BUILDING AN OPERATIONAL ENVIRONMENT MODEL USING MORPHOLOGICAL ANALYSIS

Dan-Lucian PETRESCU
„Carol I"National Defense University,Bucharest, Romania (dan_petrescu1@yahoo.com)

DOI: 10.19062/1842-9238.2016.14.1.3

Abstract: *Achieving success in current and future military operations has become questionable. Whereas the enemy is characterized by a profound character of uncertainty, in terms of shape and location and also regarding methods and procedures of action, the issue highpoints refer firstly to identifying ways and means to counter him and then to setting criteria and measurable standards by which one can appreciate the objectives achievement in military actions. This article focuses on the first part of the problem. The solution is to adapt the forms and methods of preparing the force that, projected in an operational environment that correspond to the coordinates of present and future exacerbated complexity, be able to generate sufficient effects (quantitatively and qualitatively) to achieve a state of security within acceptable limits. Given that the operational environment is the framework in which military action is carried out, this article presents an effective and comprehensive method meant to create a controllable model thereof, in order to provide military specialists a useful tool in preparing the command structures of military instrument.*

Keywords: *operational environment, PMESII, operational variables, morphological analysis, morphological space*

1. INTRODUCTION

An operational environment is a composite system of actors, conditions and circumstances which manifests itself in a well-defined space and which directly influence the use of military capabilities based on the decisions of commanders. It includes, on the one hand, all enemy, allied or neutral forces and systems participating in the full spectrum of conflict and, on the other hand, physical environment and informational framework, governance and policy making factors, level of technology, local resources as well as domestic culture.

The Romanian Doctrine defines the operational environment as "*a system of systems that each of the actors interacts within it, pursuing their own interests. They build / develop strategies and allocate resources to take the necessary actions in order to facilitate their pursuit of power exerting influence over others and achieve their targets.*"[1] For a coherent analysis we should start from the assertion that the actors in the conflict are included in a wide range, starting from regular force configuration, belonging to a state and reaching non-state actors, governmental or non-governmental organizations which act in order to meet their targets. Adding various terrorist and / or organized crime organizations, we get the comprehensive picture that constitutes the environment for conducting military actions. Thus, it can be considered that the operational environment is an arena where operational objectives are achieved not only by force but also by how fast and effective the military force can establish and maintain a stable condition. All actors, allies or enemies, state or non-state, regardless their technological or military capabilities, will likely use every political, economic, informational and / or military tool at their disposal in order to achieve the desired objectives.

Considering all these factors, the most important issue that arouses the interest of military specialists is generated by finding effective solutions to achieve success in such a context.

[1] *** *Romanian Army Doctrine*, Bucharest, 2012, Appendix 1

Analyzing recent conflicts resulted in a reality that was not to the liking of many: technological superiority over the enemy does not create the decisive advantage anymore and, as such, victory cannot be remotely achieved, by simply pressing the buttons.

Actually, this reality is well known for almost two decades. A matter of current fact is, however, the persistence of the same situations where we are still looking for solutions to materialize effective actions against a shapeless enemy, acting without complying with rules, principles or methods written in any manual, against an enemy that gives a new dimension to VUCA[2] quartet that lists the characteristics of the current operational environment.

Returning to the drawing board, among other issues, a conclusion has been reached that it is the force, through its most valuable component - the human resource, that must be refurbished in order to provide at least a consistent answer as if not a proactive action. Hence the need to develop methods that place in the boots of a fighter a human resource whose training meets the requirements to ensure success. The first activity to be carried out in such an approach is the analysis of operational environment. The last is thoroughly preparing the very force to be launched into action.

Among them there is a whole operational planning process, with all the necessary sequences so that resources can be employed effectively.

All are important, all require effort and all converge towards one point: achieving the goal with minimal effort. Concerning the analysis of the operational environment and force preparation, probably the most effective method is building models which, the closer to reality, the more useful platform is provided to the user, a better framework to enable him carrying both actions with remarkable results.

The analysis of operational environment and strategies of participating actors holds a number of specific issues determined by the nature of their characteristics. Two of these features are considered most important.

The first refers to the inability to quantify the specific features of social systems and related actors, as they concern matters of political, social, economic, cultural or other dimensions. The second refers to the high uncertainty regarding the strategy and plan of each actor and the action dimension in that it expresses.

The two features gives the analyzed system a high degree of non-linear character, situation that makes analytical methods based on the algorithms from exact sciences (e.g. mathematics, statistics, simulation, etc.) have an unacceptable degree of utility.

An important issue is the control over determining the results and identifying the conclusions. One may say that identifying the conclusions on the analysis of a system characterized by non-linearity mentioned above can be done by intuitive methods.

But a simple presentation of the quantity of information to be processed in order to cover all possibilities for future system configurations invalidate any attempt to base the analysis on intuitive. This creates the need to develop a method based on a mechanism able to operate effectively with uncertain and non-quantifiable data and to provide concrete and useable results in the next stages of the study. The solution is offered by morphological analysis method.

2. GENERAL MORPHOLOGICAL ANALYSIS METHOD

„*Essentially, GMA (General Morphological Analysis) is a method for identifying and investigating the total set of possible relationships or "configurations" contained in a given problem complex.*"[3]

The morphological analysis method was invented in the 40s by Swiss astrophysicist Fritz Zwicky for the US Army and developed in the 60s at California Institute of Technology (Caltech) as a method of structuring and investigation a full set of relationships that are established in the framework of complex, multidimensional and non-quantifiable issues.

2 Volatility, Uncertainty, Complexity and Ambiguity. One should add *fluid* in order to include easily changing nature of operational environment.

3 Tom Ritchey, *Modelling Alternative Futures with General Morphological Analysis*, World Future Review, 2011, available on http://www.swemorph.com/pdf/wfr-ritchey.pdf, accessed on 28.03.2016

He used the method in various sub-fields such as classification in astrophysics, development of jet propulsion systems for rockets or aspects related to travel and colonization of outer space (it is said that this method was the basis for Polaris mission design).[4] Afterwards, the method was developed and used in numerous prospective studies (Godet, 1994; Rhyne, 1995 or Coyle & McGlone, 1995). Once more, GMA was developed in the 90s by Tom Ritchey within the Swedish Defense Research Agency (FOI) to be implemented in studies on long-term defense planning and civil protection.

Morphological analysis method is a participatory and iterative process, involving a series of consultations carried out among a group of experts in the field or area that includes all the issues of the system under analysis. As inferred from the name (morphology[5] – *morphos* – form, shape) the method is based on decomposing the system analyzed in sub-systems, as independent components, and analyzing all the relations between them on the basis of logical processes of determining the internal compatibility.

"The method involves a number of iterative steps or phases corresponding to cycles of analysis and synthesis, the basic process for developing all scientific models"[6]*:*

3. ANALYSIS PHASE

2.1. Formulating the problem to analyze and identifying the relevant elements. In this first stage one identifies and defines the main areas or operational variables (size, dimensions etc.) that shape the operational environment. *Operational variables* are general features of the operational environment, both military and civilian which may differ from one area to another and affect decisively military operations. They describe not only the military aspects of the operational environment, but also the impact of other factors on it. Typically, military planners analyze operational environment using six interrelated operational variables (PMESII): *political, military, economic, social, information, and infrastructure*. To these, two more can be added: *the physical environment and time*. Each of these operational variables (PMESII-MT) has a set of operational sub-variables.

Besides the fact that they stand for criteria in analyzing operational environment, the operational variables describe for commanders the context in which military operations are conducted. Understanding these variables helps commanders in assessing how the military instrument of national power complements other instruments. The comprehensive analysis of the variables typically occurs at the level of joint operations. In the analysis of the operational environment, commanders continually take into account the dynamics of these variables to have an articulate image of the operational situation.

Political variable describe the distribution of responsibility and political power at all levels of government. It quantifies the political system of main state and alliance type actors. In addition, the variable takes in account the factors that define the identity of a society (culture, history, demography and religion). Population assigns different degrees of legitimacy to political structures and processes at local and international level. The authorities and political powers, constituted formally (political party official or officials) or informally (tribes, ethnic groups or other power centers), or covert political powers strongly influence the situation in the operational environment. Political leaders can use ideas, beliefs, actions and even violence to enhance the power and control over the population, territory and their resources.

There are many sources of motivation in politics. These may include charismatic leadership style or actions of domestic security institutions and even those of religious, ethnic or economic communities. Political parties or groups in the opposition can also influence the situation.

4 Tom Ritchey, *General Morphological Analysis - A general method for non-quantified modelling*, available on http:// www.swemorph.com/pdf/gma.pdf, accessed on 28.03.2016

5 The branch of biology that deals with the form of living organisms, and with relationships between their structures, Oxford Dictionaries, available on http://www. oxforddictionaries.com/definition/english/morphology, accessed on 29.03.2016

6 Tom Ritchey, *General Morphological Analysis – An overview*, *Swedish Morphological Society*, Stockholm, available on http://www.swemorph.com/blurbs/gma-blurb-eng.pdf, accessed on 28.03.2016

Each can cooperate with different actors present in the operational environment or with multinational forces. Understanding political circumstances helps commanders and staff to identify the mechanisms of power and key organizations and to determine their goals and capabilities.

Understanding the political implications requires the analysis of all relevant partnerships, political, economic, military, religious, cultural etc. This analysis holds the presence and importance of external organizations and other groups, including groups united by a common cause. Examples include private security organizations, transnational corporations and NGOs providing humanitarian assistance.

Political sphere also addresses the effect of will as intangible primary factor. This factor motivates the participants to sacrifice for achieving goals. Understanding what motivates key groups (political, military, insurgent etc.) helps commanders understand the objectives and their willingness to sacrifice in order to reach their objectives. Another benefit of understanding the mechanisms that strengthens individuals and groups existing in the operational environment is the possibility of generating credible scenarios to meet the hypothetical threats anticipated by commanders.

Last but not the list, the politic variable includes the internal specific environment. Therefore, mission analysis and monitoring of the situation include the awareness of national policy and strategy. Undertaking missions by national military forces can only be done in agreement with the national political decision-maker.

Military variable is directly influenced by the actions of all elements of the security system of a state or non-state actor. In this respect, the army is the military force primarily responsible for maintaining internal and external security. In a given operational environment variable scans military capabilities of all military forces. In this context, the military forces on both sides can be influenced substantially by paramilitary and guerrilla forces. Also, military action in the area of operation may be affected by soldiers from other countries who are not directly involved in a conflict. Therefore, the analysis in military domain, coupled with the politic, should include the relationship between forces present in the area and the actors listed above.

Essentially, military variable analysis focuses on identifying the capabilities of enemy, host - nation and multinational military organizations. The analyzed capabilities covers the following areas: equipment and weapons systems; personnel; doctrine, tactics, techniques and procedures; forces readiness; resource constraints; military leadership and its relationship with political decision-makers; organizational culture; military history and traditions; nature of civil-military relations.

Understanding these factors helps commanders in estimating the real possibilities of action for each armed forces structure. The analysis determines the possibilities of each organizational entity in the area to use its abilities not only domestically but also regionally and even globally.

Economic variable includes individual and group behaviors related to production, distribution and consumption of resources. The specific factors that contribute to defining economic variable take into account the influence of industry, trade, development level (including external support), the management of finance, the monetary policy, the economic institutional capabilities and legal constraints (or lack them) in economics.

An important aspect in this field addresses the fact that, in the international context, the economic development of the state actors sometimes differs substantially. These differences significantly influence policy options, including individual or indigenous groups' decisions to support or undermine the existing order. There are many factors that can stimulate or discourage individuals and groups to change the economic *status quo*, such as: technical knowledge and education; capital flow; investments; price fluctuations; debt; financial instruments; protection of property rights; the existence of the black market and underground economy.

Thus, it can be emphasized that economic variable defines the economic system in the area of operations as a whole, the degree of economic development and the distribution of living standards of population. The indicators for measuring the potential benefits and related costs of influencing political and economic order in the area could intensify how the commanders understand the dynamics of social and behavioral situation of allies, enemy, neutral and local entities.

Social variable describes matters such as structuring society, the judiciary and legislative system, the social and humanitarian policies, religion etc. The society is defined as the population made up of members who are subject to the same political authority, occupy a common territory, and share a common culture and sense of belonging to the same group. The society is not monolithic but includes various social structures involving relationships, often highly complex, established between institutions, organizations and groups of people in a cluster system.

Culture includes common beliefs, values, behaviors, customs and traditions that individuals and groups respect in order to integrate into society. Society usually has a culture which is dominant, but can also have many secondary others. Different societies may have similar cultures, but social attributes change over time. Changes can occur in any of the following areas: demographic; religious; population movements; urbanization; standard of living; education; ethnic, cultural and religious groups' cohesion.

The basic elements that must be analyzed are social networks, social status and social functions and norms supporting and encouraging the society members and their leaders. This analysis should also address societies from outside the operating environment whose actions, opinions or political influence may affect the mission.

People base their actions on perceptions, assumptions, customs and values. Knowing the culture of actors present in the operational environment helps in identifying points of friction, establishing relationships and reducing misunderstandings. It can improve commander's perspective on individual and group intentions and increase the efficiency of military action. Therefore, forces require a careful preparation on the cultural aspects of the participating actors and indigenous people before projecting in a new operational environment and also, a continuous updating during the mission. This allows commanders to understand how their actions affect people and prepares them to relate with local leaders.

Information variable quantifies the information field that is defined as the group of individuals, organizations and systems (information, communication and media) that collect, process, disseminate and/or use information. Information environment provides participating actors the access to information systems and the ability to use data and information to achieve their targets. Commanders use information activities to grasp and shape the operational environment.

Media significantly influences information that shapes the operational environment. Television and the Internet can broadcast real-time images of military actions throughout the world. Media coverage can significantly influence politic decisions by influencing the public opinion (domestic and international). Opponents often use the media to facilitate reaching goals by controlling and manipulating how audiences perceive the content of a situation and/or its context. They often try to create antagonistic partisan views towards a particular cause by providing its own twisted interpretation of events. Television news for propaganda purposes can reach many people. However, mostly in less developed countries, the information is disseminated by less sophisticated means such as messengers or graffiti. Commanders must understand the nature of information flow in their area of operations and apply the best available methods to communicate with the local population.

Infrastructure variable refers to facilities, services and installations needed for society to work. These facilities, services and installations include communication systems, water and electricity distribution facilities, transport infrastructure, irrigation and land reclamation, hospitals, schools, logistic resort facilities etc. Degraded infrastructure affects the entire operational environment. At the highest level, the infrastructure includes sophisticated technological capabilities that make possible the conduct of research and development activities, with further application of the results for civilian and military purposes.

It is important to note that not all segments of society perceive the same way changes to the infrastructure. Improvements seen by some as beneficial can be perceived as a threat by others. For example, the introduction of mobile phone networks and the Internet can help a local economy, but may offend the influential and conservatives local leaders who believe that it allows access to indecent material. Therefore, the actions affecting the infrastructure require a thorough analysis of the possible effects, manifested particularly in the social field.

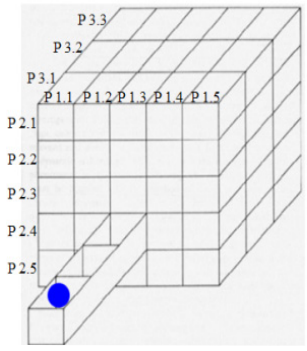
The physical environment includes the geographical and artificial structures in the operational area.

The following factors affect the physical environment: urban settlements, climate and weather, topography, rivers, natural resources, the biosphere and biological hazards and other environmental characteristics. A potential enemy threat that uses an asymmetric configuration is aware that an open and less complex space may expose his weak points. Therefore, he will try to counter conventional military advantages of own forces by carrying out his actions in urban or complex environments and in hostile weather conditions.

Time is an important element in military operations. This operational variable analysis focuses on how the duration of an operation may help or hinder each side. This has crucial implications in operational planning, regardless the level. Enemy with limited military capabilities is seeking to avoid decisive confrontation and believes that a prolonged conflict creates him certain advantages. He will adopt a strategy of attrition and fights only when the conditions are overwhelmingly in his favor. Generally, this type of enemy focuses on survival, causing victims among civilians and allies. Although the balance of power cannot be changed, this creates opportunities to affect how the local and international public opinion perceives the conflict. As an alternative, the enemy may try to achieve mass effects and achieve decisive objectives in a short period of time.

2.2. Identifying / defining the range of values. For each field or variable one must identify a sub-set of variables represented by states, relevant alternative conditions, strategies, actions, or a range of values.

From the analysis phase results what is called the morphological space, a mapping table of all possible variants of combining sub-variables or conditions identified above. Both fields / variables that are the elements of analyzed system and the assigned conditions / sub-variables are obtained through consultation sessions with experts selected to participate in the process. Morphological space is actually an n-dimensional matrix (corresponding to n fields / variables) called "Zwicky's box." For example, for a three-dimensional morphological space (shown to the right), this can be represented as below (left):



Parametrul 1	Parametrul 2	Parametrul 3
P 1.1	P 2.1	P 3.1
P 1.2	P 2.2	P 3.2
P 1.3	P 2.3	P 3.3
P 1.4	P 2.4	
P 1.5	P 2.5	

Fig. 1 Morphological Space (5×5×3) – Zwicky's box

Note that the morphological space can generate a huge number of possible combinations equal to the product of the number of variations for each of the fields / variables considered. In the example above we get 5×5×3=75 combinations. Each new field / variable included in the analysis adds a new term to the product that is equal to the number of conditions / sub-variables assigned to it. For instance, an 8-dimension morphological space each of them having three to five conditions / values (ex. 3,5,4,3,4,3,5,4) contains 3×5×4×3× ×4×3×5×4=43,200 possible combinations. The method has the advantage that lists all possible combinations (which would have been impossible to consider by intuitive methods) but the effort for processing them is significant. Therefore, it is necessary to reduce the number of combinations, activity that takes place in the next phase.

3. SYNTHESIS PHASE

3.1. Assessment of Consistency Cross (Cross Consistency Assessment - CCA) - by consulting the experts, one performs the crosscheck of each condition / sub-variable state with all other in the model to evaluate the mutual compatibility.

Alongside the establishment of morphological space, this stage involves considerable effort from experts that results in morphological space study in order to identify mutual incompatibilities between states of conditions / sub-variables. The process results in reduction the number of possible combinations by eliminating some "families" of variants that join the incompatible states of conditions / sub-set variables. The relations of mutual compatibility / incompatibility can be set at the level of fields / variables (external) or of conditions / sub-variables (internal).

The extern compatibilities are identified in terms of direct connectivity between fields / variables. We believe that two fields / variables are directly connected if one requires direct constraints on other so that one or more pairs of conditions / sub-variables determine relationships of incompatibility. In other words, if varying the state for conditions / sub-variables of the field / variable A in all the scale one identifies one or more states of conditions / sub-variables that are incompatible with one or more states of conditions / sub-variables of field / variable B, then the two fields / variables A and B are directly connected. On the other hand, if it is found that all the pairs of states of conditions / sub-variables determine a compatibility relationship and do not contain mutual constraints, then the two domains / variables A and B are not connected. It is necessary to highlight the possibility that two fields / variables A and B would be connected indirectly by the fact that each of them is connected to a field / variable C. For these situations do not occur, it is important, in determining connections, to take into consideration only those that are direct. The expert group determines the connections between fields / variables by examining the morphological analysis matrix that lists on the horizontal and vertical all the fields / variables with the assigned conditions / sub-variables. If the matrix is large, the connections identification can be made by subgroups of experts analyzing blocks.

Internal compatibilities between the states of conditions / variables in each field / variable are those that determine the final configuration of the resulting combinations. The compatibility / incompatibility relations are determined by the constraints between them that may be of four types: logical, empirical, normative and required.

Logical constraints are based only on the nature of formal relations between conditions / sub-variables. In other words, the two states set for the conditions / sub-variables of fields / variables A and B may be incompatible when, logically they cannot coexist. It is estimated that this type of incompatibility does not restrict very much the morphological space, so that the empirical, normative and required incompatibilities are those that will make the difference.

Empirical constraints are based on relationships deemed impossible or improbable, considering the knowledge or experience in the area of expertise that the field / variables belong to. Here, expert competence is valued in such extent that, moderated by designated personnel, *the experts* must discern the possibility or impossibility of existing the compatibility relationship between each pair of states of conditions / sub-variables.

Normative constraints are based on prescriptive rules or statements, in terms of what would be normal to be. Consequently, one can distinguish between practical regulations and ethical rules. Practical regulations refer to regulations of "good practice" in terms of strategic, operational or functional and are materialized in effective ways to achieve a goal. Although pointing empirical issues, too, they do not focus on the possibility or impossibility of coexistence of one pair of conditions / sub-variables but on experience and awareness that this link works and is effective. On the other hand, ethical regulations come from judgments based on ethical and ideological values and on "human" issues of the link between the two conditions / sub-variables. Sometimes, the two types of normative evaluation (practical and ethical) come into contradiction. Therefore one must have very clear in mind the real purposes of the operational environment and decide accordingly because this contradiction between practical and ethical, between efficiency and morality occurs especially in the case of "sensitive" problems, aiming social or political issues.

Normative constraints are no less important than logic or empirical ones.

However, it is important to make a clear distinction between these three types not to meet the situation where empirical aspects would cover the normative ethic ones. Typically, normative constraints are determined by institutional policies.

Required constraints relate to pre-defined criteria such as feasibility issues, preferences, operational requirements or prospective conclusions. The configuration of the operational environment built must be strictly modeled by these "*Product Specifications*" which most of the times have the upper hand on all other types of constraints. This priority stems from the fact that, beyond the logical and normative arguments, which are relatively clear as they are expressed through laws or principles, or the empirical ones, which are derived from experience, the required constraints are obtained from the analysis of the real operational environment and are considered "design parameters" that gives accuracy to the model created.

3.2. Synthesis the mutually compatible configurations. A "mutually compatible configuration" is a set of conditions/sub-variables of each field/variable that can coexist (e.g. cells marked in blue in Fig. 1). The sum of all internal compatible configurations is considered the space of morphological model solutions.

3.3. Identification of the basic model and the alternative. This stage involves interactively using the space of morphological model solutions to investigate and group the configuration that meets all constraints and requirements specified. In this last step one selects the set of values that configures each of the fields / variables (PMESII-PT), taken as layers, so as to meet the desired operational environment. Overlapping these layers results a complete picture of the desired operational environment. Alternative models are obtained by varying the required constraints, in relation with the assumptions used in the sequence of the operational environment analysis. When finding situations that could lead to incompatibilities, part or the entire process can be resumed.

CONCLUSIONS

Such operational environment can be used to set an operational framework for training military structures to execute a mission or for generating scenarios within the prospective analysis. In any case, an artificial model for the operational environment provides the military planners with a "*laboratory instrument*" extremely useful in preparing a force to be able to effectively achieve the success in any present or future confrontation.

REFERENCES

[1] Ducote, Brian. (2010). *Challenging the Application of PMESII-PT in a Complex Environment*. United States Army Command and General Staff College, Fort Leavenworth, Kansas.

[2] Moșoiu Ovidiu. (2013). *„Ensuring the security of technical equipment of the strategic information system"* in Review of the Air Force Academy, nr.1(23) /2013, Braşov: „Henri Coandă" Air Force Academy Publishing House.

[3] Ritchey, Tom. (2012), *General Morpholo-gical Analysis - A general method for non-quantified modeling*, available on http:// www. swemorph.com/pdf/gma.pdf

[4] Ritchey, Tom. (2013). *Modeling Complex Socio-Technical Systems Using Morphological Analysis*, Stockholm, available on http://www. swemorph.com/pdf/it-webart.pdf

[5] Ritchey, Tom. (2011). *Modeling Alternative Futures with General Morphological Analysis*, World Future Review.

[6] Ritchey, Tom. (2014). *General Morphologi-cal Analysis – An overview*, *Swedish Morpholo-gical Society*, Stockholm.

[7] Ritchey, Tom.(1998). *Fritz Zwicky, Morpho-logie and Policy Analysis*, *Defense Research Establishment, S-17290 Stockholm.*

[8] Godet, Michel. (1994). *From Anticipation to Action: A Handbook of Strategic Prospective*, UNESCO Publishing, Paris.

[9] ***. (2012). Romanian Army Doctrine, Bucharest.