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A Multi-Attributes Analysis Vignette For Warfighting Experiments

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A Multi-Attributes Analysis Vignette for Warfighting Experiments

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NATO

Presentation to 75th Military Operations Research Society Symposium
June 2007

"Make everything as simple as possible, but not simpler".
Albert Einstein

Abstract

"You are trading off apples and oranges and elephants" – Harvard Business Review on Decision Making, 2001

By applying the Multi-Attributes Utility Theory to analysis of a modeled system, this vignette outlines one approach by quantifying the competing and often conflicting set of objectives, and find trade offs among them based on the decision makers' preferences.

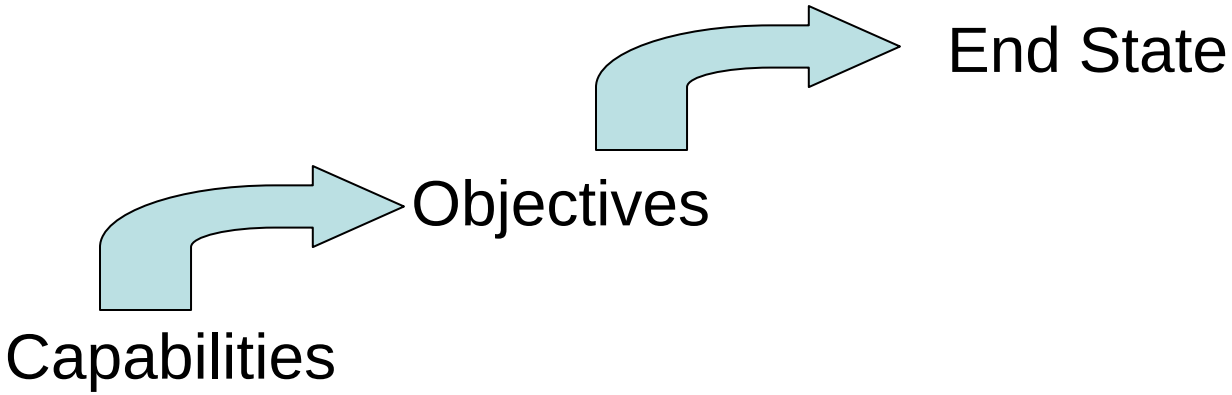
Introduction

There are many well-defined model-building procedures for experiments. The following four steps captured the essence of the general process:

- Problem definition – Set objectives
- Model development – List requirements including assumptions, preferences and constraints
- Data Handling – Attributes identification and analysis
- Model solution – Experiment outcome (trade offs)

Introduction

From operational perspective, objectives can be associated with force capabilities in the following way:



Capability enables actions, and actions result in achievement of objectives, which ultimately leads to desired end state. In an experiment, models are built to simulate the actions and interactions of different entities and their aggregated impact on the system states.

Key Points

- Make a clear and direct link between the experiment objectives and end state.
- Let the *Decision Maker* set the baseline of value functions by making a best guess – even if it is just a 60% guess.
- Understand the *Decision Maker's* preferences and incorporate them into the equations.
- Assume the mutual independence of objectives, at least for the first order treatment.
- Analyze "Soft" data ***Softly***. Make allowance for imprecise assumptions.
- **Keep it simple! This is the mother of key points.**

An Afghanistan Scenario

- The province X of Afghanistan has long been a hot spot of warlords' conflicts and instability, the Taliban and insurgents from neighboring provinces also adds chaos to the region.
- The alliance is sending forces into the province with establishing a stable local government in the province as the desired end state. The alliance sets six objectives, each corresponding to one area of the PMESII (Political, Military, Economic, Social, Information and Infrastructure) system.
- According to the scenario and the commander's guidance, three courses of action are planned.

Assign Attributes (approximately) To Objectives

Objectives:

1. **Establish a functioning provincial government**
2. **Provide sufficient internal security to province X**
3. **Improve the province's economy**
4. **Establish a functioning social (media, health and justice) system**
5. **Exchange and share information with the locals government and NGOs**
6. **Build critical infrastructure in the province**

Attributes

1. **Attribute X1 (POL): Percentage of the provincial government's functional capacity**
2. **Attribute X2 (MIL): Number of Taliban and insurgents neutralized**
3. **Attribute X3 (ECO): Number of markets and businesses opened**
4. **Attribute X4 (SOC): Percentage of schools and health clinics operating**
5. **Attribute X5 (INFO): Speed and quantity of info flow between coalition and local government (NGOs)**
6. **Attribute X6 (STRU): Percentage of critical infrastructure projects on track**

Multi-Attributes Utility Theory

According to Keeney et al [7]: Von Neumann-Morgenstern theory tells us that in order to satisfy certain competing objectives, the decision maker must assign to each of the multiple attributes (measure of objectives) a single number referring as the utility of that attribute and the assignment must be such that:

- "The more preferred the attribute the higher is the associated utility
- These utilities must be scaled in a way that justifies the maximization of expected utility."

Multi-Attributes Utility Theory

- **Objectives are hierarchical (simplified here)**

- **Desired attributes are:**

1. **Comprehensive: level of the attribute is indicative of the extent of the associated objective achieved**
2. **Operational: meaningful to the decision maker so that he understand the implications of alternatives**
3. **Decomposable: possible to break down to smaller parts**
4. **Non-redundant: no double counting**
5. **Minimal set size**

Formulate The Problem

Let c_1, c_2, and c_3 be the three courses of action chosen by the alliance commander, namely: Light, Moderate, and Aggressive.

Our aim is to find a course of action among the three such that the decision maker can maximize the aggregated utility function V whose values represent the modeled system utility:

$$\text{Max } V(X_1, X_2, .. X_{6)} = \sum_{i=1}^{6} W_i V_i(X_i) \qquad \sum_{i=1}^{6} W i = 1$$

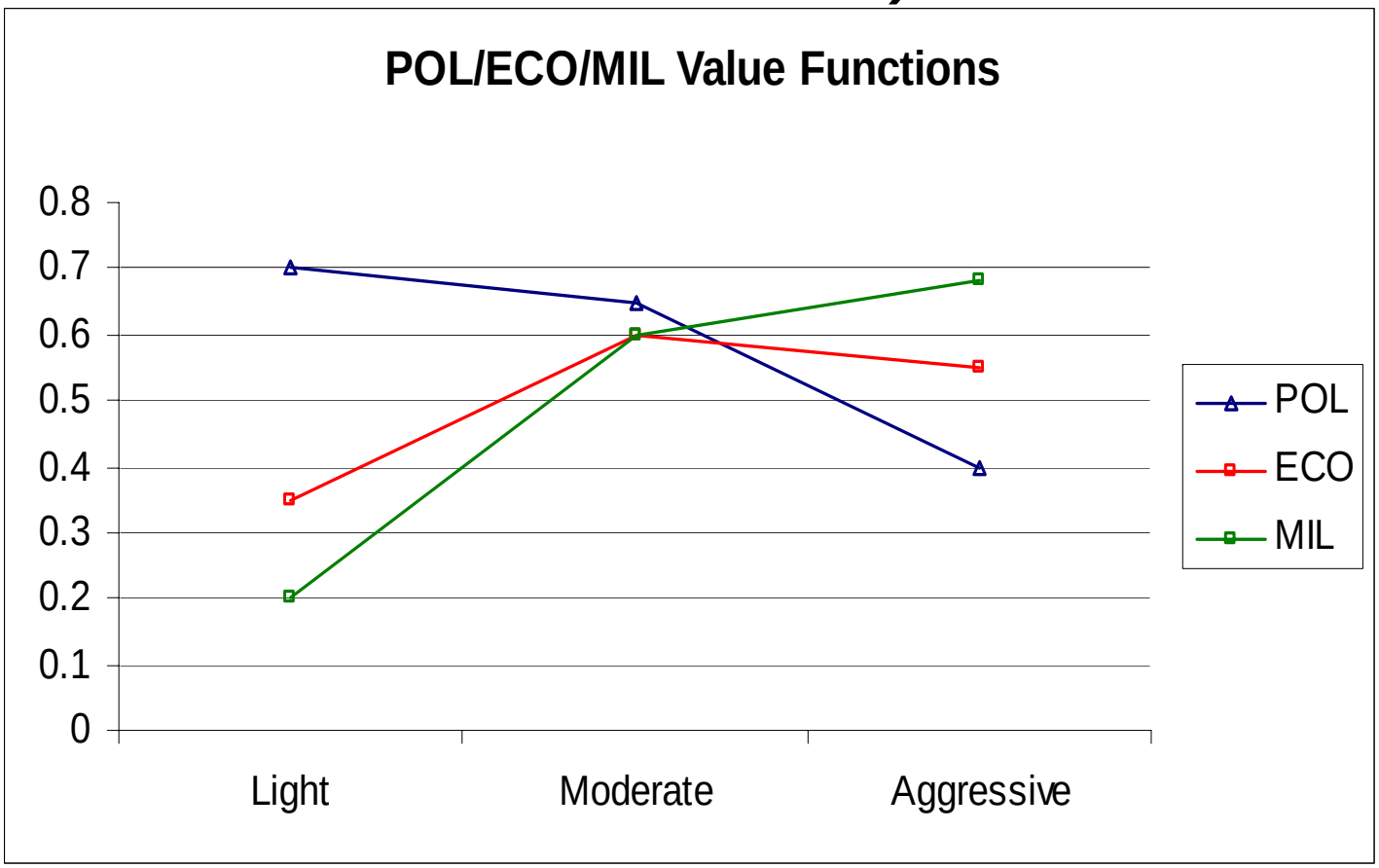
Where W_i is the weight, and $V_i(X_i)$ the value function over attribute X_i.

Consequence Table – A Judgment Call

Three Plans

Attributes	Light	Moderate	Aggressive
POL	0.7	0.65	0.4
SOC	0.6	0.65	0.5
ECO	0.35	0.6	0.55
STRU	0.3	0.65	0.5
INFO	0.4	0.55	0.6
MIL	0.2	0.6	0.68

Political, Economical and Military Attributes (~ derived from anecdotal sources*)



Preferences:

Would you prefer increasing the level of performance on the Political attribute, more than the Economical attribute? Yes.
Would you prefer increasing the level of performance on the Military attribute, more than the Political attribute? Yes.

Attributes	Light	Moderate	Aggressive	Weights		Weight Ratio
POL	0.7	0.65	0.4	0.2308	POL/ECO	1.2
ECO	0.35	0.6	0.55	0.1923	POL/MIL	0.4
					POL+ECO+MIL = 1	
MIL	0.2	0.6	0.68	0.5769		
Utility Value	0.344	0.612	0.590			

Two-Factor Sensitivity Analysis For "What if" Play

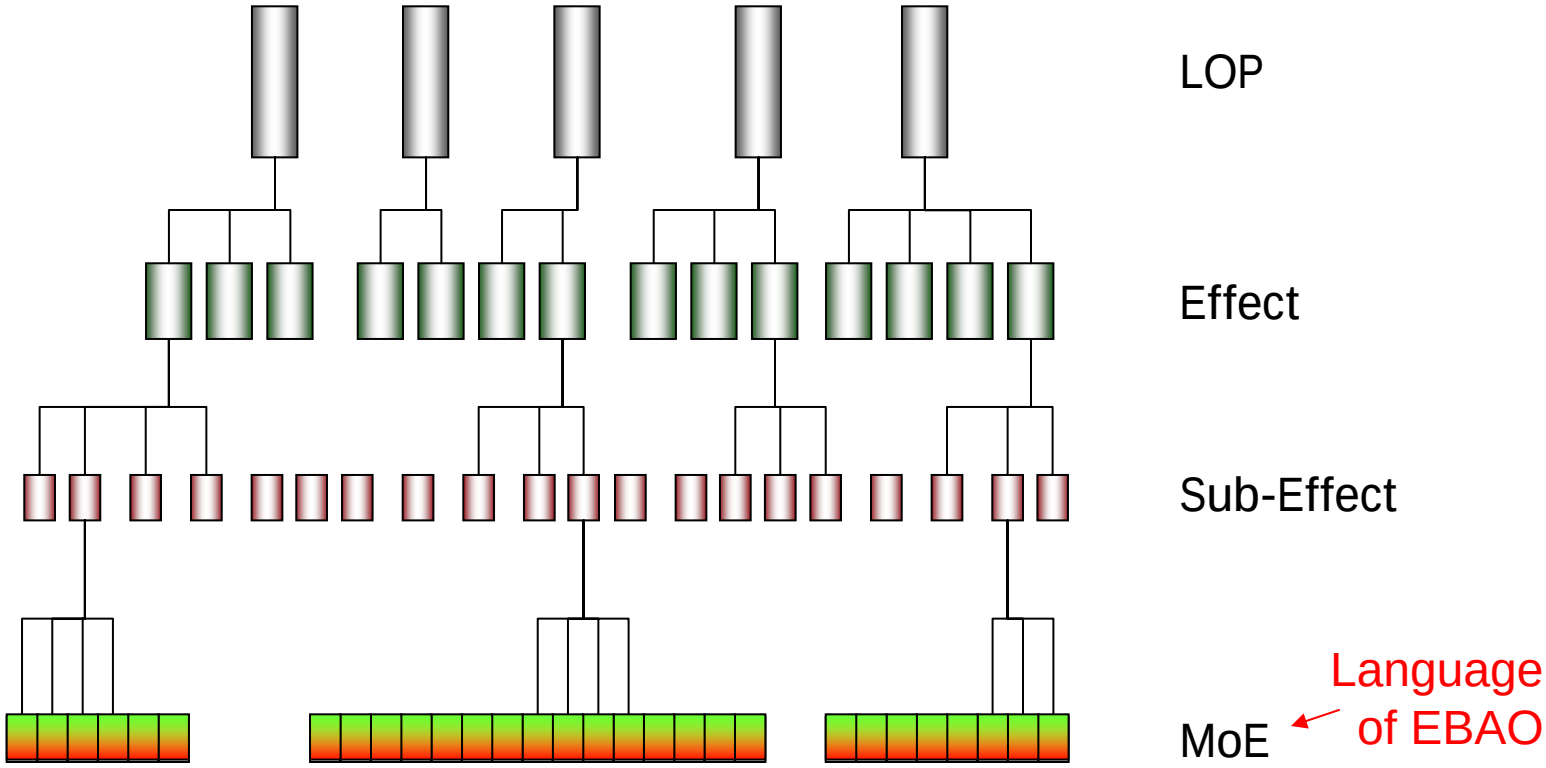
POL/ECO Weight Ratio	POL/MIL Weight Ratio 0.2	0.25	0.3	0.4
0.6	Aggressive	Tie	Moderate	Moderate
1	Aggressive	Tie	Moderate	Moderate
1.2	Aggressive	Tie	Moderate	Moderate
1.4	Aggressive	Aggressive	Tie	Moderate
1.6	Aggressive	Aggressive	Tie	Moderate
1.8	Aggressive	Aggressive	Tie	Moderate
2	Aggressive	Aggressive	Tie	Moderate
2.4	Aggressive	Aggressive	Tie	Moderate
3.6	Aggressive	Aggressive	Tie	Moderate
6	Aggressive	Aggressive	Tie	Moderate

Some Thoughts On Inputs

- Utility values of attributes and weight assessments are two basic starting points of the Multi-Attributes Utility analysis:

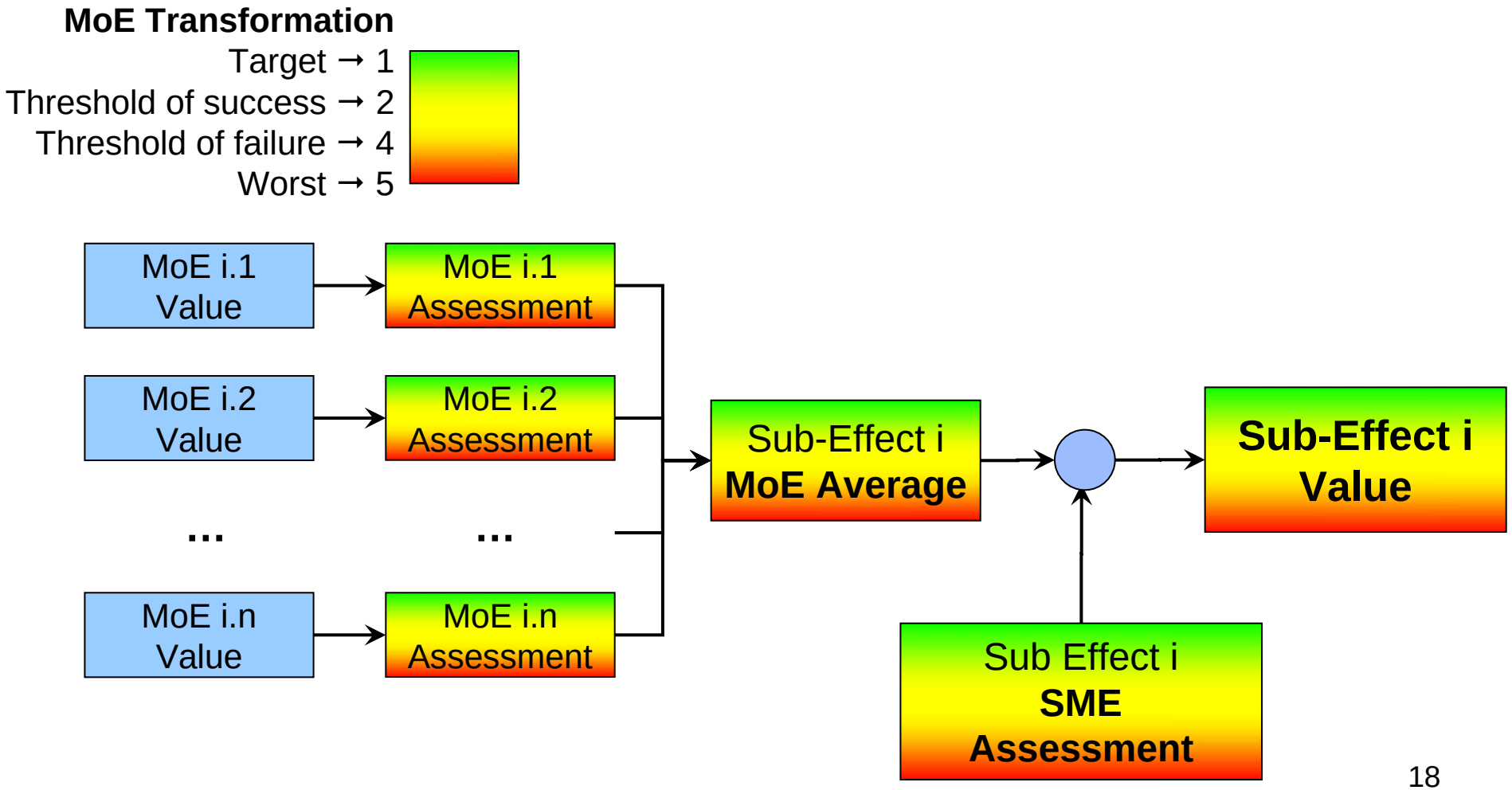
1. Assign utilities of attributes: in this paper a normalized index (0 to 1) scale is used for imprecise assignment of attributes' utility values
2. Assign weights directly: assuming that a consensus was reached among the decision makers

Example from NATO‘s ISAF: MOE ~ Attribute

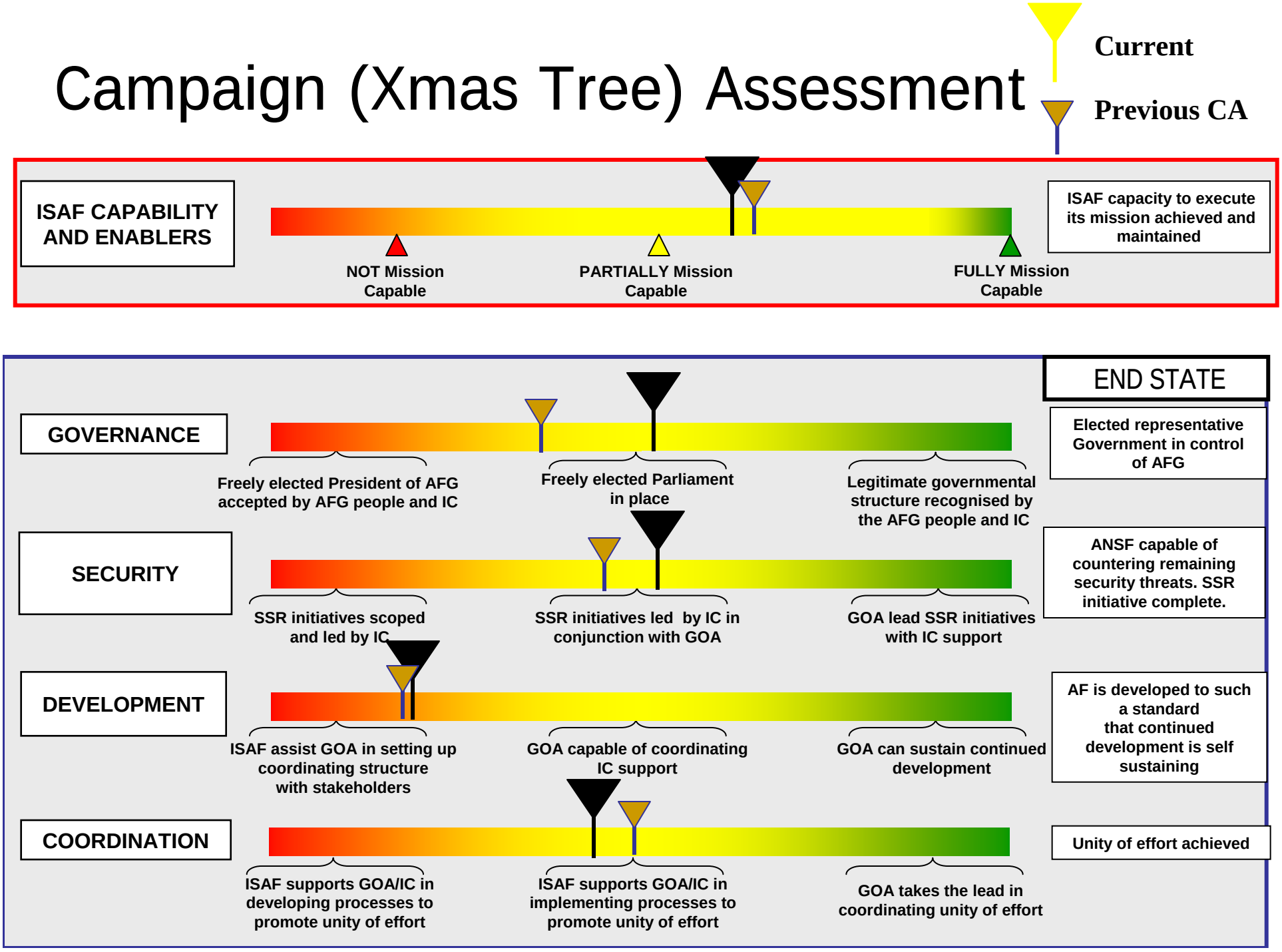


Weighting factors among the entities must be defined in advanced

ISAF: Hierarchy of Effects



Campaign (Xmas Tree) Assessment



Summary

Multi-Attributes Utility Theory (MAUT) is a practical approach in quantifying a decision maker's preferences.

MAUT has been used in industrial decision making for several decades. Recently it has been adopted into military applications. NATO school used the MAUT for its asymmetric simulation tools in its Operational Planning Course.

Multi-Attributes utility analysis is a useful tool for facilitating good decision making, with its inherent iterative process for refinement.

However Multi-Attributes utility analysis is not a tool for justifying a decision nor proving soundness of it.

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Questions?