Critical Asset & Portfolio Risk Analysis

Terminology, Fundamentals, and Case Studies

All-Hazards Forum, Baltimore, MD
October 12, 2006

Outline

- CTSM, Staff and Associates
- What Is CAPRA?
- What Decisions Would CAPRA Results Inform?
- Terminology and Risk Fundamentals
- Introduction to CAPRA
- Case Studies
  - Security Hazards: Explosives
  - Natural Hazards: Hurricanes

CTSM History & Goals

- Center for Technology and Systems Management
  - Established in 1996 in a strategic alliance with the U.S. Navy, U.S. Coast Guard, and Department of Civil and Environmental Engineering
  - Goal is to "*advance the state of the art of utilizing various technologies in engineering systems to make them efficient, safe, and beneficial to mankind and the environment throughout their lives*"
- Technologies
  - Uncertainty, risk and reliability analysis
  - Decision analysis
  - Control for intelligent systems
- Systems
  - Defense and maritime
  - Critical infrastructure
  - Mechanical

"CTSM performs high-quality research to meet national needs in reliability, risk and uncertainty analyses, and to develop products for mitigation and making appropriate decisions offered by world-renowned experts."

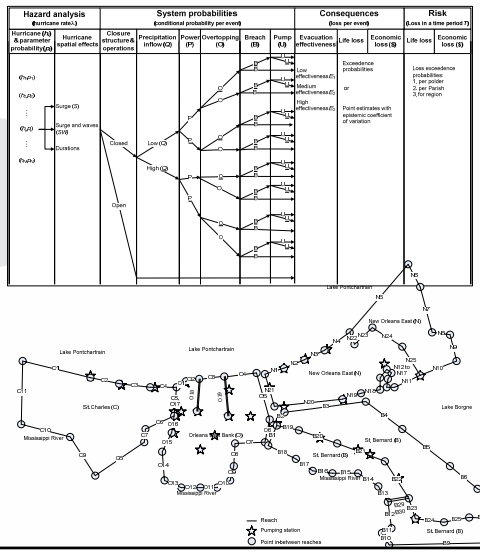
Five Primary Research Areas

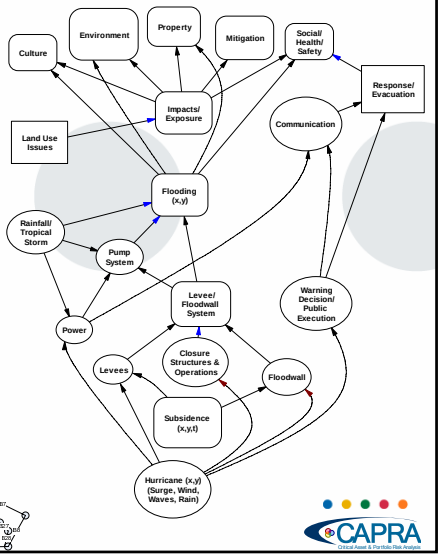
1. **Risk Analysis and Management**
2. **Reliability Analysis**
3. **Uncertainty Modeling**
4. **Homeland Security**
5. **Intelligent Systems**

Risk Analysis and Management

- *U.S. Army Corps of Engineers*
  - Risk analysis of dams
  - Flood damage assessment (residential, commercial, coastal, expert opinion elicitation)
- *U.S. Food and Drug Administration*
  - Risk analysis of drug delivery systems
- *U.S. Coast Guard*
  - Electric induced drowning
  - Approval of personal flotation devices

Hurricane Protection System



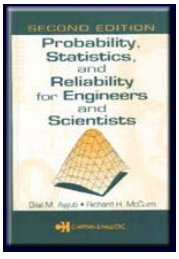


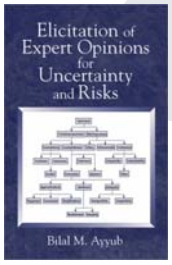
Homeland Security

- *Maryland Emergency Management Agency*
  - Protection of critical infrastructure and key resources
- *Homeland Security Institute*
  - Risk and vulnerability methods
  - Standards
  - Systems analysis
- *ASME*
  - Risk-based protection of critical assets
- *US Department of Agriculture*
  - Food security

Publications

- Ayyub, B.M., and Klir, G.J., Uncertainty Analysis in Engineering and the Sciences, Chapman & Hall/CRC Press, 2006.
- Ayyub, B.M., Risk Analysis in Engineering and Economics, Chapman & Hall/CRC Press, 2003.
- Ayyub, B. M. , Elicitation of Expert Opinions for Uncertainty and Risks, CRC Press, FL, 2001.
- Ayyub, B.M., and McCuen, R., Probability, Statistics and Reliability for Engineers and Scientists, Chapman & Hall/CRC Press, 2003.





CTSM Personnel

- Five Researchers
- Five graduate students
- Secretaries and clerical staff
- Top-ranked academic programs
- Accomplished engineering faculty

UMCP: More than 2,800 faculty. Ninety-eight majors and some of the highest ranked programs in the country.

College of Engineering: Aerospace, Biological Resources, Chemical, Civil, Electrical, Fire Protection, Materials and Nuclear, Mechanical, System, Reliability Engineering

Centers: Technology and Systems Management, Environmental Energy Engineering , Systems Research , Satellite & Hybrid Communication Networks, Plasma Research , Electronic Packaging

Faculty and Staff

- ***Bilal M. Ayyub, Director***
- *Mark Kaminskiy*
- *Ibrahim Assakkaf*
- *Zbigniew Karaszewski*
- *Clara Popescu*

Graduate Students

- *Adel Al-Wazeer*
- *Kleio Avrithi*
- ***William McGill***
- *Jinny McGill*
- *Joe Prokop*

Associates

- *Khaled Atua*
- *Andrew Blair*
- *S. Lahiri*
- *Robb Wilcox*
- *Bob Finklestein*

Outline

- CTSM, Staff and Associates
- What Is CAPRA?
- What Decisions Would CAPRA Results Inform?
- Terminology and Risk Fundamentals
- Introduction to CAPRA
- Case Studies
  - Security Hazards: Explosives
  - Natural Hazards: Hurricanes

What is CAPRA?

CAPRA: **C**ritical **A**sset and **P**ortfolio (*including regional*) **R**isk **A**nalysis

CAPRA is a methodology and a process that can be used

- To quantitatively assess risks
- For a single asset, a portfolio of assets, or a region
- Due to natural hazards or human-caused hazards

What is CAPRA?

CAPRA attributes:

- **Analytic** – breaks risk down into its contributing components
- **Transparent –** all assumptions and analytical steps are clearly and explicitly identified
- **Quantitative** – defines and quantifies these components using meaningful metrics/units (e.g., $)
- **Probabilistic** – uses probability theory to measure likelihood/chance
- **Defensible** – all assumptions are supported by data and our credible expert judgment
- **Consistent** with existing practices of probabilistic risk analysis (PRA) used in many other fields and DHS practices including RAMCAP™
- **Adapted** to the unique nature of human-caused hazards such as dynamic and gaming

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What decisions would CAPRA results inform?

CAPRA risk results at the **asset level** can be used for:

- Prioritizing hazards, critical elements and potential consequences
- Identifying potential actions to limit risks
- Computing benefit/cost ratios for these actions
- Informing decisions relating to critical asset protection and consequence mitigation
- Justifying previous decisions and responding to inquiries by governmental and elected officials
- Providing information for assessing capabilities, readiness, and grant funding opportunities

What decisions would CAPRA results inform?

CAPRA risk results at the **asset-portfolio level** can be used for:

- Prioritizing (in tiers) assets, hazards and potential consequences
- Providing a framework to examine interdependence
- Identifying potential portfolio-level actions to limit risks
- Computing benefit/cost ratios for these actions
- Informing decisions relating to critical asset protection and consequence mitigation
- Justifying previous decisions and responding to inquiries by governmental and elected officials
- Providing information for assessing capabilities, readiness, and grant funding opportunities

What decisions would CAPRA results inform?

CAPRA risk results at the **regional level** can be used for:

- Screening hazards based on their regional impacts
- For each hazard applicable to a region, providing
  - Losses by hazard intensity (accounting for physical vulnerabilities and existing mitigation measures)
  - Security vulnerabilities
  - Conditional risk profiles (without the hazard rates)
  - Regional risk profiles
- Developing HIRA reports

What decisions would CAPRA results inform?

CAPRA risk results at the **regional level** can be used for (cont.):

- Prioritizing (in tiers) hazards and potential consequences
- Providing a framework to examine interdependence
- Identifying potential region-level actions to limit risks
- Computing benefit/cost ratios for these actions
- Informing decisions relating to protection and consequence mitigation for the region
- Justifying previous decisions and responding to inquiries by governmental and elected officials
- Providing information for assessing capabilities, readiness, and grant funding opportunities

What decisions would CAPRA results inform?

Other CAPRA uses are:

- Identification of data gaps
  - Consequences
  - Security vulnerabilities
  - Rates

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Terminology and Risk Fundamentals

Risk: The potential for loss or harm to systems due to the likelihood of an unwanted event and its adverse consequences.

- Potential means likelihood relating to vulnerability, consequences, and hazard rates
- Losses depend consequences and hazard rates
- Event(s) are defined by scenarios

Risk is an aggregate of (Hazard and scenarios, Consequences, Vulnerability, Threat rate)

Risk Assessment and Management

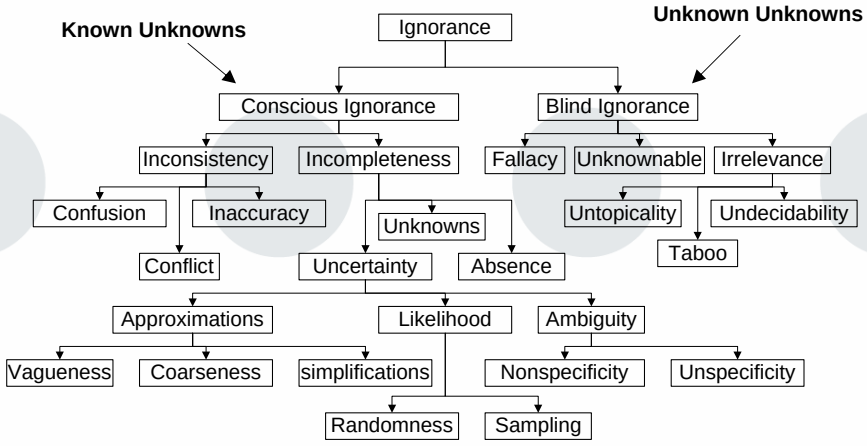
1. What could happen? (hazards)
2. How can it happen? (scenarios & vulnerabilities)
3. How likely is it to happen? (probabilities)
4. What are the consequences if it happens? (impacts)

Risk Assessment

5. What can be done to reduce the risks in a cost effective manner?
6. What effect will these actions have on subsequent risks and options?

Risk Management

Hierarchy of Ignorance



Terminology: What Are The Consequences?

Failure Consequences: The immediate, short-and long-term effects of an event (e.g., a dam breach).

- Human loss
- Property damage and loss
- Environmental damages and loss of lifelines
- Operation interruption costs
- Changes in the quality of life

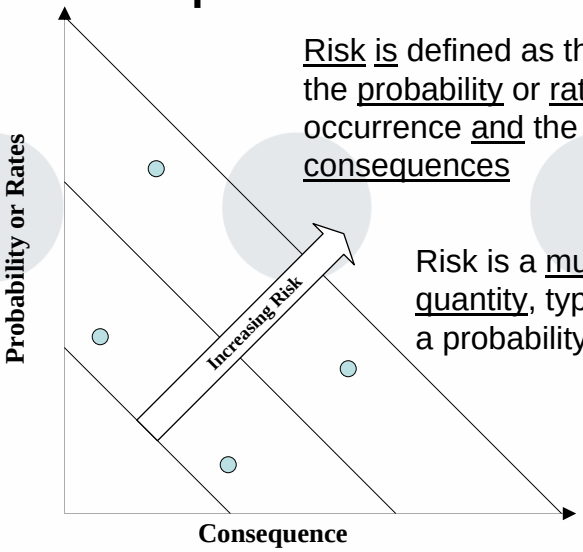
Terminology – What are the Consequences?

- Homeland security consequence types
  - Human health and safety impacts
  - Economic losses and impacts
  - Environmental impacts
  - Socio-political impacts
  - Impacts on national security
  - Lost output or capability
- Consequence uncertainties
- Valuation of failure consequences

Valuation

"O.K., who can put a price on love? Jim?"

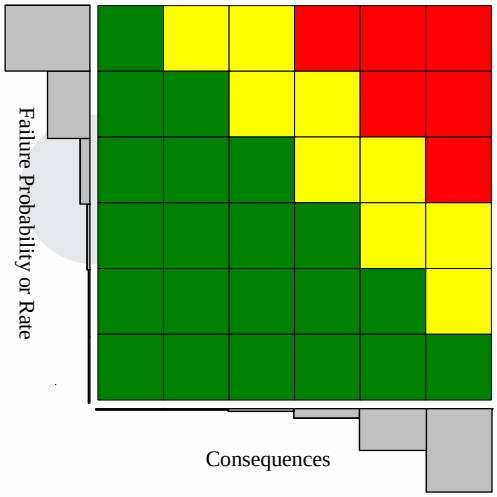
Risk Representation



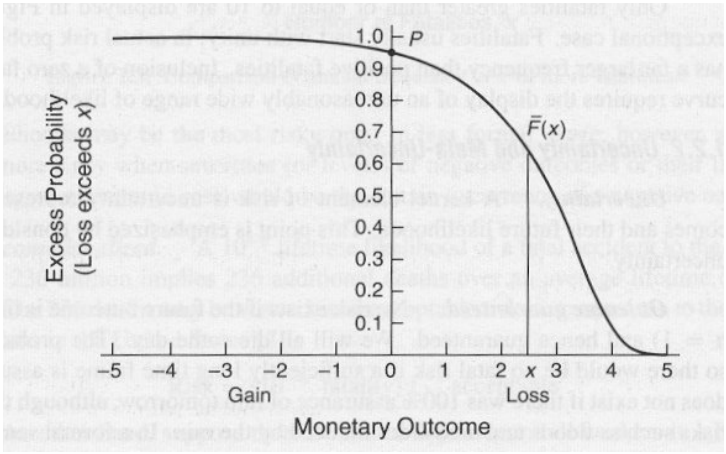
Risk is defined as the combination of the probability or rate of scenario occurrence and the ensuing consequences

Risk is a multidimensional quantity, typically characterized by a probability distribution of loss

Risk Matrix for Qualitative Analysis



Risk Profile – Loss-Exceedence Curves

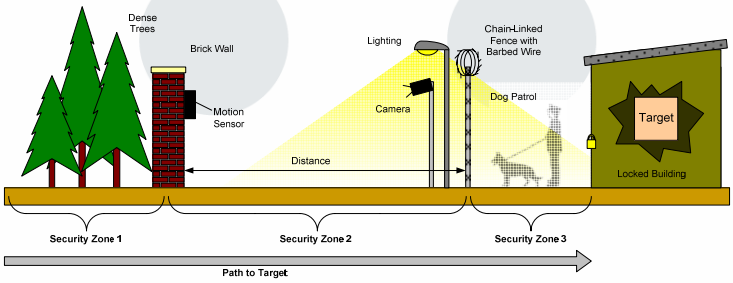


Risk Fundamentals

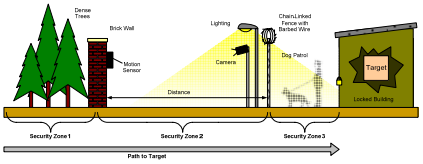
Event Tree: A logic diagram that begins with an initiating event, and progresses through a series of branch points to define a scenario.

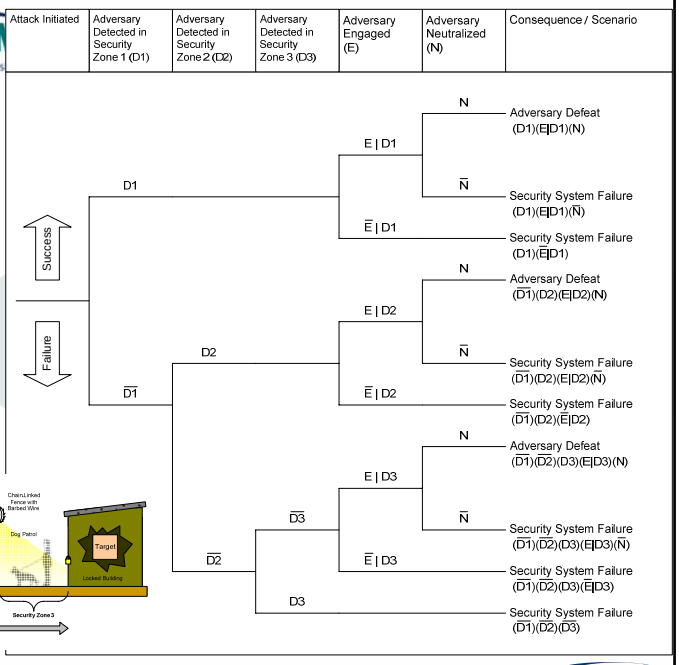
Security Vulnerability Assessment

- For an *attack profile*, assess the probability of adversary success (with existing countermeasures)



Security Vulnerability Assessment





Considerations in Limiting Risk

- Not every risk is avoidable
- Risks are uncertain (subjective information)
- Wealthier is healthier (affordability)
- Countermeasures can have adverse side effects
- More lives would be saved, if risks are prioritized

Putting Risk in Perspective

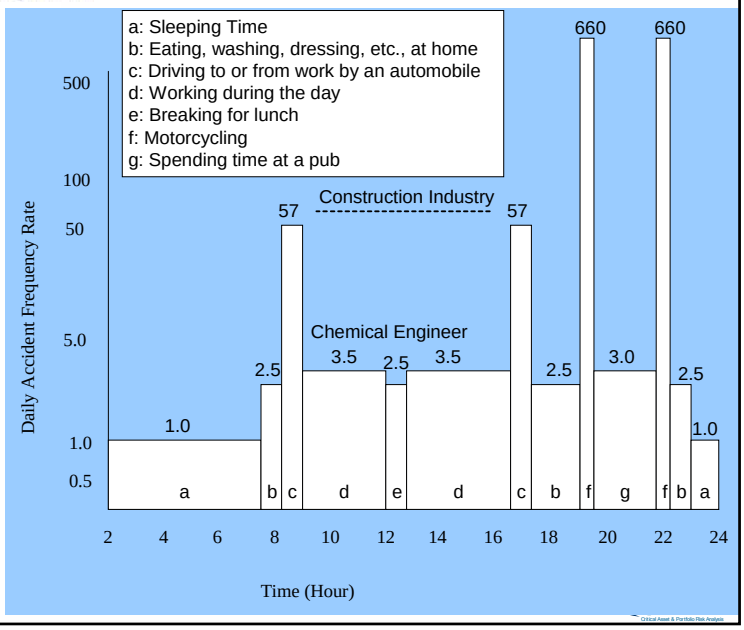
Risk of Death	Occupation	Lifestyle	Accidents/ Recreation	Environmental Risk
1 in 100	Stuntman			
1 in 1,000	Racecar driver	Smoking (1pack/day)	Skydiving Rock climbing Snowmobile*	
1 in 10,000	Fireman Miner Policeman	Heavy drinking	Canoeing Driving motor vehicle Home accident	
1 in 100,000	Truck driver Engineer	Light drinking	Skiing	Living down of a dam
1 in 1,000,000		X-Rays Smallpox Vaccination	Fishing	Background radiation Living near nuclear power plant
1 in 10,000,000				Hurricane Lightening

Daily Risk

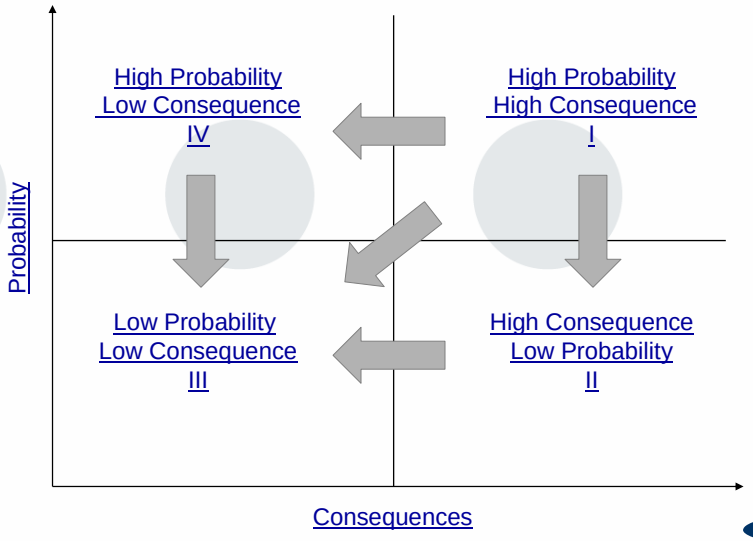
Hours of exposure per activity assumed 10^8

FAFR of 1.0 corresponds to one fatality in 11,415 years, or 87.6 fatalities per one million years

Source: Imperial Chemical Industries, Limited



Limiting Risk



Identification of potential actions for limiting risk (consequences, vulnerabilities, Threats)

- Consequences
  - Capabilities of first responders
  - Evacuation plans and strategies
  - Health care facilities
  - Shelters
  - Hardening an asset or region
  - Enhancing recovery

Identification of potential actions for limiting risk (consequences, vulnerabilities, Threats)

- Vulnerabilities
  - Access limitation or denial
  - Detection
  - Response
  - Defense

Identification of potential actions for limiting risk (consequences, vulnerabilities, Threats)

- Threats
  - Deterrence
  - Intelligence
  - Early identification
  - Limiting financial capability or support
  - Policy
  - International collaboration

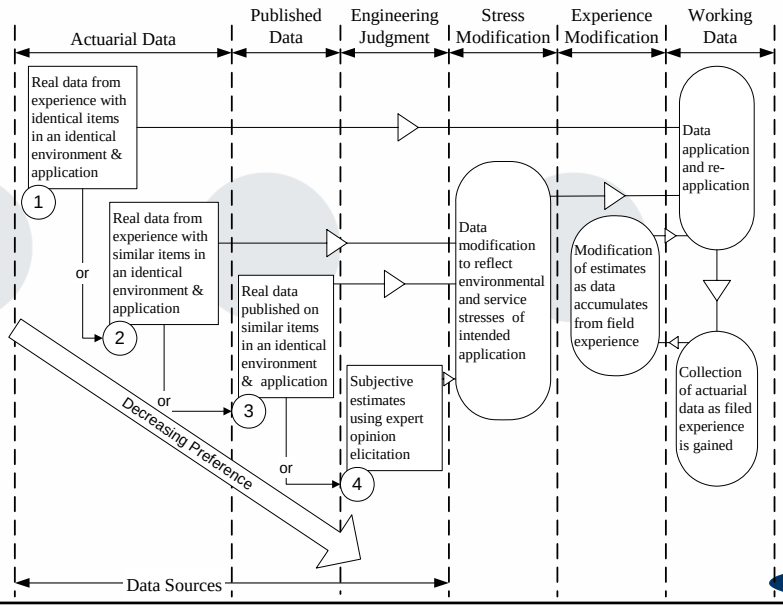
Benefit-Cost Analysis

$$\text{Benefit} = (\text{Risk Before}) - (\text{Risk After})$$

$$\text{B/C Ratio} = \frac{\text{Benefit}}{\text{Cost}}$$

But to quantify requires data…

Data Sources for Risk Analysis



Need for *REAL* Data

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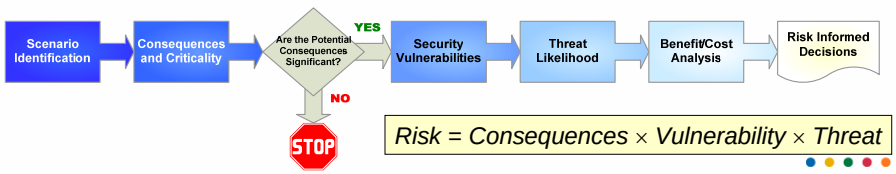
National Strategy for Homeland Security 2002

- Prevent terrorist attacks within the United States
- Reduce America's vulnerability to terrorism
- Minimize the damage and recover from attacks that do occur.

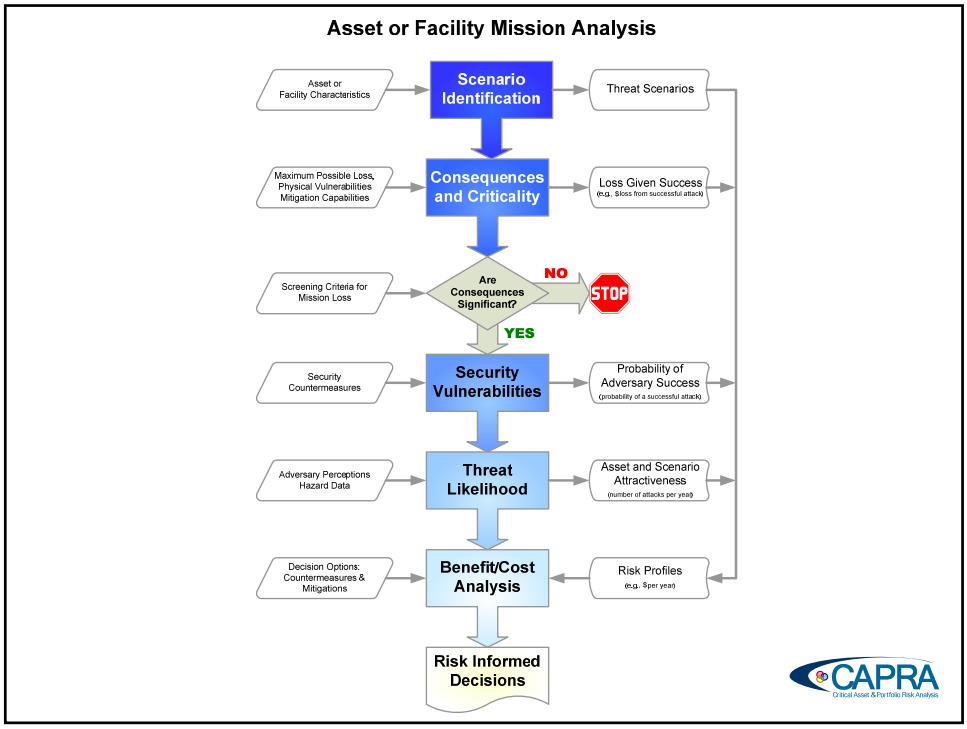
CAPRA Overview

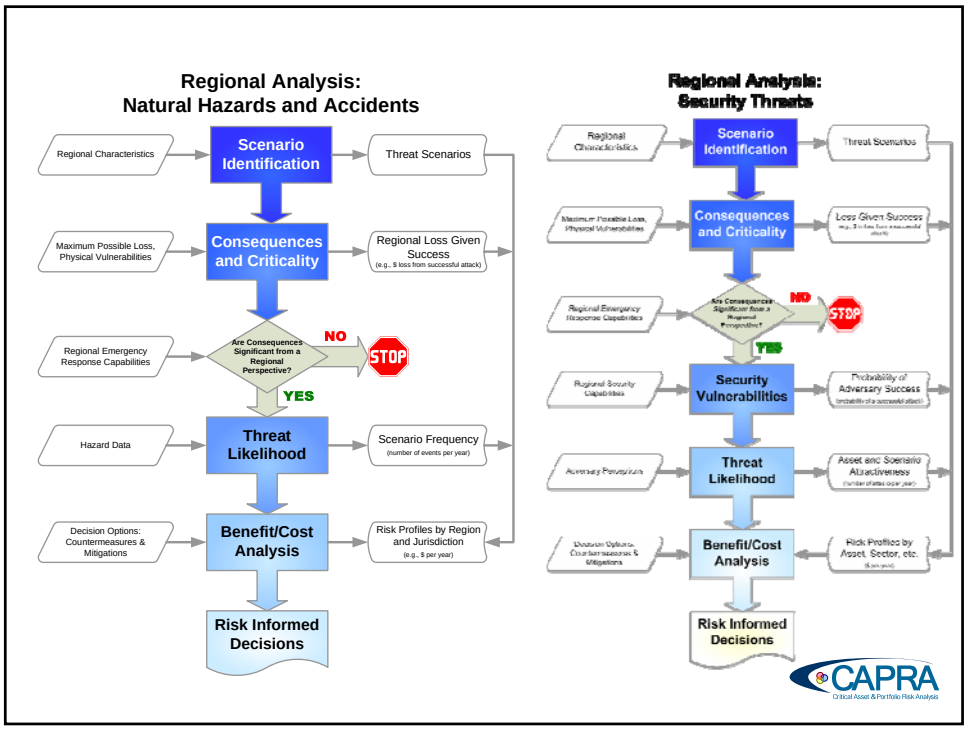
Five phases:

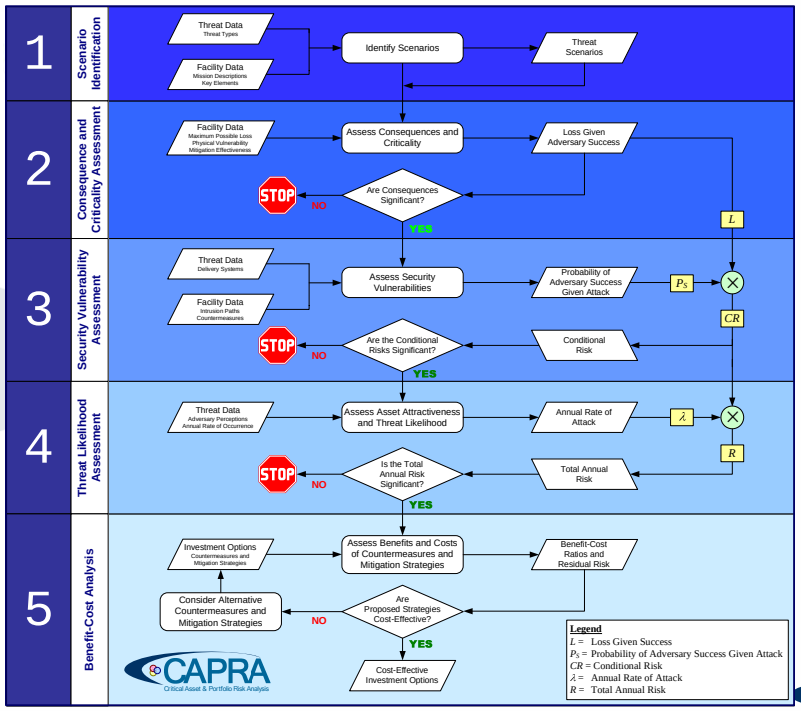
1. Scenario identification
2. Consequence and criticality assessment
3. Security vulnerability assessment
4. Threat likelihood assessment
5. Benefit-cost analysis



Risk = Consequences × Vulnerability × Threat


Asset or Facility Mission Analysis
Asset or Facility Characteristics
Scenario Identification
Threat Scenarios
Maximum Possible Loss, Physical Vulnerabilities Mitigation Capabilities
Consequences and Criticality
Loss Given Success
(e.g., $/loss from successful attack)
Screening Criteria for Mission Loss
Are Consequences Significant?
NO
STOP
YES
Security Countermeasures
Security Vulnerabilities
Probability of Adversary Success
(probability of a successful attack)
Adversary Perceptions Hazard Data
Threat Likelihood
Asset and Scenario Attractiveness
(number of attacks per year)
Decision Options: Countermeasures & Mitigations
Benefit/Cost Analysis
Risk Profiles
(e.g., $per year)
Risk Informed Decisions
CAPRA
Critical Asset & Portfolio Risk Analysis


Regional Analysis:
Natural Hazards and Accidents
Regional Characteristics
Scenario Identification
Threat Scenarios
Maximum Possible Loss, Physical Vulnerabilities
Consequences and Criticality
Regional Loss Given Success
(e.g., $ loss from successful attack)
Regional Emergency Response Capabilities
Are Consequences Significant from a Regional Perspective?
NO
STOP
YES
Hazard Data
Threat Likelihood
Scenario Frequency
(number of events per year)
Decision Options: Countermeasures & Mitigations
Benefit/Cost Analysis
Risk Profiles by Region and Jurisdiction
(e.g., $ per year)
Risk Informed Decisions
Regional Analysis:
Security Threats
Scenario Identification
Consequences and Criticality
Security Vulnerabilities
Threat Likelihood
Benefit/Cost Analysis
Risk Informed Decisions
CAPRA
Critical Asset & Portfolio Risk Analysis



CTSM
Technology for Intelligent Decisions

Scenario Identification

- Collects basic *asset (or regional) information*
  - Boundaries, hazards considered, and scope
  - Security POC, addresses, etc.
- Identifies those *key elements* that are either essential for functions or highly valued
- Pairs key elements against relevant threats based on their *susceptibility* to damage from the threats
- Screen out scenarios that are unlikely and/or with insignificant impact

CAPRA

Natural and Technological Hazards

- Industrial Accidents / Sabotage
- Contagious Disease Outbreak
- Earthquake
- Tropical Storm / Hurricane
- Blizzard / Winter Storm
- Tornado
- Tsunami
- Landslide
- Flooding
- Wildfire
- High Wind / Windstorms
- Extreme Temperature

Security Threats

- Explosive
- Projectile / Ballistic
- Incendiary
- Chemical
- Biological
- Radiological
- Nuclear
- Radiofrequency/EMP
- Sabotage
- Theft
- Cyber
- Laser
- Panic-Inducing

Susceptibility Matrix for Security Threats

Threat	Element Class					
	HAZMAT Storage	Building	Pipeline	Rail Car	People	Computer Network
Explosive	X	X	X	X	X	X
Projectile / Impact	X	X	X	X	X	-
Incendiary	X	X	-	-	X	X
Chemical	-	-	-	-	X	-
Biological	-	-	-	-	X	-
Radiological	-	-	-	-	X	X
Laser	-	-	-	-	X	-
Radiofrequency	-	-	-	-	-	X
Cyber	-	-	-	-	-	X
Sabotage	X	-	X	X	-	X
Panic-Inducing / Harassment	-	-	-	-	X	-

Consequence and Criticality Assessment

- Assesses *maximum possible loss* associated with each consequence type considered
- Assesses the *loss potential* (hardness) of key elements with respect including physical vulnerabilities and threat capabilities
- Assesses *effectiveness of consequence mitigation* strategies

Facility-Level Consequence Types

Dimension	Description
Fatalities	Number of equivalent fatalities resulting from a successful attack (accounts for deaths and injuries using tools such as the Accident Injury Scale [1]).
Repair Costs	Costs to repair damage resulting from an attack measured in dollars.
Asset Loss	Value of assets (e.g., goods, property, information) lost as a result of an attack measured in dollars.
Recuperation Time	Time to recuperate mission following an attack measured in units of time.
Environmental Damage	Environmental damage resulting from an attack measured in area affected.

Consequence and Criticality Assessment

- For a given scenario of specified intensity:

$$Loss = MPL \times (PV \times ME)$$

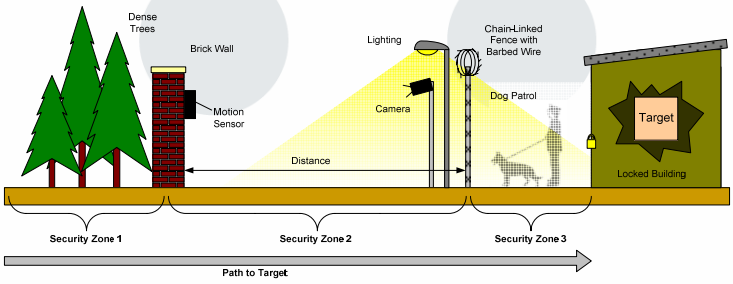
where:

  - MPL: maximum possible loss
  - PV: physical vulnerability factor
  - ME: mitigation effectiveness factor

- Equation can be applied at all levels (region, sector, jurisdiction, asset, etc.)

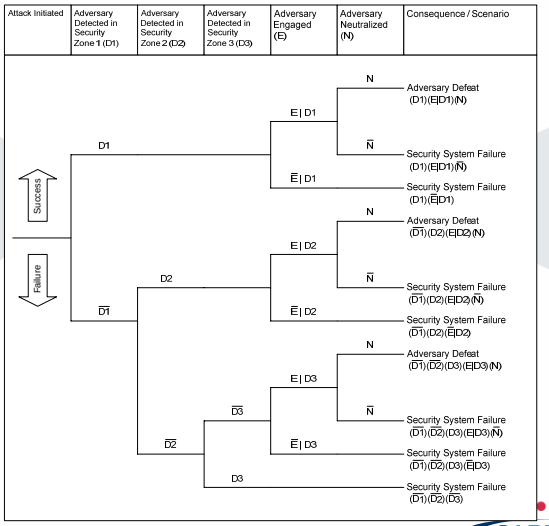
Security Vulnerability Assessment

- Identifies a set of representative *attack profiles* for each threat scenario
  - Attack profile is the combination of threat delivery system and intrusion path



Security Vulnerability Assessment

- Assesses the effectiveness of existing countermeasures to *detect*, *delay*, *respond to*, and *defeat* potential adversaries
- Determines the *probability of adversary success* for each attack profile



Conditional Risk

- The risk given the occurrence of a scenario is:

$$Conditional\ Risk = Loss \times PS$$

where:

- PS = probability of adversary success (security threats only, otherwise PS = 1)
- Loss = loss given success

Threat Likelihood Assessment

- Assesses *scenario (and/or asset) attractiveness* from the attacker point of view
  - Considers perceived probability of success, gain from success, loss from failure, and capability to execute the scenario
  - Also considers the *visibility* of the asset, its key elements, and intrusion paths
- Accounts for adversary tendencies to shift preferences in response to countermeasures

Rate of Scenario Occurrence

- The risk given the occurrence of a scenario is:

$$Threat = SA \times Rate$$

where:

- SA = scenario attractiveness
- Rate = annual rate of attack occurrence

Total Annual Risk

- The total risk for a scenario is:

$$Risk = Loss \times PS \times Threat$$

where:

- Loss = loss based of scenario occurrence
- PS = probability of adversary success (security threats only, otherwise PS = 1)
- Threat = as annual rate of scenario occurrence

Total Annual Risk

- The total risk for a scenario is:

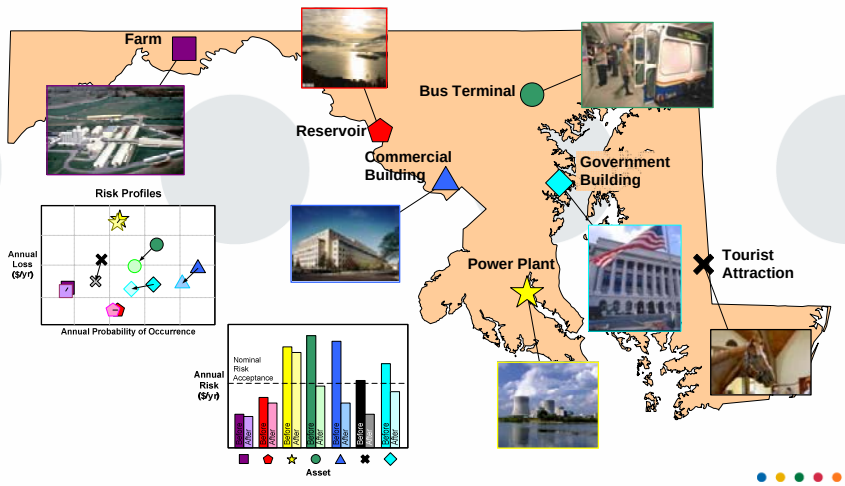
$$Risk = Consequences \times Vulnerability \times Threat$$

$$Risk = MPL \times PV \times ME \times PS \times SA \times Rate$$

where:

- MPL = maximum possible loss
- PV = physical vulnerability
- ME = mitigation effectiveness
- PS = probability of adversary success (security threats only, otherwise PS = 1)
- SA = scenario attractiveness
- Rate = annual rate of attack occurrence

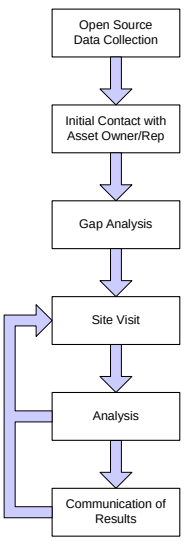
Portfolio Risk Analysis



Benefit-Cost Analysis

- Evaluates the *cost-effectiveness* of alternative countermeasure and consequence mitigation strategies
- Additional considerations include whether these alternatives meet budgetary and risk reduction objectives
- Result summaries are designed to be informative, not prescriptive

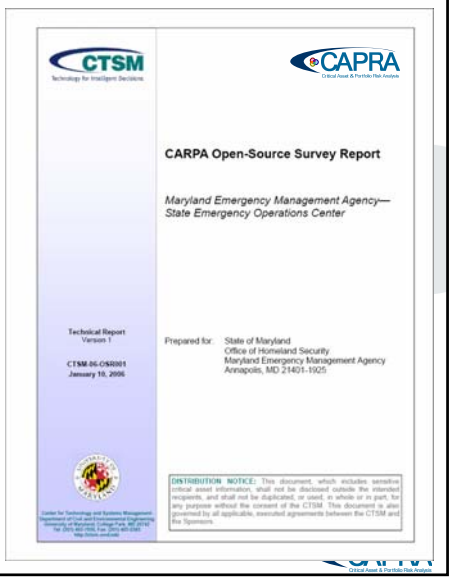
CAPRA Asset-Level Data Collection Strategy



Process Step	Personnel	Description
Open Source Data Collection	Open-Source Analyst	- Assess the "visibility" of the asset and identify its key elements based on available open source information - Integrate credible open-source information into the CAPRA tools and identify asset-specific questions
Initial Contact with Asset Owner/Rep	Team Leader	- Discuss the apparent "visibility" of the asset and the review the available open-source asset information - Obtain results from previous analyses and plans (risk, vulnerability, COP/COG) and integrate them into the CAPRA analysis
Gap Analysis	Full-Team	- Develop list of critical information requirements for completing the CAPRA analysis of the asset - Determine the appropriate composition of the Survey of Assets team for on-site data collection
Site Visit	Based on Level of Analysis Required	- Conduct an on-site asset survey to gather required information for risk analysis
Analysis	Full-Team	- Integrate site-collected data into CAPRA analysis - Assess expected consequences, security vulnerability, threat likelihood - Compute conditional and total annual risk - Identify additional data requirements to enhance the quality of results
Communication of Results	Team Leader	- Communicate the results from the analysis to the asset owner in the form of an analysis summary pamphlet, figures, and tables - Discuss potential strategies for reducing risk

Open-Source Report

- Gathers open-source information that supports:
  - Pre-visit risk analysis
  - Adversary perceptions
  - Asset visibility


CTSM
Technology for Intelligent Decisions
CAPRA
CARPA Open-Source Survey Report
Maryland Emergency Management Agency—State Emergency Operations Center
Technical Report
Version 1
CTSM-06-OSR001
January 10, 2006
Prepared for: State of Maryland
Office of Homeland Security
Maryland Emergency Management Agency
Annapolis, MD 21401-1925
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Data Sources

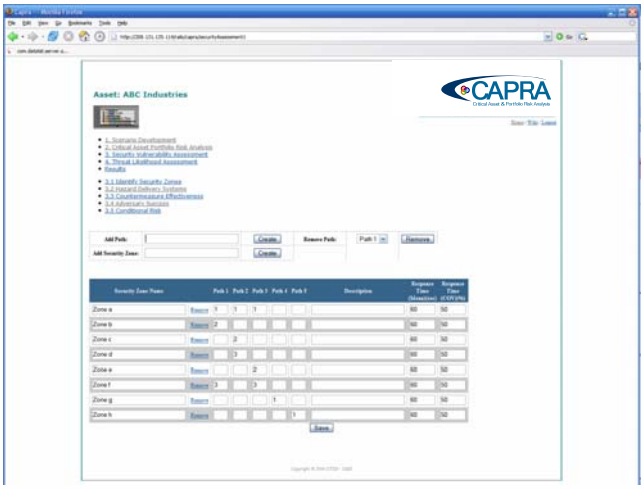
- CAPRA Can Leverage Information From Prior:
  - Risk studies
  - Vulnerability Assessments
  - Balanced Survivability Assessments
  - Site Assistance Visits
  - Asset Surveys
  - Buffer Zone Protection Plans
  - And others…

CAPRA Team Composition (Proposed)

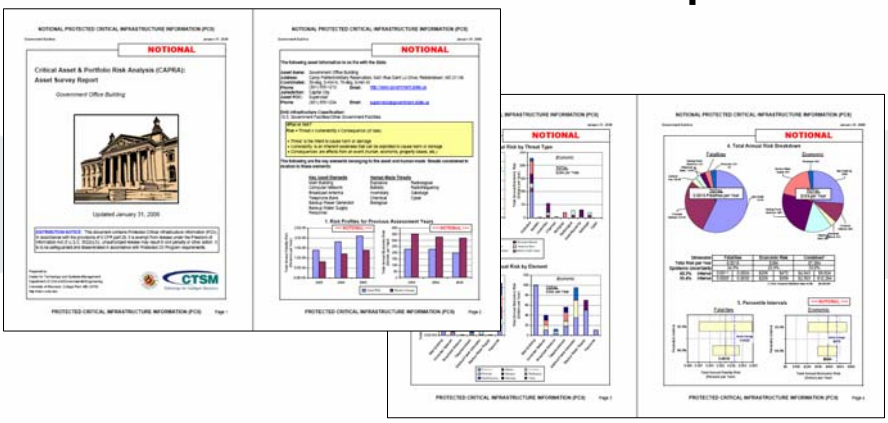
- Team Leader
- Hazard and Emergency Response Specialist
- Professional Engineer
- Security Operations Specialist
- Interdependency Analyst

Level of Analysis Required	Asset Size		
	Small	Medium	Large
Minimal	Small Team (2 members)	Small Team (2 members)	Medium Team (3-4 members)
Partial	Small Team (2 members)	Medium Team (3-4 members)	Medium Team - or - Full Team
Complete	Medium Team (3-4 members)	Full Team (5 members)	Full Team (5 members)

Web Implementation



Risk Communication – Asset Report



Goal: Communicate ***Actionable Risk Information***

Outline

- CTSM, Staff and Associates
- What Is CAPRA?
- What Decisions Would CAPRA Results Inform?
- Terminology and Risk Fundamentals
- Introduction to CAPRA
- Case Studies
  - Security Hazards: Explosives
  - Natural Hazards: Hurricanes

Outline

- CTSM, Staff and Associates
- What Is CAPRA?
- What Decisions Would CAPRA Results Inform?
- Terminology and Risk Fundamentals
- Introduction to CAPRA
- Case Studies
  - Security Hazards: Explosives
  - Natural Hazards: Hurricanes

Case Study:
Explosive Attack Against Sport Center

Case Study: Explosive Attack Against Sport Center

- Scenario Identification
  - Step 1: Identify key mission areas

    - The sport center hosts men's and women's basketball games, and serves as a site for special events and select community events.

Case Study: Explosive Attack Against Sport Center

- Scenario Identification
  - Step 2: Identify key elements

Key Element	Description
Cooling Tower	Provides air conditioning for the Comcast Center
Backup Electric Power Generators	Provides backup power in the event of utility service disruption
Main Arena	Actual location of the special event
Personnel	Staff of the Comcast Center and Visitors
Air Intake Units	Collects outside air for internal circulation
Broadcast Antenna	Antenna used to broadcast events
Parking Structure	Provides extra space for event parking

Case Study: Explosive Attack Against Sport Center

- Scenario Identification
  - Step 3: Identify security threat types

Security Threat Types	
Explosive	Laser
Projectile / Impact	Radiofrequency/EMP
Incendiary	Cyber
Chemical	Sabotage
Biological	Panic-Inducing / Harassment
Radiological	

Case Study: Explosive Attack Against Sport Center

- Scenario Identification
  - Step 4: Construct threat scenarios

	Key Element						
Hazard	Cooling Tower	Backup Generators	Main Arena	Personnel	Air Intake Units	Broadcast Antenna	Parking Structure
Explosive	X	X	X	X	-	-	X
Projectile / Impact	X	X	X	X	X	X	X
Incendiary	X	X	X	X	X	X	X
Chemical	-	-	-	X	X	-	-
Biological	-	-	-	X	X	-	-
Radiological	-	-	-	X	X	-	-
Laser	-	-	-	X	-	-	-
Radiofrequency	-	X	-	-	-	X	-
Cyber	-	-	-	-	-	-	-
Sabotage	X	X	-	-	X	X	-
Panic-Inducing / Harassment	-	-	-	X	-	-	-

Case Study: Explosive Attack Against Sport Center

- Consequence and Criticality Assessment
  - Step 1: Assess maximum possible loss

Dimension	Description	Loss Conversion Factor
Fatalities	Number of equivalent fatalities resulting from a successful attack (accounts for deaths and injuries using tools such as the Accident Injury Scale [1]).	$4,000,000 / fatality
Repair Costs	Costs to repair damage resulting from an attack measured in dollars.	None.
Asset Loss	Value of assets (e.g., goods, property, information) lost as a result of an attack measured in dollars.	None.
Recuperation Time	Time to recuperate mission following an attack measured in units of time.	$25,000 / day
Environmental Damage	Environmental damage resulting from an attack measured in area affected.	$2,000,000 / acre

Dimension	Maximum Possible Loss
Fatalities	20,000 people
Repair Costs	$125,300,000
Asset Loss	$500,000
Recuperation Time	730 days
Environmental Damage	1.0 acres

Fatality Risk			
Variable	Value		
MPL	20,000		
PV			
ME			
Loss by Intensity			
Loss			
PS			
Conditional Risk			
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Consequence and Criticality Assessment
  - Step 2: Assess physical vulnerability

Scenario	Physical Vulnerability Factor – Small Explosive				
	Fatalities	Repair Costs	Asset Loss	Recuperation Time	Environment Damage
Explosive – Cooling Tower	0.00	0.01	0.00	0.01	0.00
Explosive – Backup Generators	0.00	0.01	0.00	0.01	0.00
Explosive – Main Arena	0.001	0.01	0.00	0.04	0.00
Explosive – Personnel	0.001	0.01	0.00	0.04	0.00
Explosive – Parking Structure	0.00	0.01	0.00	0.13	0.00

Scenario	Physical Vulnerability Factor – Medium Explosive				
	Fatalities	Repair Costs	Asset Loss	Recuperation Time	Environment Damage
Explosive – Cooling Tower	0.00	0.01	0.00	0.02	0.00
Explosive – Backup Generators	0.00	0.01	0.00	0.02	0.00
Explosive – Main Arena	0.005	0.05	0.00	0.13	0.00
Explosive – Personnel	0.005	0.05	0.00	0.13	0.00
Explosive – Parking Structure	0.00	0.03	0.00	0.25	0.00

Scenario	Physical Vulnerability Factor – Large Explosive				
	Fatalities	Repair Costs	Asset Loss	Recuperation Time	Environment Damage
Explosive – Cooling Tower	0.00	0.01	0.00	0.02	0.00
Explosive – Backup Generators	0.00	0.01	0.00	0.02	0.00
Explosive – Main Arena	0.25	0.20	0.00	0.25	0.00
Explosive – Personnel	0.25	0.20	0.00	0.25	0.00
Explosive – Parking Structure	0.00	0.05	0.00	0.50	0.00

Fatality Risk			
Variable	Value		
MPL	20,000		
PV	0.001	0.005	0.25
ME			
Loss by Intensity			
Loss			
PS			
Conditional Risk			
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Consequence and Criticality Assessment
  - Step 3: Assess mitigation effectiveness
    - Conservative value of 1.0 assumed for all mitigation effectiveness factors.

Fatality Risk			
Variable	**Value**		
MPL	20,000		
PV	0.001	0.005	0.25
ME	**1.00**	**1.00**	**1.00**
Loss by Intensity			
Loss			
PS			
Conditional Risk			
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Consequence and Criticality Assessment
  - Step 4: Calculate loss per event

Loss = MPL × PV × ME

Scenario	Loss per Event, Small Explosive		
	Fatalities	Economic Loss	Total Loss
Explosive – Cooling Tower	0	$816,604	$816,604
Explosive – Backup Generators	0	$1,443,104	$1,443,104
Explosive – Main Arena	20	[illegible]	[illegible]
Explosive – Personnel	20	$2,013,417	$82,013,417
Explosive – Parking Structure	0	$3,534,250	$3,534,250

Scenario	Loss per Event, Medium Explosive		
	Fatalities	Economic Loss	Total Loss
Explosive – Cooling Tower	0	$1,006,708	$1,006,708
Explosive – Backup Generators	0	$1,633,208	$1,633,208
Explosive – Main Arena	100	[illegible]	$408,546,250
Explosive – Personnel	100	$8,546,250	$408,546,250
Explosive – Parking Structure	0	$7,695,000	$7,695,000

Scenario	Loss per Event, Large Explosive		
	Fatalities	Economic Loss	Total Loss
Explosive – Cooling Tower	0	$1,006,708	$1,006,708
Explosive – Backup Generators	0	[illegible]	$1,633,208
Explosive – Main Arena	5,000	$29,622,500	$20,029,622,500
Explosive – Personnel	5,000	$29,622,500	$20,029,622,500
Explosive – Parking Structure	0	$15,390,000	$15,390,000

Fatality Risk			
Variable	**Value**		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	**20**	**100**	**5,000**
Loss			
PS			
Conditional Risk			
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Consequence and Criticality Assessment
  - Step 5: Consequence screening
    - The following scenarios were removed from additional analysis:
      - Explosive – Cooling Tower
      - Explosive – Backup Generator

Fatality Risk			
Variable	**Value**		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss			
PS			
Conditional Risk			
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Security Vulnerability Assessment
  - Step 1: Identify Attack Profiles and Intrusion Paths
    - Considers delivery by:
      - Ground vehicle
      - Hand-emplaced
      - Aerial vehicle
    - Also considers all relevant intrusion paths
    - Expected loss calculated considering all possible attack profiles

Fatality Risk			
Variable	**Value**		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss	**1,848**		
PS			
Conditional Risk			
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Security Vulnerability Assessment
  - Step 1: Assess probability of adversary success

Scenario	Probability of Success
Explosive – Main Arena	0.94
Explosive – Personnel	0.94
Explosive – Parking Structure	1.00

Fatality Risk			
Variable	Value		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss	1,848		
PS	**0.94**		
Conditional Risk			
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Security Vulnerability Assessment
  - Step 2: Calculate conditional risk

Conditional Risk = PS × Loss

Scenario	Conditional Risk per Event		
	Fatalities	Economic	Total
Explosive – Main Arena	1,737	$12,073,303	$6,959,703,679
Explosive – Personnel	1,737	$12,073,303	$6,959,703,679
Explosive – Parking Structure	0	$8,140,159	$8,140,159

Fatality Risk			
Variable	Value		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss	1,848		
PS	0.94		
Conditional Risk	**1,737**		
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Security Vulnerability Assessment
  - Step 3: Conditional risk screening
    - No scenarios were removed from additional analysis

Fatality Risk			
Variable	**Value**		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss	1,848		
PS	0.94		
Conditional Risk	1,737		
Rate			
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Threat Likelihood Assessment
  - Step 1: Annual rate of attack occurrence
    - An annual rate of occurrence for an explosive attack against the sports center was estimated to be 0.0002
    - This value assumes one explosive every 15 years, and considers attractiveness of the sports center with respects to other assets in a region

Fatality Risk			
Variable	**Value**		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss	1,848		
PS	0.94		
Conditional Risk	1,737		
Rate	**0.0002**		
SA			
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Threat Likelihood Assessment
  - Step 2: Estimate scenario attractiveness

Scenario	Scenario Attractiveness
Explosive – Main Arena	0.32
Explosive – Personnel	0.32
Explosive – Parking Structure	0.23

Fatality Risk			
Variable	**Value**		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss	1,848		
PS	0.94		
Conditional Risk	1,737		
Rate	0.0002		
SA	**0.32**		
Threat			
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Threat Likelihood Assessment
  - Step 3: Determine annual rate of scenario occurrence

Threat = Rate × SA

- An annual rate of occurrence for an explosive attack against the main arena of the sports center was estimated to be 0.000064 events per year

Fatality Risk			
Variable	**Value**		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss	1,848		
PS	0.94		
Conditional Risk	1,737		
Rate	0.0002		
SA	0.32		
Threat	**0.000064**		
Risk			

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Threat Likelihood Assessment
  - Step 4: Calculate total annual risk

Risk = Loss × PS × Threat

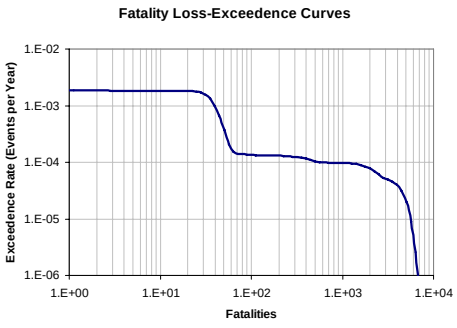
Scenario	Total Annual Risk		
	Fatalities	Economic Loss	Total Loss
Explosive – Main Arena	0.12	$827	$487,736
Explosive – Personnel	0.12	$827	$487,736
Explosive – Parking Structure	0.00	$406	$406
Total	0.24	$2,060	$971,878

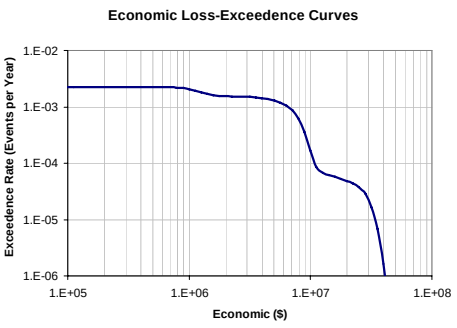
Fatality Risk			
Variable	Value		
MPL	20,000		
PV	0.001	0.005	0.25
ME	1.00	1.00	1.00
Loss by Intensity	20	100	5,000
Loss	1,848		
PS	0.94		
Conditional Risk	1,737		
Rate	0.0002		
SA	0.32		
Threat	0.000064		
Risk	**0.12**		

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Explosive Attack Against Sport Center

- Risk Assessment
  - Considering all security threat scenarios





Risk = MPL × PV × ME × PS × SA × Rate

Outline

- CTSM, Staff and Associates
- What is CAPRA?
- What decisions would CAPRA results inform?
- Terminology and Risk Fundamentals
- Introduction to CAPRA
- Case Studies
  - Security Hazards: Explosives
  - Natural Hazards: Hurricanes

Case Study: Hurricane Affecting a Region

- Scenario Identification
  - Step 1: Identify key mission areas

    - Protect residents and visitors (P)
    - Maintain flow of people / commerce (F)
    - Maintain availability of lifeline services and critical infrastructure (S)

Case Study: Hurricane Affecting a Region

- Scenario Identification
  - Step 2: Identify key elements

Key Element	Description	P	F	S
Electric power infrastructure	Provides energy to regional residents and businesses			X
Major interstate	Provides major route of traffic into and out of the region		X	
Emergency response	Provides response in the event of an emergency to minimize casualties and damage	X	X	

Case Study: Hurricane Affecting a Region

- Scenario Identification
  - Step 3: Identify hazards and intensities

Intensity (Based on Saffir-Simpson Scale)	Wind Speed	Storm Surge	Return Period	Annual Rate
Tropical Depression	0-38 mph	0 ft	5	0.2
Tropical Storm	39-73 mph	0-3 ft	10	0.1
Category 1 Hurricane	74-95 mph	4-5 ft	50	0.02
Category 2 Hurricane	96-110 mph	6-8 ft	500	0.002
Category 3 Hurricane	111-130 mph	9-12 ft	5,000	0.0002
Category 4 Hurricane	131-155 mph	13-18 ft	50,000	0.00002
Category 5 Hurricane	>155 mph	>18 ft	500,000	0.000002

Fatality Risk	
Variable	Value
Rate	0.002
MPL	
PV	
ME	
Loss	
PS	
Conditional Risk	
SA	
Threat	
Risk	

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Scenario Identification
  - Step 4: Scenario screening

- Minimum recurrence rate: 10^{-4} events per year
  - Category 4 hurricanes removed
  - Category 5 hurricanes removed

Fatality Risk	
Variable	**Value**
Rate	0.002
MPL	
PV	
ME	
Loss	
PS	
Conditional Risk	
SA	
Threat	
Risk	

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Scenario Identification
  - Step 5: Construct threat scenarios

Hazard	Key Element		
	Electric Power Infrastructure	Major Interstate	Emergency Response
Tropical Depression	X	-	-
Tropical Storm	X	-	X
Category 1 Hurricane	X	X	X
Category 2 Hurricane	X	X	X
Category 3 Hurricane	X	X	X

Fatality Risk	
Variable	**Value**
Rate	0.002
MPL	
PV	
ME	
Loss	
PS	
Conditional Risk	
SA	
Threat	
Risk	

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Consequence and Criticality Assessment
  - Step 1: Assess maximum possible loss

Dimension	Description	Loss Conversion Factor
Persons Affected	Number of persons affected for a given effect type	Depends on Effect
Property Damage and Loss	Costs to repair or replace damaged public property	None
Duration of Disruption	Duration of mission disruption	Depends on Key Element

Dimension	Maximum Possible Loss
Persons Affected	500,000 people
Property Loss	$1,000,000,000
Duration of Disruption	Not Available

Fatality Risk	
Variable	**Value**
Rate	0.002
MPL	**500,000**
PV	
ME	
Loss	
PS	
Conditional Risk	
SA	
Threat	
Risk	

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Consequence and Criticality Assessment
  - Step 2: Assess physical vulnerability

Scenario	Physical Vulnerability				
	Persons Affected: Electric Power Disruption	Persons Affected: Closure of Major Interstate	Persons Affected: Disrupted Emergency Response	Fatality Equivalents	Regional Property Damage
Tropical Depression	0.02	0.5	0.001	0.00002	0.001
Tropical Storm	0.1	0.5	0.002	0.0001	0.005
Category 1 Hurricane	0.5	0.5	0.005	0.0002	0.05
Category 2 Hurricane	0.8	0.5	0.020	0.002	0.1
Category 3 Hurricane	1.0	0.5	0.05	0.02	0.2

Fatality Risk	
Variable	**Value**
Rate	0.002
MPL	500,000
PV	**0.002**
ME	
Loss	
PS	
Conditional Risk	
SA	
Threat	
Risk	

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Consequence and Criticality Assessment
  - Step 3: Assess mitigation effectiveness

Scenario	Mitigation Effectiveness (ME) and Disruption Duration (DD, days)							
	Persons Affected: Electric Power Disruption		Persons Affected: Closure of Major Interstate		Persons Affected: Disrupted Emergency Response		Fatalities	Regional Property Damage
	ME	DD	ME	DD	ME	DD		
Tropical Depression	1.0	1	1.0	0	1.0	0.5	1.0	1.0
Tropical Storm	1.0	2	1.0	0	1.0	1	1.0	1.0
Category 1 Hurricane	1.0	3	1.0	1	1.0	2	0.95	1.0
Category 2 Hurricane	1.0	5	1.0	1	0.9	3	0.9	1.0
Category 3 Hurricane	1.0	7	1.0	2	0.9	4	0.8	1.0

Fatality Risk	
Variable	Value
Rate	0.002
MPL	500,000
PV	0.002
ME	**0.9**
Loss	
PS	
Conditional Risk	
SA	
Threat	
Risk	

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Consequence and Criticality Assessment
  - Step 4: Calculate loss per event

Loss = MPL × PV × ME

Hazard Scenario	Loss per Event	
	Fatalities	Economic Loss
Tropical Depression	10	$2,012,500
Tropical Storm	50	$15,050,000
Category 1 Hurricane	95	$373,250,000
Category 2 Hurricane	900	$551,350,000
Category 3 Hurricane	8,000	$1,054,500,000

Fatality Risk	
Variable	Value
Rate	0.002
MPL	500,000
PV	0.002
ME	0.9
Loss	**900**
PS	
Conditional Risk	
SA	
Threat	
Risk	

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Consequence and Criticality Assessment
  - Step 5: Consequence screening

Fatality Risk	
Variable	**Value**
Rate	0.002
MPL	500,000
PV	0.002
ME	0.9
Loss	900
PS	
Conditional Risk	
SA	
Threat	
Risk	

- All scenarios kept for additional analysis

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Security Vulnerability Assessment
  - Not applicable for natural hazards

Conditional Risk = PS × Loss

- Threat Likelihood Assessment
  - Not applicable for natural hazards

Threat = Rate × SA

Fatality Risk	
Variable	**Value**
Rate	0.002
MPL	500,000
PV	0.002
ME	0.9
Loss	900
PS	**1.0**
Conditional Risk	**900**
SA	**1.0**
Threat	**0.002**
Risk	

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Risk Assessment

Risk = Loss × PS × Threat

Scenario	Total Annual Risk	
	Fatalities	Economic
Tropical Depression	2	$402,500
Tropical Storm	5	$1,505,000
Category 1 Hurricane	1.9	$7,505,000
Category 2 Hurricane	1.8	$1,102,700
Category 3 Hurricane	1.6	$210,900

Fatality Risk	
Variable	Value
Rate	0.002
MPL	500,000
PV	0.002
ME	0.9
Loss	900
PS	1.0
Conditional Risk	900
SA	1.0
Threat	0.002
Risk	**1.8**

Risk = MPL × PV × ME × PS × SA × Rate

Case Study: Hurricane Affecting a Region

- Risk Assessment
  - Total Fatality Risk: **12.3 fatalities per year**
  - Total Economic Risk: **$10,726,100 per year**

Risk = MPL × PV × ME × PS × SA × Rate

Benefit-Cost Analysis

$$\text{Benefit} = (\text{Risk Before}) - (\text{Risk After})$$

$$\text{B/C Ratio} = \frac{\text{Benefit}}{\text{Cost}}$$

But to quantify requires data…

Contact

Professor Bilal M. Ayyub
Center for Technology and Systems Management
Department of Civil and Environmental Engineering
University of Maryland, College Park, MD 20742

301.405.1956 TEL 301.405.2585 FAX
ba@umd.edu http://www.ctsm.umd.edu

Additional terminology slides

Terminology – What Could Happen?

Hazard: A hazard is an act or phenomenon posing potential harm to some person(s) or thing(s), i.e., a source of harm, and its potential consequences.

Threat: An indication of possible violence, harm, or danger that includes both an adversary's intent and capabilities to perform harm to a particular target or type(s) of target(s).

Terminology – What Could Happen?

Asset: Any physical structure or key resource (contained in the National Asset Database)

Initiating Event: An event that appears at the beginning of a chain of events or a sequence of events, such as in an event tree.

Terminology – How Can It Happen?

Scenario: A sequence of a hazard or threat and subsequent events affecting an asset or region.

Attack Profile: Combination of delivery system and intrusion path for a given security threat scenario.

Terminology – How Likely Is It To Happen?

Probability: A measure of the likelihood or chance, or degree of belief that a particular outcome or consequence will occur.

Conditional Probability: Probability of event occurrence based on the assumption that another event (or multiple events) has occurred.

Terminology – How Likely Is It To Happen?

Relative Frequency: is the number of occurrences of an event of interest divided by the total number of repetitions.

Subjective Probability: is a probability that is based on the state of knowledge.

Rate: The number of a particular type of event expected to occur in a particular time period of interest.

Subjective Probability

Table A-1. Linguistic Probabilities and Translations (Lichtenstein and Newman 1967)

Rank	Phrase	No. of Responses	Mean	Median	Standard Deviation	Range
1	Highly probable	187	0.89	0.90	0.04	0.60-0.99
2	Very likely	185	0.87	0.90	0.06	0.60-0.99
3	Very probable	187	0.87	0.89	0.07	0.60-0.99
4	Quite likely	188	0.79	0.80	0.10	0.30-0.99
5	Usually	187	0.77	0.75	0.13	0.15-0.99
6	Good chance	188	0.74	0.75	0.12	0.25-0.95
7	Predictable	146	0.74	0.75	0.20	0.25-0.95
8	Likely	188	0.72	0.75	0.11	0.25-0.99
9	Probable	188	0.71	0.75	0.17	0.01-0.99
10	Rather likely	188	0.69	0.70	0.09	0.15-0.99
11	Pretty good chance	188	0.67	0.70	0.12	0.25-0.95
12	Fairly likely	188	0.66	0.70	0.12	0.15-0.95
13	Somewhat likely	187	0.59	0.60	0.18	0.20-0.92

Terminology – Risk Evaluation

Risk Evaluation: The process of examining and judging the significance of risk.

Risk Perception: The manner and extent to which a decision-maker or a person comprehends risk. The risk perception for a particular consequence and associated probability is a function of such attributes as that person's tolerance.

Safety: The judgment of risk tolerance.

Risk Perception

Activity or Technology	League of Women Voters	College Students	Experts
Nuclear Power	1	1	20
Motor Vehicles	2	5	1
Hand Guns	3	2	4
Smoking	4	3	2
Motorcycles	5	6	6
Alcoholic Beverages	6	7	3
General Aviation	7	15	12

Terminology – Risk Management

Residual Risk: The amount of risk remaining after realizing the net effect of risk reducing actions taken.

Risk Tolerance: The degree of risk associated with normal daily activities that people tolerate, usually without making a conscious decision.

Terminology – Risk Communication

Risk Communication: is the open, two-way exchange of information and perception about risk leading to a better understanding of the risks and better risk management decisions. It provides a forum for the interchange of information with all concerned about the nature of hazards, the risks, the risk assessments, and how risks should be managed.