Risk

Additional Foci

Need to define “robust”

Cost is secondary
Business Case Analysis

Additional Foci

Cost Estimating

Benefits/Effectiveness

Risk

Policies, Processes, and acquisitions

Enterprise Sensitivity
Cost Benefit Analysis

Risk

Additional Foci

Benefits are measured in monetary terms

Cost Estimating

Benefits/Effectiveness

Sensitivity
Cost Estimating

Benefits/Effectiveness

Risk

Additional Foci

Cost Effectiveness Analysis

Benefits are quantitatively measured

Sensitivity
Economic Analysis

Additional Foci

Cost Estimating

Benefits/Effectiveness

Risk
Cost Estimation
Total Cost of Alternative

• All relevant costs of the system
• Over the lifecycle of the system
• Based on expected operating conditions

Having accurate and revealing cost information is critical for decision making. Understanding cost behavior is the key to useful cost analysis.
Present Value Analysis

• Time value of money
  – Discounting
  – Present Value Analysis

• Mandated by OMB A-94

• Used **ONLY** pre-decision analysis
• Not used in budgeting
Avoid Surprises

• ~2010 T-6 Texan II took over for T-34 as the primary Navy **flight trainer**
  – Group buy with the Air Force
  – Air Force had fielded it for years

• Provides examples of life cycle costing issues and second and third order effects
Unexpected Cost

• Navy was told that the planes needed to be parked under shelters to avoid heat damaging the flight computers
  – Decided this was a “luxury” – fine during winter
  – A closed cockpit canopy on a 90 degree day can get the temps in the cockpit to be anywhere from 300-400 degrees.
  – Started loosing computers (and planes)

• Cost
  – Shelters built later at additional expense
  – Had to pay for new computers in damaged planes
  – Availability ??
Runway Issues (Pt 1)

• Aircraft required MINIMUM 6,000 ft runways
  – Longer in **hot** or **wet** conditions
  – No issue for Air Force (they had 10,000 ft)
• Many NAVY runways ~3,000 – 4,000 ft
  – Acquire land
  – Lengthen runways
  – Built to “minimum” requirements
  – Unexpected cost
Cost Estimating

• Lots of different ways to do this
  – Direct assessment
  – Handbook/catalog
  – Vendor quote
  – Analogy
  – Regression
  – Resource requirements
  – Actual costs
Effectiveness Analysis
Effectiveness Analysis

- What is the benefit of the decision
  - $$$
  - More flight hours
  - Mission readiness
  - Healthier soldiers

- Benefits to whom (which stakeholders)

- How are you going to measure / quantify these benefits
Effectiveness Analysis

• Why quantify?
  – Many potential ways to generate benefit
  – Very rare that they all produce the same benefits at the exact same levels
  – Each alternative costs money
  – How do you decide between them

• Lots of different ways to do this
Cost-Benefit Analysis (CBA)

• Convert all costs and benefits into monetary values
• Calculate NPV of costs and benefits
• Subtract costs from benefits
Problems in Estimating Benefits and Costs?

• It is hard to place a value on many things such as air and water quality, scenic views, historical landmarks, endangered species, etc.
• How do we get around this?
• That is **THE** issue
Cost-Effectiveness Analysis

• Requires measurable costs
• Requires **measurable** benefits
  – Hard question
  – How to quantify benefits so that they are comparable across alternatives (choices)
  – Based on decision makers’ preferences
  – Frequently based on multiple objectives
An Integrated Approach

- Use monetary values for everything that comes measured in money.
- Estimate monetary values for everything that such values can meaningfully be estimated.
- Use CEA if there are a lot of things that matter that cannot be estimated in monetary terms.
Risk Analysis
“Risky” Decisions

• What makes a decision “risky”?  
  – Something can go wrong  
  – Dangerous environment  
  – Uncertainty  
  – Probability of failure  
  – High stakes (consequences)
People are bad at Estimating Risk

Perceived and actual risks

Susanna Hertrich, 2008: "Reality Checking Device"
Risk Management Process

Identify Risks

Assess Risks
- Analyze
- Quantify
- Prioritize

Implement

Control Risks
- Preventive
- Mitigative

Monitor

Review
Why “Easy” Approaches Go Awry

Example 1: Choice by Priority
Example 2: Choice by Rank and Weight
### TSA Screening Example

<table>
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<tr>
<th>Alternative</th>
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<th>Average passenger wait time (minutes)</th>
<th>Annual chance of a successful terrorist attack in the U.S. (%)</th>
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<td>4</td>
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<td>B</td>
<td>6</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>13</td>
<td>32</td>
<td>0.5</td>
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Imagine that TSA is considering the above alternatives for airport security, and it is basing its decision on operational costs, average passenger wait time, and the probability of a successful terrorist attack per year.
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What if?
## Idea 1: Prioritizing Objectives

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Idea 2: Rank and weight

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<th>Alternative</th>
<th>Motorcycle Fatalities</th>
<th>Training System Costs ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>83</td>
<td>8.3</td>
</tr>
<tr>
<td>B</td>
<td>75</td>
<td>6.5</td>
</tr>
<tr>
<td>C</td>
<td>90</td>
<td>0.5</td>
</tr>
<tr>
<td>Weights</td>
<td>0.1</td>
<td>0.9</td>
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# Idea 2: Rank and weight

<table>
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<th>Alternative</th>
<th>Motorcycle Fatalities (RANK)</th>
<th>Training System Costs (RANK)</th>
<th>Score</th>
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<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>3</td>
<td>2.9</td>
</tr>
<tr>
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<td>1</td>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>1</td>
<td>1.2</td>
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Lower is better
# TSA Screening Example

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What if?
Idea 2: Rank and weight

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Weights

Lower is better
Post Decision
Post-Decision Analysis

• The analysis you conduct to see how well you are doing
Cost Accounting

• What does it actually cost
• Who is incurring the costs
• Who is receiving the benefits
• Are there secondary costs

• Lots of different methodologies
Performance Management

• Mandated by a series of laws
  – Government Performance and Results Act of 1993 (Public Law 103-62)
  – GPRA Modernization Act of 2010 (Public Law 111-352)
• Designed to help manage cost, time, risk, and effectiveness challenges
Performance Management

• Focuses on:
  – Improving effectiveness, focusing on how well desired outcomes are achieved;
  – Improving efficiency, focusing on how well the costs of producing services and goods are managed; and
  – Improving accountability, focusing on bringing together budgets and performance measures
Performance Management

• Requires “properly” setting/measuring progress against performance targets
  – Measuring the right things
  – Construct bounded targets (restrictions on possible negative incentives for behavior)
Cross Cutting Analyses/Methodologies
At the end
Sensitivity and Robustness

• **Sensitivity analysis**: explores how variation in parameters affects which alternative is the best; choice of alternative is **sensitive** if small or likely changes in parameter values change the choice of best alternative.

• **Robustness**: an alternative is **robust** if it is good (i.e. effective and/or cost-effective) under many or most possible or likely future conditions.
Important Questions Answered by Sensitivity Analysis

- Where should you spend more time and effort reducing uncertainty?
- How much variation can happen before we change our choice?
- Which variables are most important to your decisions?
Scenario Analysis

- Variation in the components is dependent on the scenario (operational conditions)
- Developing future alternatives
- Uncertain future conditions

Looking for robustness across different scenarios
Secondary (+) Consequences

• Combination scenario analysis and systems analysis
  – Scope
  – Often “Unintended” consequences
  – Never hard *AFTER* the fact - *very* hard to determine at the outset

• Requires thought
• Worth the effort !!
Runway Issues (Pt 2)

• Recall: T-6 Texan II, aircraft used for training pilots
  – Found themselves with “book minimum” runways not sufficient in hot or wet conditions
  – Throughput of student flights fell to less than 50% of prior norms
  – Massive training delays
  – Affecting pilot pipeline
Runway Issues (Pt 2)

- Work around(s)
  - Keep airfields with longest runways open nights and weekends
    - Additional cost (triple overtime)
    - Contractor eventually couldn’t do it
    - Dramatic increase in O&M costs
  - Fly out of Pensacola International Airport
    - Additional costs in ramp fees
    - Costs to students/instructors drive 30 miles each way
    - (Indirect) Political capital
Decision Environment

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Analyses / Methodologies

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At the START

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