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Modelling of Capability-Based Defence Planning Processes

Ivo G. Radulov
Rakovski National Defence College
Defence Advanced Research Institute
Sofia, Bulgaria
i.radulov@rndc.bg

***Abstract*. The realization of the planned level of effectiveness of decisions in the field of defence, and thus the development of the necessary defence capabilities, depends and is determined to a significant extent by the quality of defence planning and the implementation of the transformation of the armed forces. This feature is of crucial relevance in the uncertain future security environment. The preservation and development of defence capabilities in response to threats and commitments to national and global security, under conditions of severe constraints on available resources, necessitates a search for adequate methods to enhance the effectiveness of the defence planning process.**

The purpose of this publication is to present an revised model of the Defence Planning System used in the Ministry of Defence and the Bulgarian Army. The model is presented with tools for formal description and analysis. An analysis of the activities is performed. The formed model of the future state (To-Be) has been verified for adequacy, completeness, and consistency using the presented methodology.

Revised model has been adopted as the main methodology for the Strategic Defence Review of the Ministry of Defence and the Bulgarian Army from 2019-2021.

Keywords: Modelling, Capability-based defence planning, E-nets.

I. Introduction

NATO countries have well-established defence planning processes, procedures and methods. Using these tools, participants in this process determine the capabilities required of their armed forces so that they can meet the standards set over the long term. It has been proven in practice that when it comes to the actual acquisition and development of defence capabilities, the necessary resources are always insufficient. The result is a capability gap. These gaps take various forms and dimensions, most often in the form of shortages of weapons and equipment, combat training, logistic support and communications, incompatible and/or vulnerable communication and information technologies, command and control systems, etc. Other negative examples of shortfalls resulting from budget spending on the purchase of assets and services that do not contribute to the development of the capabilities actually required by the armed forces (AF) are no exception. The result of all this is incapable formations and structures that are unable to perform their missions and tasks.

The purpose of the study is to propose an adequate defence planning system model. To achieve this goal, a methodology for the analysis and formal description of the model will be used.

II. Materials and Methods

The following formal description and analysis methods were used to find realistic solutions:

IDEF0. IDEF0 is a set of elements of a system or a domain. It was developed based on the ICOM (Input, Control, Output, Mechanism) concept and is integrated in the architectural approach to represent activities in an organization [8].

IDEF0 is used to describe the activities in the system as well as the end products.

IDEF0 is a modelling tool based on a combination of graphics and text. IDEF0 are presented in an organized and systemized manner to support analysis, provide logic for potential changes, define requirements, or support the design of individual system levels and integration activities.

An IDEF0 model is composed of a hierarchical series of diagrams that progressively reveal increasing levels of detail describing functions and their interfaces in the context of the system.

Graphschemes of the algorithm. They are used to describe sequential and parallel algorithms [9]. Their main elements describe: 1) the places of logical branching of the algorithm; 2) the places of joining

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parallel sections of the algorithm; 3) the execution of certain actions (steps) of the algorithm.

Using graphschemes to describe algorithms (especially in programming systems) provides the following advantages:

- better tractability;
- simplicity in program implementation;
- verification of the correspondence between the algorithm and its implementation;
- fast and natural transition to description using Logical schemas of the algorithm (LSA) and Matrix schemas of the algorithm (MSA) to prove completeness and consistency of the model.

Tabular graph of the algorithm. Serves for description of interactions. It consists of two types of elements.

- static: 1) a single timeline - to account for the beginning and end of the execution of the interactions; 2) a table in which each column corresponds exactly to one user or resource.
- dynamic: 1) vertical arrows - placed in columns of the table corresponding to the interaction that is being executed, with the projections of the two ends of the arrow on the single timeline indicating the start and end of the interaction; 2) horizontal arrows (starting in one column and ending in another column) - reflect the relationships between interactions and their input and output parameters.

Matrix schemes of algorithms. Matrix schemes of algorithms have universal application. They can be used to describe and analyse processes, program systems, are used for structural representation of algorithm interaction (operations, logical conditions and transitions), facilitate program implementation and serve to prove the completeness and consistency of the model.

The matrix scheme of the algorithm (MSA) is given by a square matrix, on each row of which an operator in the order A0, A1,..., Ak-1 is matched, and on each column - A1, A2,..., Ak. In element a(i, j) of the matrix a logical condition (function) is written.

A properly constructed MSA possesses characteristic features that allow to check such important properties of the algorithm as completeness and consistency conditions [10]. The completeness condition is satisfied exactly when the disjunction of all elements of a row is equal to 1. The non-consistency condition is satisfied exactly when the conjunction of any two elements of a row is equal to 0.

Evaluation Nets. Defined by Nutt and Noe, E-nets are a modelling tool that further develops Petri nets in terms of the types of transitions and conditions in them [3, 4, 5, 6]. They belong to the simulation modelling tools and allow to represent not only the dynamics of processes (synchronous and asynchronous) but also the way to control them and the associated data transformation procedures. It is appropriate to use them in the analysis of models with the presence of asynchrony, parallelism, non-determinism of processes and dynamics of functioning. Describe them with simple syntax and clarity.

E-nets provide theoretical insight into the structure and dynamics of systems of discrete events expressed by graphs. They can be used to provide a mathematical description of the processes to be analysed and to provide an assessment of functionality.

E-nets are defined as ordered sevens:

Ne=<B,Bp,Br,D,F,H,Mo>, where:

B is a non-empty finite set of symbols called positions;

Bp is a set of peripheral positions, a subset of B:

Br - set of decision (control) positions, a subset of B;

D - a non-empty finite set of transition descriptions di:di=(s,t(di), p), where s is a transition type, t(di) is a transition time, and p is a transition procedure;

F is an input function F:BXD→{0,1};

H - output function H:DXH→{0,1};

M is the position marking M:B→{0,1}, and Mo is the initial marking.

The graphical representation of E-nets is a labelled, bipartite, oriented multigraph.

The functioning of the net consists in the transitions of the kernels from one position to another. Five basic elementary type transitions have been defined for E-nets. The logic of operation of the individual transitions is specified by guidelines for the allowed changes of core locations:

- Te-type transition movement of cores {1,0}→{0,1};
- Fe-type transition a fork - {1,0,0}→{0,1,1};
- Je (union) type transition - {1,1,0}→{0,0,1};
- Transition of type Xe (controlled logic connection)

{0,1,0,0}→{0,0,1,0},
{0,1,0,1}→{0,0,1,1},
{1,1,0,0}→{0,0,0,1},
{1,1,1,0}→{0,0,1,1};

- Transition of type Ye (priority logic connection)

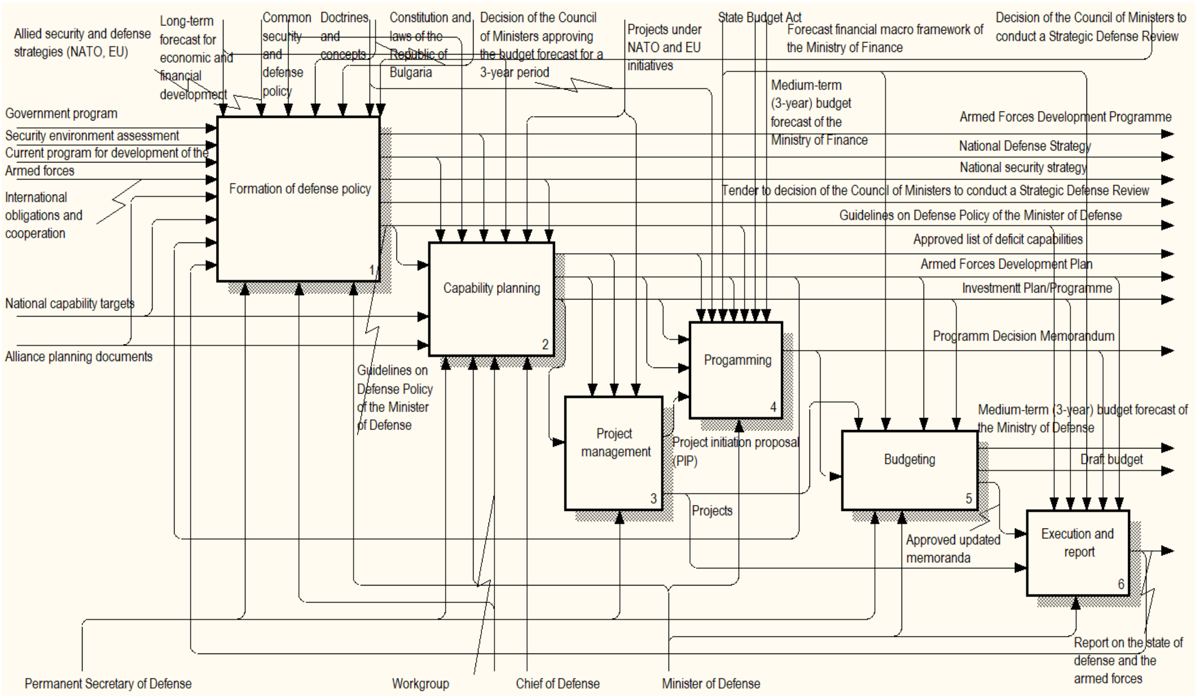
{0,1,1,0}→{0,0,1,1},
{0,1,0,0}→{0,0,0,1},
{0,0,1,0}→{0,0,0,1},
{1,1,1,0}→{0,1,0,1},
{1,1,0,0}→{0,0,0,1},
{1,0,1,0}→{0,0,0,1}.

III. RESULTS AND DISCUSSION

Fig. 1. To-Be model of capability-based defence planning processes

1. ANALYSIS OF THE EXISTING (AS-IS) DEFENCE PLANNING MODEL IN THE AF

The capability-based defence planning process is the main tool to be used in today's security environment, characterized by extreme dynamism, blurring of the boundaries between internal and external security, and an expanding spectrum of hybrid threats [1]. The aim of this process is to protect and promote national interests by building, maintaining and employing defence capabilities adequate to the security environment and by building interoperable modern armed forces with a unified command and control system in peacetime and in crises.



Since 2012, the Ministry of Defence and the Bulgarian Army have used the capability-based defence planning process as a planning mechanism. A methodological guide has been developed for the implementation of this approach. The realities of the security environment have required a review and update of this document. A comprehensive analysis of the existing defence planning model has been made. The main conclusions of the analysis are that the activity model of the planning process is inconsistent, incomplete and does not correspond to the current defence management system. There is a need to create a new, updated planning model that should: 1) conform to current regulatory and legislative requirements; 2) capture the overall design and dynamics of the system and operating environment; 3) be relevant to the organization's strategic plans; and 4) enable change and transformation activities.

To resolve the identified weaknesses, the model has been refined into an advanced (To-Be) state model to integrate and reflect all major functional and systems perspectives of defence management.

The advanced (To-Be) activity model is depicted in Fig. 1 [1].

2. *Verification of the Adequacy, Completeness and Inconsistency of the Formed (To-Be) Model of the Defence Planning System*

The basic requirement for any model is to have the following characteristics: 1) simplicity; 2) adequacy; 3) non-inconsistency; 4) completeness; 5) reliability; 6) flexibility; 7) manageability; 8) constructability; and 9) invariance [2].

The proving of the main characteristics of the To-Be model adequacy, non-inconsistency, completeness, constructability and invariance was done using the described methods.

2.1. E-net model

Based on the IDEF0 activity diagrams in Fig. 1, an E-net interaction model is built (Fig. 2).

To demonstrate the method, only the basic E-net model A0 of the system will be explored. Due to the large size of evidence, the remaining subnetworks are not the subject of this paper. A validation of the overall E-net model, with a complete decomposition of the activities, was accomplished using the Visual Object Net++ Evaluation Version 2.0.

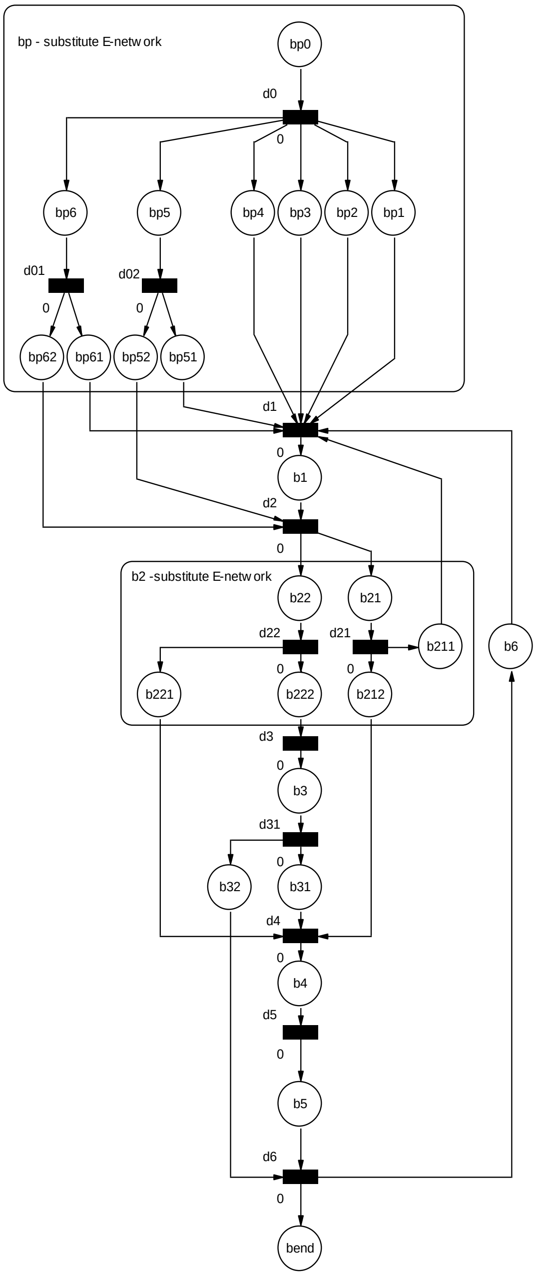


Fig. 2. E-net model of the To-Be A0 model for capability-based defence planning process

When using E-net to model systems and processes, it is possible to use substitute E-net to simplify elementary transitions and positions [5, 6]. In Fig. 2, the macro positions bp and b2 are surrogate E-net as follows:

bp - substitution E-net with the following positions:

bp1 - Government program;

bp2 - Security environment assessment;

bp3 - Current program for development of the Armed forces;

bp4 - International obligations and cooperation;

bp5 (bp51;bp52) - National capability targets;

bp6 (bp61;bp62) - Alliance planning documents.

b2 - Substitute E-net with the following headings:

b21 (b211;b212) - Armed Forces Development Plan;

b22 (b221;b222) - Investment Plan-Programme.

After the refinements, the E-net model in Fig. 2 obtains the simplified form presented in Fig. 3.

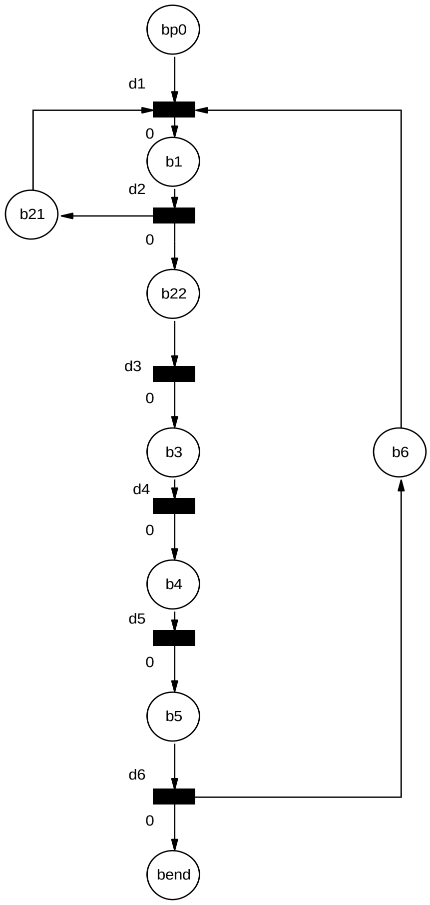


Fig. 3. Simplified E-net model E_A0

For E-net interaction model E_A0 the following is defined:

The E_A0 model is an E-net:

E_A0 (Bp,B,Br,D,F,H,M0),

Where: Bp = {bp} is set of input positions,

B = {b1, b2, b3, b4, b5, b6, bend} is a set of the following states:

b1 - Guidelines on Defence Policy of the Minister of Defence;

b22 - Investment Plan-Programme;

b21 - Armed forces development plan;

b3 - Projects;

b4 - Program Decisions Memorandum;

b5 - Approved updated memoranda;

b6 - Report on the state of defence and the armed forces.

Br = {Ø}, set of control states;

D = {d1, d2, d3, d4, d5, d6}, set of transitions, where:

d1 - Formation of defence policy;

d2 - Capability planning;

d3 - Project Management;

d4 - Programming;

d5 - Budgeting;

d6 - Execution and report.

F: D∞ B∞, Bp∞, Br∞, (F is a finite set of the input functions F: D∞ B∞, Bp∞, Br∞)

F(d1) = {bp0; b21; b6}, F(d4) = {b3},

F(d2) = {b1}, F(d5) = {b4},

F(d3) = {b2}, F(d6) = {b5}.

H: D∞ B∞, (H is a finite set of output functions D∞ B∞)

H(d1) = {b1}, H(d4) = {b4},
H(d2) = {b2; b21}, H(d5) = {b5},
H(d3) = {b3}, H(d6) = {b6; bend}.
M0 - initial marking;
M0 = (1, 0, 0, 1, 0, 0, 0, 1), i.e. there is one core at positions bp, b21 and b6.

The core at position bp occurs when the loop starts and moves to the next position when a transition is executed, and the cores at positions b21 and b6 occur after the initial loop of the process is completed.

The core movement through transitions is shown in Table 1.

TABLE 1 CORE MOTION IN E-NET MODEL E_A0

Transition	**Name**	**Core motion**
d1	Formation of defence policy	1,1,1,0→0,0,0,1
d2	Capability planning	1,0,0→0,1,1
d3	Project Management	1,0→0,1
d4	Programming	1,0→0,1
d5	Budgeting	1,0→0,1
d6	Execution and report	1,1,0→0,1,1

Five basic elementary transition types have been defined for E-net. The logic of operation of the individual transitions is specified by guidelines for the allowed shifts of core locations. In this case, we observed transitions of type Je - a union of cores {1,1,1,0}→{0,0,0,1}, type Te - a movement of cores {1,0}→{0,1}, type Fe - a fork {1,0,0} →{0,1,1} and {1,1,0}→{0,1,1}.

The relationship between the input F and output H functions of the E-net model is shown in Fig. 3.

Conclusion: When the transitions and reachability of the states of the E-net model E_A0 are checked, it turns out that all the states are reachable, which means that the presented model is adequate.

2.2. Algorithm of E-net model E_A0

The action algorithm of the process in Fig. 3 is described using a graph diagram. The process primitives of the activity diagram are as follows:

- Start process - primitive (Start);
- Formation of defence policy - primitive (Def_Pol);
- Capability planning - primitive (Cap_Plann);
- Project management - primitive (Proj_Manag);
- Programming - primitive (Progg);
- Budgeting - primitive (Budg);
- Execution and report - primitive (Exec_Rep);
- Process ending - primitive (End).

The graph schema of the algorithm takes the form of Fig. 4.

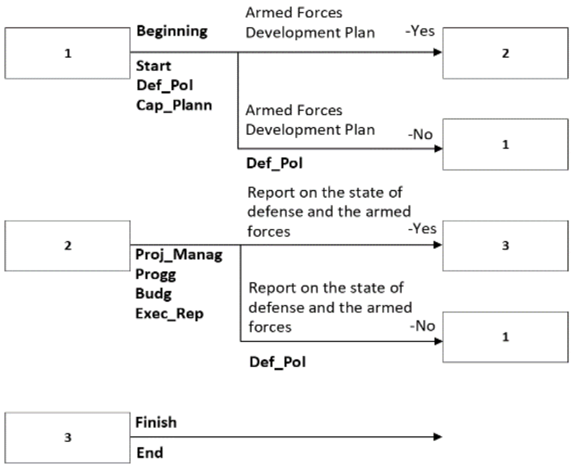


Fig. 4. Graph schema of the algorithm

Statement 1: The operational algorithm of the capability-based defence planning model is complete and non-inconsistent.

Proof: The matrix diagram of the algorithm shown in Table 3 is used to verify Statement 1. The correlation between the primitives and operators of the matrix scheme of the algorithm is presented in Table 2.

TABLE 2 CORRELATION BETWEEN PRIMITIVES AND OPERATORS

Primitives	Start	Def_Pol	Cap_Plann	Proj_Manag
Operators	B_0	B_1	B_2	B_3
Primitives	Progg	Budg	Exec_Rep	End
Operators	B_4	B_5	B_6	B_{end}

Logical conditions:
p1 - Armed Forces Development Plan (Yes);
p2 - Report on the state of defence and the armed forces (Yes).

The matrix scheme of the algorithm has the form depicted in Table 3.

TABLE 3 MATRIX DIAGRAM OF THE ALGORITHM

	B_1	**B_2**	**B_3**	**B_4**	**B_5**	**B_6**	**B_{end}**
B_0	1						
B_1		1					
B_2	$\bar{p}_1$		p_1				
B_3				1			
B_4					1		
B_5	$\bar{p}_2$					p_2	
B_6							1

According to E. Piil the matrix scheme of the algorithm possesses characteristic features that allow to check such important properties of the algorithm as the completeness and non-inconsistency conditions. The completeness condition is met when the disjunction of all elements of a row is equal to 1, and the non-inconsistency condition is met when the conjunction of any two elements of a row is equal to 0 [7].

From the matrix diagram of the algorithm for E-net model E_A0, it is proved that the model algorithm is complete because the disjunction of all elements in each row is 1 and non-inconsistent because the conjunction of any two elements in each row is 0.

It follows from the proofs that, proposed process model for capability-based defence planning is constructive and invariant, making it suitable for defining a program application architecture. The model is adequate, complete and non-inconsistent and this ensures its workability in practical implementation.

By analogy, the proofs are applied to all sub-networks of the To-Be model of the capability-based defence planning system.

IV. Conclusion

The presented revised model of the defence planning process has been adopted as the main methodology for the Strategic Defence Review of the Ministry of Defence and the Bulgarian Army from 2019-2021. The implementation of the model, in practice, occurred through the adopted "Capability-based defence planning guidance-2019” [1]. It was developed for the purpose of the Review and was promulgated by order of the Minister of Defence of the Republic of Moldova. Bulgaria.

The Defence Review validates the updated capability-based defence planning model in practice. It has proven to be a workable tool with a practical application. All the activities of the review have been performed according to the described model, where national strategic objectives are translated into military objectives, possible operations and tasks, and these in turn into forces and capabilities needed to perform these tasks in operations.

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