Multi-Criteria Decision Making

Criteria – plural of **criterion**

Definition: Criterion

A quality or attribute of an alternative that is related to its desirability.

Definition: Alternative

A potential course of action.

This may be an item to be purchased, a group of items purchased, or a policy or management action.

Definition: Decision

A commitment to

a single course of action.

Often, the commitment is an expenditure, or allocation of resources.

Single-Criterion Decision Problems

Examples:

- Choose least-cost airline ticket
  - All alternatives have same route, same schedule, same comfort, etc.
- Choose color of suit you like best
  - All alternatives have same style, same price, same size

Multiple-Criteria Decision Problems

Examples:

- Choose an airline ticket
  - Alternatives have different routes, schedules, types of airplane, costs, etc.
- Choose a suit
  - Alternatives have different styles, colors, and prices

Multiple-Criteria Decision Problems

- There is a choice – multiple alternatives are possible
- Alternatives differ in more than one criterion
- Usually, the criteria are “competing” – i.e. no single alternative is best in every criterion

Terminology

- MCDM (multiple-criteria decision-making)
- MODM (multi-objective decision-making)
- MODA (multi-objective decision analysis)
- MAVT (multi-attribute value theory)
- MAPT (multi-attribute preference theory)
- MAUT (multi-attribute utility theory)

All address the problem of balancing multiple, competing criteria.
In many ways, they are all similar.

Why do formal analysis?

Because criteria are competing and trade-offs among the criteria are difficult.

Types of Multiple-Criteria Decision-Making Problems

- **Mutually exclusive alternatives** – choose exactly one option
- **Portfolio selection** – choose a set of options or projects, whose desirability must be evaluated together

This type is more common

Mutually Exclusive Alternatives: Plutonium Disposal

Problem: What to do with excess-weapons plutonium

Issues of concern:

- Plutonium is highly radioactive and long-lived and poses health and environmental threat
- Terrorists could use plutonium to make weapons
- All alternatives are costly – some very costly

Source: Butler, J.C., A.N. Chebeskov, J.S. Dyer, T. Edmunds, J. Jia, and V.I. Oussanov, "The United States and Russia Evaluate Plutonium Disposition Options with Multiattribute Utility Theory," *Interfaces*, Volume 35, No. 1., January-February 2005, pp. 88-101.

Major Categories of Criteria

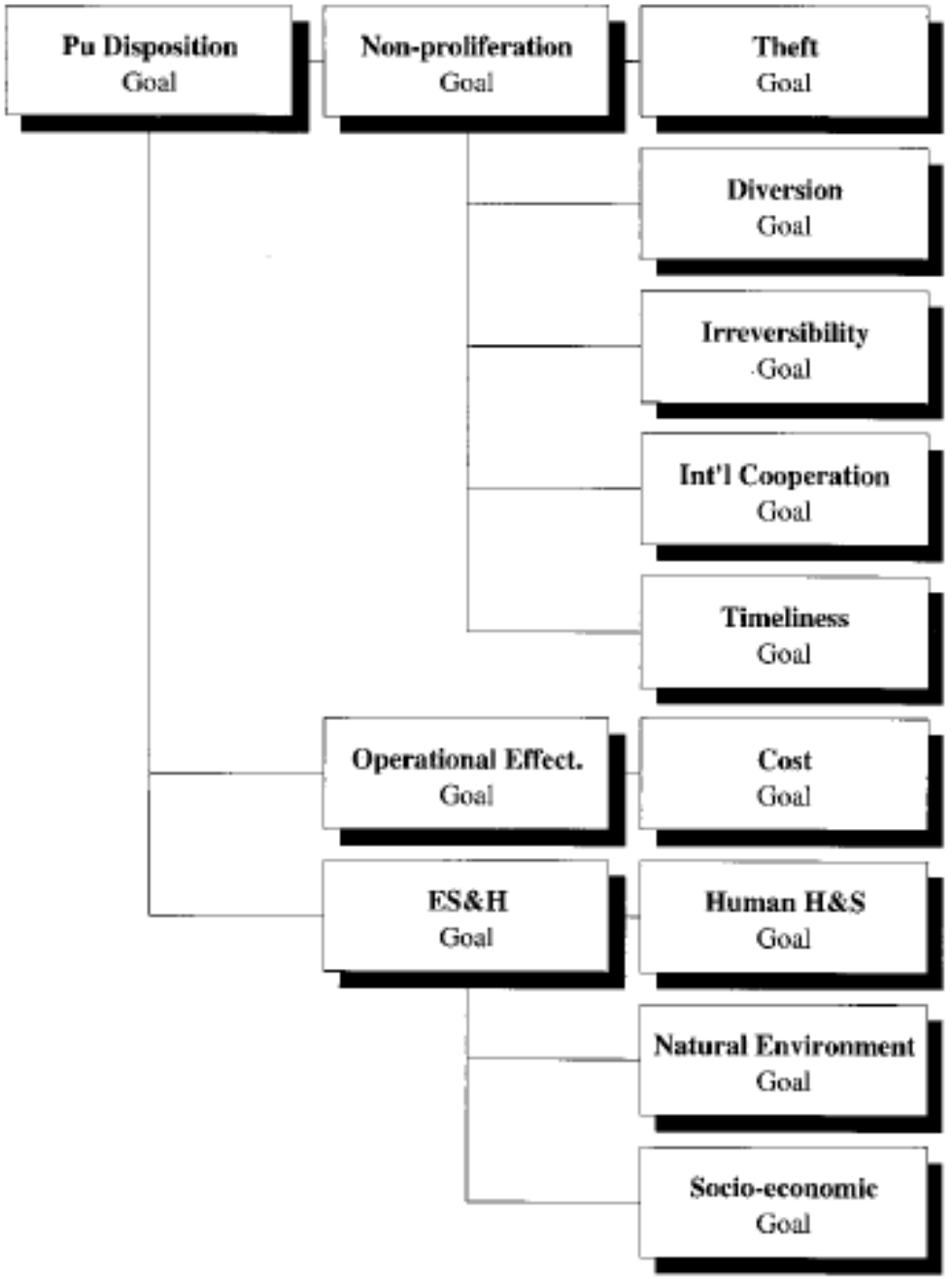


Figure 1. High-level objectives.

Mutually Exclusive Alternatives: Plutonium Disposal

Alternatives:

- Use to make fuel for electric power plants (reactors)
- Immobilize in glass, ceramics, metal
- Permanent disposal underground

There are multiple alternative ways to do each of the above – 13 alternatives total.

Table I
Disposition Alternatives

Reactor Alternatives
Existing Light Water Reactors, Existing Facilities MOX fuel fabrication plant built in an existing building at a DOE site, MOX irradiated in existing privately-owned commercial reactors
Existing Light Water Reactors, Greenfield Facilities A new co-located pit disassembly/conversion and MOX fabrication facility built at a DOE site, MOX irradiated in existing privately owned commercial reactors
Partially Completed Light Water Reactors Commercial LWRs on which construction had been halted would be completed and operated by DOE. A co-located MOX facility would be built at the site.
Evolutionary Light Water Reactors New LWRs would be built and operated by DOE along with a new co-located MOX facility.
CANDU Reactors MOX fuel fabricated at a U.S. facility would be transported to one or more Canadian commercial heavy water reactors and irradiated.
Immobilization Alternatives
Vitrification Greenfield Surplus plutonium would be mixed with glass and radioactive materials at a new facility to form homogeneous borosilicate glass logs.
Vitrification Can-in-Canister Surplus plutonium would be mixed with nonradioactive glass and poured into small cans. These small cans would be placed in larger canisters, which are then filled with radioactive waste glass.
Vitrification Adjunct Melter Surplus plutonium would be mixed with glass and radioactive materials in a supplemental melter facility to form homogeneous borosilicate glass logs.
Ceramic Greenfield Surplus plutonium would be mixed with ceramic and radioactive materials at a new facility to form homogeneous ceramic disks. These disks would be placed in a canister.
Ceramic Can-in-Canister Surplus plutonium would be mixed with nonradioactive ceramic materials to form sintered ceramic pellets. These pellets would be placed in larger canisters filled with radioactive waste glass.
Electrometallurgical Treatment Surplus plutonium would be immobilized with radioactive glass-bonded zeolite.
Direct Disposal Alternatives
Deep Borehole (Immobilization) Surplus plutonium would be immobilized with ceramic pellets and placed in a borehole.
Deep Borehole (Direct Emplacement) Surplus plutonium would be converted to a suitable form and placed in a deep borehole.

Why do formal analysis?

Because multiple stakeholders have different values and judgments. Formal analysis improves communication and consensus.

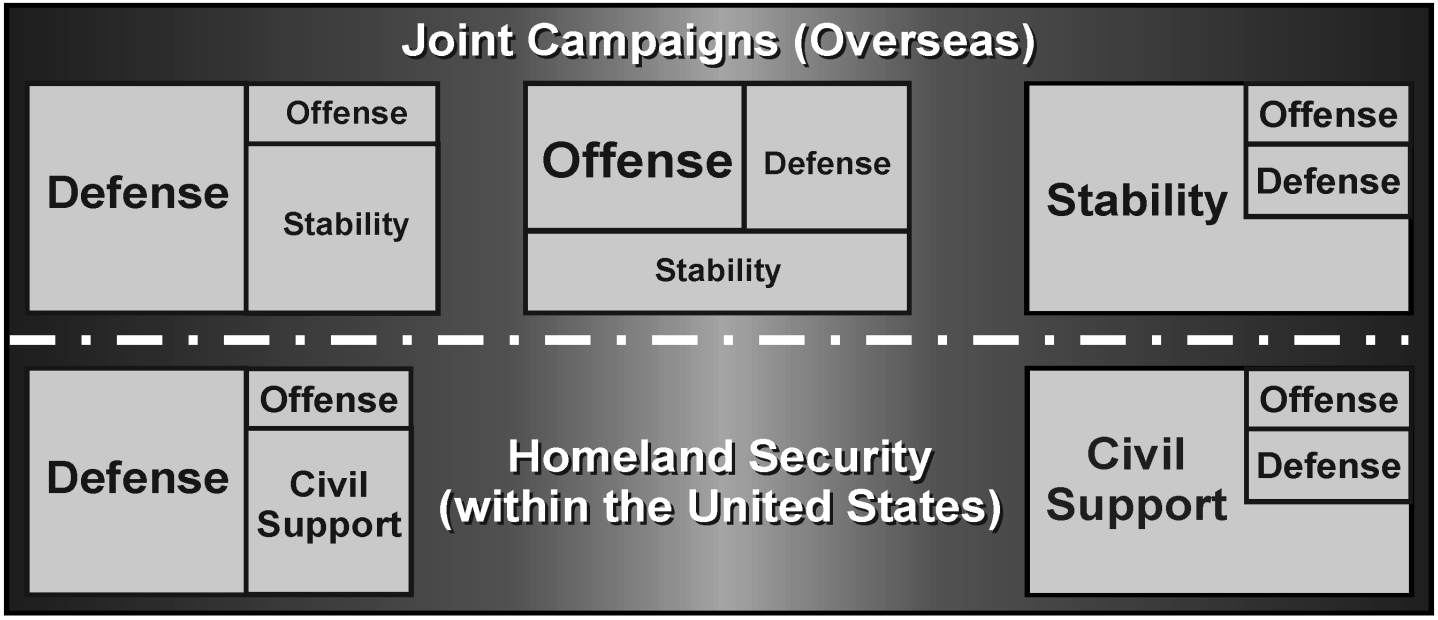
Contexts for Multiple-Criteria Decision-Making Problems

- **Single decision-maker** – a single person has ultimate power to choose
- **Group decision-maker** – a single, identifiable, cooperative group has the decision-making authority
- **Multiple stakeholders** – multiple groups and individuals, who do not necessarily cooperate, are all affected by the decision, and ideally should all buy-in to final decision

Types of Multiple-Criteria Decision-Making Problems

- **Mutually exclusive alternatives** – choose exactly one option
- **Portfolio selection** – choose a set of selected options or projects, whose desirability must be evaluated together
- **Design** – choose characteristics of a design that are most desirable, constrained by feasible designs
- **Measurement** – assessing performance with many outputs/outcomes

Army forces combine offensive, defensive, and stability or civil support operations simultaneously as part of an interdependent Joint force to seize, retain, and exploit the initiative. They employ synchronized action – lethal and nonlethal – proportional to the mission, and informed by a thorough understanding of all dimensions of the operational environment. Mission command that conveys intent and an appreciation of all aspects of the situation guides the adaptive use of military forces.



The mission dictates which component of full spectrum operations predominates.

Source: Army Doctrine Update #1, 24 February 2007

Full Spectrum Operations

- Offense
- Defense
- Stability
    - Civil security;
    - Civil control;
    - Restore essential services;
    - Support to governance;
    - Support to economic and infrastructure development.
- Civil support
    - Provide support in response to disaster;
    - Support civil law enforcement;

Is Stability Ops a Portfolio Problem?

- What does it mean to provide stability?
- Is civil security more important than civil control?
    - Civil security;
    - Civil control;
    - Restore essential services;
    - Support to governance;
    - Support to economic and infrastructure development.

Why MCDM Analysis?

- Criteria are competing and trade-offs are difficult to evaluate any other way.
- To balance multiple stakeholders' values.
- To improve communication.
- Analysis provides justification for decisions, and improves chances of acceptance of result.

Why MCDM in Public Sector?

- In the private sector, the central decision-making criterion is to maximize profit.
- Unlike the private sector, the public sector has no single “bottom line”.
- Many stakeholders, and many values must be considered.
- Defining – and measuring – the benefit(s) of defense systems and policies is difficult!

There is no single right answer in MCDM analysis!!!

- Different decision-makers have different preferences – legitimately.
- Subjective assessments are usually required in MCDM analysis.
- In general – the results (selected alternatives) may not be highly sensitive to subjective assessments.

Themes of this Course

- Purpose of MCDM analysis
- Mechanics of MCDM analysis
  - how to build a MCDM model,
  - how it works, and
  - how to use its results to make decisions
- Organizational considerations

  Organizational benefits and strategies in MCDM analysis

Operational Themes

and Types of Military Operations

Major Combat Operations

Irregular Warfare

- Counterinsurgency
- Support to an Insurgency *
- Unconventional Warfare
- Foreign Internal Defense (FID) *
- Combating Terrorism *

Peace Operations *

- Peacekeeping
- Peace Enforcement
- Peacemaking
- Peace Building
- Conflict Prevention

*** Previously defined as stability operations in the 2001 version of FM 3-0**

Limited Intervention

- Noncombatant Evacuation Operations (NEO) *
- Raid
- Strike
- Show of Force *
- Foreign Humanitarian Assistance (FHA) *
- Consequence Management
- Enforcement of Sanctions

Peacetime Military Engagement (PME)

- Multinational training events and exercises
- Joint Combined Exchange Training (JCET)
- State Partnership Program (SPP)
- Military Support to Security Assistance
- Regional Defense Counterterrorism Programs *
- Recovery Operations
- Nation Assistance *
- Arms Control *