SAND2008-2741C

Overview of Risk Assessment Methodologies for Security Applications

International Discussion of Bioterrorism Risk

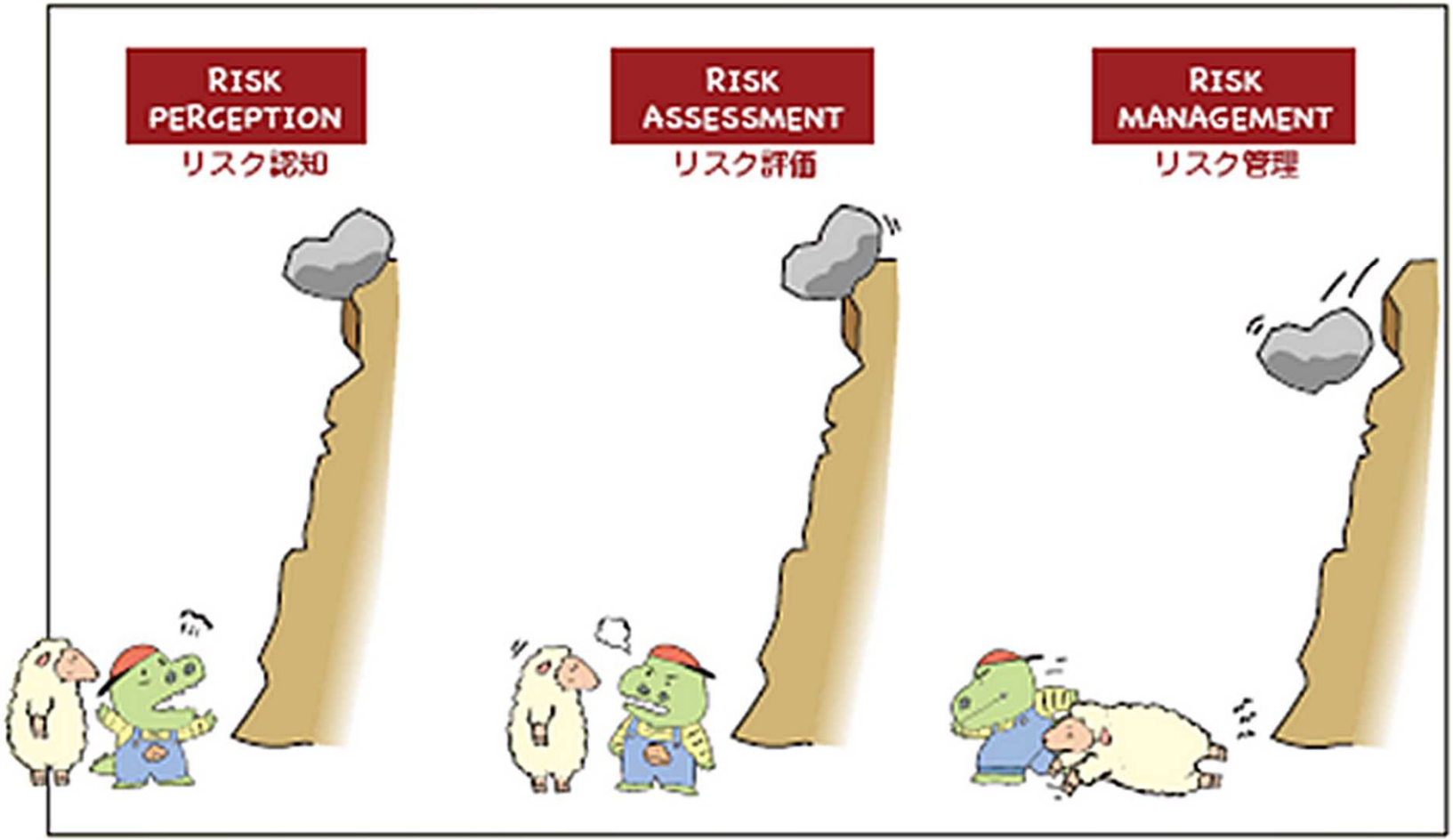
Susan Caskey
International Biological Threat Reduction Program
Sandia National Laboratories
Albuquerque, NM USA

May 2008

www.biosecurity.sandia.gov

International
BIOLOGICAL THREAT REDUCTION

Risk Assessment



(NIID, Japan)

Hazard vs. Risk

- Hazard: The way in which an object or a situation may cause harm
  - A hazard exists where an object (or substance) or situation has an inherent ability to cause an adverse effect
- Risk: The chance that harm will actually occur
  - The risk can be high or negligible
- Risk is a function of likelihood AND consequences

International
BIOLOGICAL THREAT REDUCTION

Risk

- **Is a function of the likelihood an adverse event will occur**
  - Threat Potential (TP)
- **And the potential consequences of that event**
  - Consequences (C)

Risk = TP * C

Traditional Security Assessments vs. Traditional Hazard Assessments

- **Traditional Security Assessments**
  1. Asset Characterization
  2. Threat Characterization
  3. Vulnerability Assessment
  4. Consequence Assessment
  5. Likelihood Assessment
  6. Risk Assessment Results

- **Traditional Hazard Assessment**
  1. Hazard Identification
  2. Consequences if Hazard Occurs
     1. **Direct**
     2. **Indirect**
  3. Likelihood of Occurrence
  4. Risk Assessment Results

Risk Assessment Schemes

- Qualitative Schemes
- Quantitative Schemes
- Probabilistic
- Relative
- Tree Based Techniques
- Multi-Criteria Techniques
- Dynamic Systems
- Weighted
- Unweighted
- Expert Judgments
- Collected Data

International
BIOLOGICAL THREAT REDUCTION

Risk Assessment Principles

- Risk Assessment methods can use a single or multiple schemes
- The problem should drive the method
- The method should be as simple as possible, but no simpler
- Be explicit about uncertainties
- Elaborate when needed, simplify when needed

International
BIOLOGICAL THREAT REDUCTION

Steps for Conducting a Risk Assessment

1. State the Problem
2. Formulate the approach – determine the method(s)
3. Collect data/Interview Experts
4. Build the model
5. Run base case in the model
6. Conduct sensitivity analysis
7. Record results
8. Document model

"We've considered every potential risk except the risks of avoiding all risks."

Qualitative vs. Quantitative Schemes

- **A quantitative scheme attempts to make a numerical determination the probabilities of the adverse event and the consequences**

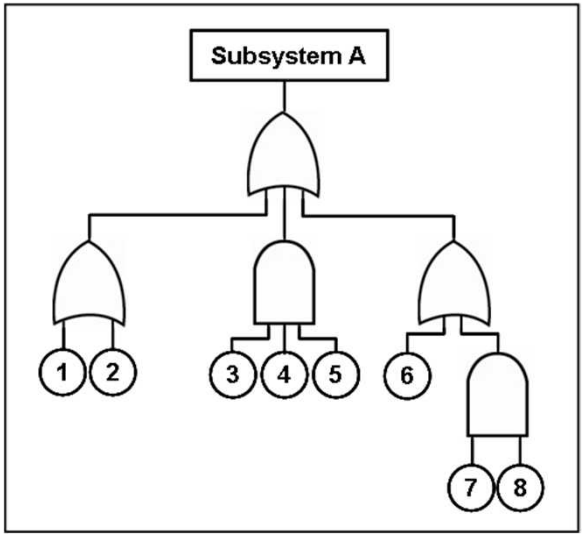
- **A qualitative scheme involves defining the various threats and determining the extent of vulnerabilities**
  - Qualitative risk assessment does not involve numerical probabilities or predictions of lose

Relative vs. Probabilistic Schemes

- **Relative schemes typically use a qualitative method to compare multiple threats with differing consequences to determine the greatest risk**
  - E.g. planning the route from home to work, determining which biological agents require the greatest level of protection, prioritizing needed physical security enhancements
- **Probabilistic scheme typically use a quantitative method to determine the likelihood of occurrence (as a probability) and the magnitude of the possible occurrence**
  - E.g. assessing the probability of a small prop airline crashing during a rain storm

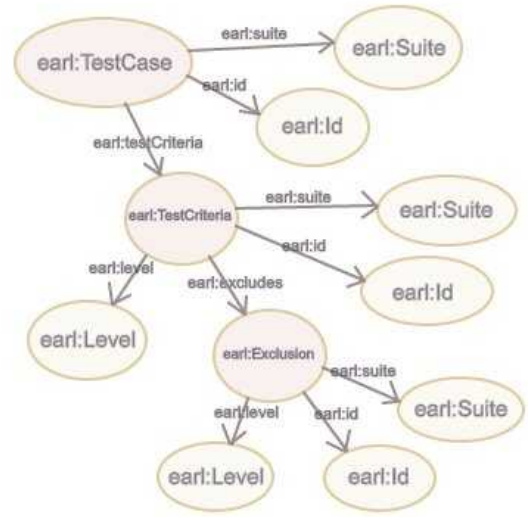
Tree based Techniques (Probabilistic Risk)

- The undesired effect is the top event of the tree
- Each situation that could cause that effect is added to the tree
- More detailed situations can be added to each branch
- Each event and situation is given a probability of success or failure
- Modeling software is often used to determine the overall probability of the undesired effect based upon analysis of all the possible routes



Multi-Criteria Techniques

- **Threat potential and the consequences are broken into criteria which can be scored by experts or by collection of data**
- **The criteria are created by breaking up the results into its various factors**
  - These factors can be broken into one or more sub parts which reflect the various attributes



Weighted vs. Unweighted

- **Weighted models assume a different overall impact to risk for each criteria.**
  - Used in assessments where criteria may interrelate or impact the risk at differing degrees
  - The Analytic Hierarchy Process (AHP), a criteria weighting scheme, uses quantitative pair-wise comparisons of each criteria
- **Unweighted models assume equal importance of all criteria**
  - Simpler to implement
  - Used in areas where the criteria have been defined as equal elements of the overall risk

Data Analysis for Expert Judgment

- **Single point scores are scored criteria with a single inputs**
  - Individual scoring
  - Group consensus
- **Multiple point scores are scored criteria with multiple inputs**
  - Multiple experts individually scoring criteria

- **Single point scores are easier to analyze, but may not be as statistically strong**
- **Multiple point scores must be combine prior to weighting and roll up**
  - Scores can be combine based upon the score distribution
  - Determination of the distribution function is based upon
    - **A continuous distribution is best choice if each expert provided a single score for each criteria**
    - **A triangle distribution is the best choice if each expert a range of scores or provided the 5% and 95% confidence values along with their scores**
    - **Monte Carlo Integration (MC)**
      - Several different methods to a Monte Carlo Integration
      - Each best suited for a different type of distribution

Examples Of Models

- **Multi-Criteria Decision Analysis (MCDA)**
  - Multi-Criteria, weighted, expert judgment and collected data, qualitative or quantitative, provides relative risk
- **Probabilistic Risk Assessment (PRA)**
  - Multi-Criteria, can be weighted, required probability data, quantitative, provides probabilities
- **CARVER + Shock: Criticality, Accessibility, Recuperability, Vulnerability, Effect, Recognizability, Impact (or Shock)**
  - Set Criteria, unweighted, expert judgment, provides relative risk

Examples Con't

- **Failure Mode and Effects Analysis (FMEA)**
  - Matrix model of system, probability of failure at each indices in matrix, unweighted, provides probability of overall system failure
- **Fault Tree Analysis (FTA) or Event Tree Analysis (ETA)**
  - Multi-Criteria (in hierarchical structure), unweighted, uses Boolean logic (And/Or), requires probabilities, provides probabilistic risk
  - Often used in PRA to define structure of model
- **Dynamic Models**
  - Use time explicitly
  - Often can have multiple states and feed back loops

Summary

Risk = Threat Potential * Consequence

- The problem should drive the method
- The method should be as simple as possible, but no simpler

  - State the Problem
  - Formulate the approach
  - Collect data/Interview Experts
  - Build the model
  - Run base case in the model
  - Conduct sensitivity analysis
  - Record results and document model