Domain-Specific Criteria to Direct and Evaluate Planning Systems

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Abstract

This document is the result of a joint effort to understand what are relevant factors to consider when there are several possible courses of action (COAs) to accomplish a Non-combatant Evacuation Operation (NEO) military mission. These relevant factors are useful for generation and evaluation of COAs and provide the basis for a good decision in selecting a COA. The document compiles the relevant factors from the perspective of logistics that are useful to evaluate whether or not alternative proposed COAs can be supported logistically, and which ones seem to be better alternatives compared to the others. The ultimate goal of this joint effort is to use these factors to automate the evaluation and comparison of COAs and use the comparison to determine what are critical aspects of a COA that may be changed to produce a better option with a generative planner. We discuss how we envision using EXPECT and O-Plan2 for this purpose.

1 Introduction

Generating qualitatively different plans is crucial in decision-making support systems within the Planning Initiative. Current planners are tasked such that all the alternative COAs generated are pretty much produced under some fixed patterns. Typical patterns are to produce one COA that uses many resources but can be deployed very fast, another that uses less resources and the deployment takes longer, another is somewhere in the middle, and another is a bit more extreme. Generating qualitatively different plans would allow more variety and better quality solutions.

What we foresee as the framework is that an outer "strategic/task assignment" layer of the system performs some task analysis and sets direction. This would be used to set up definite targets and constraints for the "tactical" planner to flesh out. The tactics planner would thus establish that a plan was possible within the framework specified (keeping certain elements of evaluation at favorable levels). The planner would be tasked with different such requirements to produce alternate plans which are qualitatively different.

The intent of this document is to add to the PRECiS domain description [5] such that together they provide a rich domain example that is simple enough for enabling technology research, but also that can be realistically evaluated and recognized as addressing real issues.

This document attempts to clarify the following issues:

1. Clear separation of *task assignment* and scoping of a request to a *tactical* planner. Why these differ and how it helps to clearly separate the two.

2. Need for criteria against which plans will be evaluated. Idea that the *same* criteria can be used to *direct* the planner from the task assigner and can also be used to *evaluate* alternatives produced.

Our main goals are the following:

- To understand how domain criteria will be used to evaluate a plan *however it was produced – manually, automatically or with mixed initiative.*

- To relate each of these *domain criteria* to *plan features* in order to ensure that these plan features can be reasoned about by future planners.

- To give feedback to plan representation design efforts, to indicate which parts of the KRSL plan representation should be the primary targets for our work as being most relevant to domain issues of concern.

- To design an evaluation function to rate plan alternatives which will guide alternatives selection, such that the planner is using the *same* knowledge in choice making that will be used to rate COA options by the higher level analysis and direction people.

- To influence planner design and features to ensure that support is available to generate plans with the desirable domain features required.

This document runs as follows. After laying some background on the purpose of COA evaluations, the paper shows the evaluation factors relevant for NEO operations. We then describe in detail how to evaluate relevant factors from a logistics perspective. Finally, we discuss how the O-Plan2 and EXPECT systems can cooperate in the generation and evaluation of alternative courses of action. The paper includes an appendix with a concrete example of how tentative COAs are described, evaluated, and compared.

2 Background

During the concept development phase of a plan, it is crucial to develop careful estimates of the situation and the alternative courses of action. This analysis can help in making certain that:

a) a broad spectrum of possible courses of action is considered;

b) the uncertainties in each COA are analyzed and estimated to reduce unknowns;

c) the analysis can be used as the basis for a commander's estimate and subsequent selection of the appropriate options.

The concept development phase is composed of the following steps [6]:

1. *Mission Analysis.* The CINC analyzes the mission and the assigned task. The result is a *mission statement* that contains the tasks to be accomplished and the purpose they achieve. These tasks are described by who/what/when/where/why/how.
2. *Planning Guidance.* The supported commander produces a *planning directive*, that contains several tentative courses of action and other information that is used as initial guidance for the analyses. Each tentative COA is described a sa series of elements composed of who/when/what/where.
3. *Staff Estimates.* The six staff divisions use the planning directive to analyze the situation, each one from a different perspective. J-1 is concerned with personnel, J-2 with intelligence, J-3 with operations, J-4 with logistics, J-5 with transportation, and J-6 is concerned with C^3. The result of this analysis is a more refined description of each tentative COA, as well as staff estimates of relevant factors.
4. *Commander's Estimate.* A commander's estimate that summarizes the staff estimates is put together that is the basis to select one of the tentative COAs.
5. *Concept of Operations.* Produce an OPLAN (operation plan) that fully develops the CINC's concept of operations and includes time-phased force and deployment data (TPFDD).

The preparation of the staff estimates and the commander's estimate may be the most critical and time consuming task of task-sensitive planning operations. This is currently done by human planners, and our goal is to contribute to the automation (or partial automation) of this process.

Another important problem is that the generation of alternative courses of action cannot be fine-tuned because of time constraints. Courses of action turn out to be one of three types [7]:

1. conservative, using few forces,
2. use massive forces,
3. take little force with the hope that the operation will succeed anyway.

These three types are too gross grain and lie on stereotypical positions of the spectrum of possible alternatives. There are many tradeoffs that should be considered. For example, using a large force is a trivial way to make an operation succeed. However, such COA is considered unacceptable because it is too expensive. The goal is to use the minimum amount of force sufficient to hold the operation and of acceptable cost. If we increase automation during this phase, more satisfactory COAs will be produced.

3 Evaluation Factors for NEO Operations

In the staff estimates process, 23 of the 39 JOPES identified elements of evaluation (EEs) [4] are applicable to most NEO operations and should therefore be considered in the identification and recommendation of a NEO COA. Of these factors, many will remain constant across all COAs and are usually not addressed. Of those that differ, a few are identified as *critical factors* and are thus instrumental in the nomination of the recommended COA.

The 23 EEs are:

1. *Agreements and treaties*

   Do we have overflight rights and freedom of navigation for all lines of communications?

   Do we have basing rights for all staging bases, intermediate locations, and safe havens?

   Do we have all necessary host nation support at each location?

   Would we be violating any treaties with any country involved while conducting the proposed activities?

2. *Airfields and air facilities*

   Are the airfields close to the evacuation areas?

   Are the airfields capable of supporting the proposed evacuation aircraft types?

   Are the airfields capable of supporting the proposed aircraft quantities?

   Are there enough of the right types of staff available (refuelers, air traffic control, maintenance, etc.)?

   Do the airfields have facilities for refueling (only if necessary) or do we need to bring it in?

   Are the airfields capable of providing the equipment necessary to support aircraft operations (radios, radar, etc.)?

   Do the airfields have maintenance facilities (hardstands, hangers, etc.) if maintenance is going to be needed there?

3. *Allied and friendly cooperation*

   Is this a joint operation? If so, have tasks/missions been allocated?

   Do we have the political backing of our friends and allies for this operation?

4. *American firms overseas*

   Are there firms that will require staff and essential records/equipment evacuation?

5. *Ammunition*

   Do we have access to sufficient quantities?

   Do we have access to sufficient types?

   Can we acquire the ammunition in a timely manner to support operations?

   Are we prepared for contingencies with respect to needed ammunition?

6. *Communications*

   Will the Host Nation communications be sufficient (phones)?

   Do we need secure communications? If so, can we provide it?

7. *Concept of operations*

   Is the concept of operations in accordance with all guidance and constraints currently supplied?

   Is the concept robust (no/minimal single point failure)?

   Is the concept flexible (is this option able to adapt to worsening / improving conditions)?

   Are the success, termination, and transition criteria well defined?

8. *Effects of US response*

   Will there be repercussions based on our response (sanctions, diplomatic relations, etc.)?

   Will the American people support the operation?

9. *Environment, weather, and oceanography*

   Can critical portions of the operation be done at night?

   Will weather potentially hamper / delay our operation?

   Can the weather be used to hamper / delay enemy activities / reaction?

   Do the tides negatively affect the operation?

10. *Facilities (US and allied)*

    Are allied and US facilities sufficient to support operations?

    Intermediate locations: food, water, shelter, safety?

    Safe Havens: food, water, shelter, hospital, political, onward transportation?

11. *Facilities (enemy)*

    Are enemy facilities a "center of gravity" for their operations? Can they be disabled?

    Can enemy facilities be captured / utilized for our benefit?

12. *Forces (US and allied)*

    Are the forces trained for this type of operation?

    Are there sufficient forces to offset anticipated and contingency enemy reactions?

    Can the forces be in position in the timeframe identified?

    Do the forces have sufficient equipment?

    Can we accomplish the mission with a "minimum footprint" (minimal troops, destruction, minimum area, etc.)?

13. *Forces (enemy)*

    Can enemy forces be countered during the operation to minimize their impact, especially loss-of-life?

14. *Geography and terrain*

    Are the friendly forces trained to support operations in this type of area and terrain?

    Does the terrain / geography inhibit / facilitate the operation?

    Are beaches accessible as transportation alternative?

15. *Legal authorities*

    Would we be violating any local or international laws or treaties in conducting these operations?

    Will we be coordinating with local peacekeeping authorities?

16. *Maps and chart availability*

    Do we have sufficient information about the local geography and topology?

17. *Medical services*

    Sufficient (in both quantity and type) medical facilities must be provided both en-route and at each safe haven.

    Medical units must be available at each of the evacuation centers in country.

18. *Non-combatant personnel*

    Accommodations (both transportation, food, and lodging) must be made available for all evacuees including both US and other friendly nationals evacuated by US.

19. *Operational comparison (US and adversary)*

    What activities might the enemy undertake to undermine our operation?

    How susceptible is our operation to enemy activities?

20. *Reconnaissance reporting*

    Can we get assessments of enemy activities for this operation?

    Can we get information regarding the agencies, facilities, and resources involved and updates on that status over the course of the operation?

21. *Rules of engagement (ROE)*

    Will the operation be able to be conducted within the specified rules of engagement?

22. *Seaports and port facilities*

    Are the seaports close to the evacuation areas?

    Are the seaports capable of supporting the proposed evacuation ship types?

    Are the seaports capable of supporting the proposed ship quantities?

    Are there enough of the right types of staff available (refuelers, sea traffic control, maintenance, etc.) if necessary?

    Do the docks have facilities for refueling (only if necessary) or do we need to bring it in?

    Are the docks capable of providing the equipment necessary to support ship operations (radios, etc.)?

23. *Transportation (local)*

    Is sufficient local transportation available for transport to assembly areas?

    Can transportation be rented or purchased locally as opposed to provided by the evacuation forces?

    Are the routes susceptible to enemy intervention?

    Can the local lines of communications be protected during use?

The remaining 16 are normally not a consideration during NEO operations but are included here for completeness:

1. *Construction*
2. *Critical Assets*
3. *Emergency Response Elements*
4. *Intelligence Collection Assets*
5. *Intelligence Collection Priorities*
6. *LERTCON Actions*
7. *Manpower*
8. *Mobilization (Forces)*

9. *Mobilization (Industrial Base)*
10. *National/Regional Interests and Objectives*
11. *Nuclear Weapons Accounting*
12. *Political, Economic, and Social Factors*
13. *Petrol and Lubrication (POL)*
14. *Security Assistance/Military Aid Programs*
15. *Sustainment*
16. *World Reaction*

4 Relevant Logistics Factors for COA Evaluation

As we described before, each staff division produces evaluations of COAs that take into account the factors relevant to that division. For example, the logistics directorate (J-4) is concerned with ensuring effective logistic support for all forces, including transportation, supply, and maintenance issues. This section describes relevant factors to evaluate COAs from a logistics perspective in more detail than the previous section. The main factors from a logistics perspective are the following five:

A-PORTS (*Airports*) — For each airport mentioned in COA, two aspects are evaluated: (1) number of sorties/day, and (2) the number of square feet of aircraft parking.

S-PORTS (*Seaports*) — For each seaport mentioned in COA, the aspects considered are: (1) number of piers, (2) number of berths, (3) the max size of vessels allowed in the seaport (in feet), and (4) number of oil facilities or POLs (petrol and lubrication.)

LOG PER (*Logistics Personnel*) — The number of people needed to support the operation. Support personnel includes unloading personnel, stevedores, and military police.

Closure Date (*Earliest deployment closure allowed by COA*) — This is also known as the COA *closure date*, and is given as an offset from D-day (D+X).

LOCs (*Lines of Communication*) — This factor evaluates the operation in terms of how the different force modules involved will be able to communicate when they are physically distributed in different locations. It is usually qualified as good, ok, or bad.

Other factors considered include resupply capability of airports and seaports in terms of storage and refrigeration, pre-positioned war reserve material stock, covered storage areas, logistics command and control, host nation support in terms of resources allocated by host country for the operation, medical services, the logistic over the shore, whether ships are stacked up at the seaports waiting to be unloaded, onward movement coordination, oil facilities gained, who is in charge of C2, whether forces must move to other locations, topography, C3 physical protection, climate and weather, and enemy C3CM.

4.1 Estimating the Value of Relevant Factors for COA Evaluation

The value of most factors is estimated using back of the envelope calculations. The estimates for the five logistics factors being considered are calculated as follows:

A-PORTS: For all the airports mentioned in COA, add

- number of sorties/day allocated to the operation by the host nation.
- aircraft parking space available.

S-PORTS: For all the seaports mentioned in COA, add

- number of piers in the seaport.
- number of cargo berths.
- maximum size of vessels allowed by the seaports of the COA. This is calculated by taking the maximum length of the types of cargo berths available in all the seaports.

Closure Date: Maximum of airlift and sealift closure times. The procedure to calculate the airlift closure is described in detail in [8].

LOG PER: The logistics personnel needed is a function of the size of the personnel involved in the operation. It can be estimated as a percentage of the people who compose the force modules involved in the COA. First, the total amount of troops to be moved is calculated. These troops come from any non-organic units involved in the COA. We take an 8% of the total personnel as unloading support personnel, 0.42% of the total personnel for each airport as airport support personnel, and 1% of the total personnel for each seaport as seaport support personnel.

LOCs: There are three relevant aspects to evaluate:

- number of locations
- maximum distance between those locations (in miles)
- whether or not there are both air and sea locations.

5 Comparing Alternative COAs

Once the factors relevant for the evaluation have been estimated for each COA, the COAs can be compared against each other to produce a comparison matrix. The matrix is filled out with pluses and/or minuses depending on how the alternative COAs compare.

A-PORTS is better the more throughput they have, which depends mostly on sorties and parking. S-PORTS is better the more berths of bigger size that they have. The closure date is better the closer it is to the D day. LOG PERS is good if it is not a large number.

LOCs are compared as follows. If only one geoloc involved in COA, then they are good. If two geolocs, then they are ok. If three or more geolocs, they are bad. It is better if the locations are close to each other and also if they are far from the enemy border. It is also good if there are both air and sea locations.

In general there are tradeoffs in these factors. For example, the more ports in the COA the better A-PORTS and S-PORTS, but LOG PERS increases and that is not so good. This is key to give feedback to a generative planner from this evaluation: to keep a good value in a factor while improving in another one.

6 Generating Qualitatively Different Plans: EXPECT and O-Plan2

This section describes our ideas to combine the COA generation via O-Plan2 and the COA evaluation capabilities of EXPECT within the Planning Initiative. We first present very briefly the two systems, then we show how they can be combined.

6.1 O-Plan2

The O-Plan2 Project at the Artificial Intelligence Applications Institute of the University of Edinburgh is exploring a practical computer based environment to provide for specification, generation, interaction with, and execution of activity plans. O-Plan2 is intended to be a domain-independent general planning and control framework with the ability to embed detailed knowledge of the domain. See [1] for background reading on planning systems. See [2] for details of O-Plan (now referred to as O-Plan1), the planning system that was a forerunner to the O-Plan2 agent architecture. That paper also includes a chart showing how O-Plan relates to other planning systems. Further detail on O-Plan2 is available in [3].

The overall O-Plan2 plan representation and system allows for "tasks" (Missions, constraints, resources, etc) to be explored and compared in a supportive interface for doing plan option analysis. This strategic "Task Assignment" level gives more specific tactical requirements to the computer planner and human planner who work with mixed initiative alongside each other. Neither is "in charge" in our system - they both are "editing" plans constrained by the mission options being explored and the "authority" given to them for planning or execution. Finally, when a COA to be used as a basis for operations is selected, operational planning and execution monitoring support is offered along with some simple forms of plan repair to keep things on track.

The Edinburgh O-Plan2 prototype is currently being demonstrated generating plans in a cut down Tunisian IFD-2 scenario. Work is now underway for mid 1994 to demonstrate the O-Plan2 planner working with an enriched resource model of NEO evacuee transportation in the PRECiS domain. A later demonstration in 1995 is intended to show how plans can be generated and their execution monitored and simple fixes applied in the PRECiS domain.

6.2 EXPECT

The goal of the EXPECT project of the Information Sciences Institute of the University of Southern California is to provide an environment for the development of knowledge-based systems that aids in the acquisition, maintenance, and documentation of the knowledge about a task.

The EXPECT architecture [9, 10, 11] is being applied to producing staff estimates for tentative courses of action to produce briefings for a commander. To date, we have a prototype system that takes an assessment of the situation and evaluates relevant factors for the alternative courses of action from the logistics perspective. The system has a map-based interface that displays force deployment, and allows the user to analyze factor evaluations through interactive dialogues. The user can correct the system's knowledge about how to compute these evaluations if a knowledge

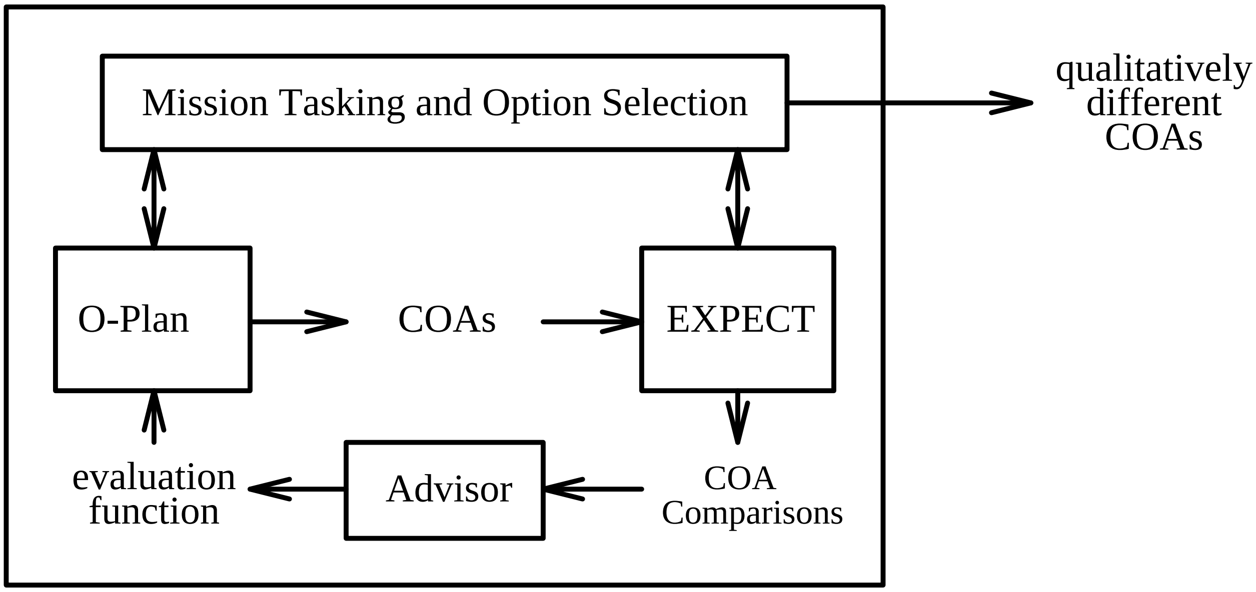

Figure 1: O-Plan2 and EXPECT could cooperate to produce better alternatives for COAs.

deficiency is detected. The user can also correct the system's knowledge base to add new relevant factors or to expand the level of detail at which the evaluations are computed.

6.3 Generating Qualitatively Different Plans

Figure 1 shows how the two systems could cooperate to produce better alternatives. O-Plan2's generated COAs are given to EXPECT. EXPECT evaluates these COAs, and gives feedback to O-Plan's evaluation function in terms of what factors can be improved to produce a better COA.

A higher level Mission Tasking component provides the framework within which options are being explored and compared.

The Advisor module would provide the feedback to make a COA of better quality. This feedback can be at different levels of detail. The more details, the easier it is for a generative planner to operationalize the feedback. For example, a high-level piece of feedback could be "The airlift closure date needs to be a day earlier," while a more detailed one would be "use a bigger airport."

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A An Example Scenario

This appendix shows with concrete examples what are the relevant inputs and outputs of the various steps of the development of the concept of operations. The examples used are extracted from the PRECiS scenario.

A.1 Tentative Courses of Action

Tentative COAs are described as a set of elements composed of who/when/what/where specifications. These correspond to a force module, a time frame (a start date and an end date as offsets from D-day), an action, and a location.

The following are the alternative COAs for this scenario.

COA 1 (Delta) — On D day, the MEU[1] will conduct amphibious operations in Delta and the LIB[2] will airland in Delta. Starting on D+2 and ending no later than D+5, the ACR[3] will begin unloading in Delta. Starting on D+5 and ending no later than D+15, the MID[4] will begin unloading in Delta. The MEU will reimbark no later than D+9. On D day, the CVBG[5] will MODLOC near Barnacle.

COA 2 (Calypso) — On D day, the MEU will conduct amphibious operations in Calypso and the LIB will airland in Calypso. Starting on D+2 and ending no later than D+5, the ACR will begin unloading in Calypso. Starting on D+5 and ending no later than D+15, the MID will begin unloading in Calypso. The MEU will reimbark no later than D+9. On D day, the CVBG will MODLOC near Barnacle.

COA 3 (Delta and Calypso) — On D day, the MEU will conduct amphibious operations in Calypso and the LIB will airland in Delta. Starting on D+2 and ending no later than D+5, the ACR will begin unloading in Delta. Starting on D+2 and ending no later than D+15, 1 Brigade of the MID will begin unloading in Calypso. Starting on D+5 and ending no later than D+15, the rest of the MID will begin unloading in Delta. The MEU will reimbark no later than D+9. On D day, the CVBG will MODLOC near Barnacle.

COA 4 (Delta and Calypso and Abyss) — On D day, the MEU will conduct amphibious operations in Calypso and the LIB will airland in Delta. On D+1, a LI Battalion will airland in Abyss. Starting on D+2 and ending no later than D+5, the ACR will begin unloading in Delta. Starting on D+2 and ending no later than D+15, 1 Brigade of the MID will begin unloading in Calypso. Starting on D+5 and ending no later than D+15, the rest of the MID will begin unloading in Delta. The MEU will reimbark no later than D+9. On D day, the CVBG will MODLOC near Barnacle.

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[1] Marine Expeditionary Unit
[2] Light Infantry Brigade
[3] Armored Cavalry Regiment
[4] Mechanized Infantry Division
[5] CV Battle Group

A.2 Staff Estimates

Staff estimates are presented as matrices of factors and alternative COAs. Section 4 describes how these evaluations are produced based on the description of each COA. The following is example of a logistics staff estimate.

	COA 1	COA 2	COA 3	COA 4
A-PORTS:				
- airports	1	1	2	3
- sorties/hr	315	165	480	580
- sq ft ac parking	2M	.9	2.9	4.4
S-PORTS:				
- seaports	1	1	2	3
- piers	6	9	15	18
- berths	6	10	16	21
- max vessel size in ft	600	none	none	none
- oil facilities	1	2	3	4
CLOSURE DATE	D + 15	D + 12	D + 9	D + 9
LOG PERS	3300	3300	3800	4300
LOCs:				
- number locations	1	1	2	3
- miles max distance	20	20	64	208
- air and sea?	yes	yes	yes	yes

A.3 Comparison Matrices

Based on the estimates, each staff division produces a comparison matrix that compares the alternative COAs. Section 5 shows how these comparisons are constructed. This is an example of a logistics staff comparison matrix:

	COA 1	COA 2	COA 3	COA 4
A-PORTS	++	+	+++	+++
S-PORTS	+	++	+++	+++
CLOSURE	+++	++	+	+
LOG PERS	+	+	+/-	-
LOCs	+	+	++	+/-

These comparisons are represented as pluses and minuses. Based on the data in this figure, COA 3 would probably be selected.