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RESEARCH OF MATHEMATICAL MODEL FOR OPERATIONS TO DETERMINE RISKS FOR PROTECTIONS OF CRITICAL INFRASTRUCTURE

Lyubomir I. Pashov

MUNICIPAL COUNCIL OF SHUMEN

***ABSTRACT**: This work is a research of the mathematical model for operations to determine the risk to critical infrastructure protection. We introduce the concept of determined uncontrollable factors, providing an opportunity to differentiate some variables, which cannot be influenced by the operating party in any way. The random factors are considered known for their distribution function. Particular attention is paid to the mathematical models which are classified as dynamic or static, depending on their specific characteristic.*

***KEY WORDS**: mathematical model; operations to determine the risk, critical infrastructure protection*

Operation is any set of actions aimed to achieve certain goal. The existence of a goal in an operation implies the existence of active participants striving to achieve that goal. The participants in an operation are frequently referred to as the operating party [1].

Operating party is any set of individuals striving to achieve the goal in an operation. When researching a certain operation, we see that apart from the operating party, there are other individuals involved, whose goals differentiate from the goal of the operation [2].

To be able to study the operations that determine the risk, we shall use a mathematical model as a basic tool. This model includes the so called active resources (denoted as "a") which are essentially the resources needed to carry out the operation. Any action aimed to reach the goal is a way of using the resource, and any way of using the active resources is called a strategy. The strategies are denoted with "X" where "X" can be a vector, number or function. Strategies are factors used to achieve the defined goal. These factors are controllable in general. However, in line with the controllable factors, there are also uncontrollable factors which could influence the operation progress. We shall denote those uncontrollable factors with "Y", i.e. they form the environment in which the operation is carried out [1].

The description of each operation will end with the awareness of the operating party for the operation progress. Furthermore, the exchange of information between the separate components of the operating party is also of paramount importance for the decisions, actions and outcomes from the actions undertaken by those separate components. On the other hand, the uncontrollable factors can be divided into three groups as far as the availability of information for them is concerned: determined, random and undetermined.

The determined uncontrollable factors are composed of predetermined variables. The random uncontrollable factors can be determined by use of the distribution laws, while the undetermined uncontrollable factors are composed of undetermined or random variables for which we know only some sets of values or the class of possible distribution laws for these random variables.

The usefulness of the term "determined uncontrollable factors" comes from the fact that the operating party can determine variables which cannot be influenced by the party in any way. The random and undetermined uncontrollable factors cannot be influenced by the operating party either as the latter cannot determine their values which further complicates the operating party tasks. The random factors are known for their distributive function. When an operation is examined, much less is known about the undetermined uncontrollable factors but they still remain a part of the investigation process. The operating party may receive additional information during or immediately before the start of an operation, which information fully eliminates the undetermined factor. The operation progress can be described by a set of time-dependent phase changes, $E_1(t)$; $E_2(t)$... $E_k(t)$. The conformity between the operation progress and the achievement of the goal as stipulated in the model is called efficiency and is denoted by "W". Efficiency is a function of the phase changes, the strategies and the uncontrollable factors which can also be time-dependent. In the mathematical model, the goal of the operation is expressed by the extremes (maximum or minimum) of the efficiency.

When researching the model, we need to cover all important issues of an operation, including all significant factors that could influence the operation progress.

In the specialized literature there are different classifications of the mathematical modeling, but in general the existing models are divided into dynamic and static.

The dynamic models study the phenomena as a function of time. In other words, they try to describe the phenomena as realistically as possible. In most of the cases, however, it is perfectly enough to take into account the static model. In this case, the strategy and action are uncontrollable factors and are considered as a single act, the phase coordinates are not taken into account, while the efficiency is not

considered only as a function of strategy and uncontrollable factors.

$$W=F(x,y)$$

The research of an operation starts by building up of its static model. Sometimes it is not possible to clearly describe the efficiency as a function of strategy and uncontrollable factors.

In the general case, the strategy (X) in the static model is a function of the random and undetermined uncontrollable factors (Y). The model does not include any other unknown parameters. In many cases, the X(Y) dependency is denoted as $\tilde{x}$. The set of values in $\tilde{x}$ is denoted as X and depends on the active means. In general, the strategy represents the set of possible uncontrollable factors Y in the set X. The set of the strategy $\tilde{x}$ defined by the active means and the awareness of the operating party is called space of strategy and is denoted by $\bar{x}$ (mathematical expectation). Logically, it is possible to assume that all strategies which do not depend on information about the uncontrollable factors also belong to $\bar{x}$. The set of such constant strategies coincides with the set of the possible X values therefore it is also denoted as X. Consecutively, if the operating party excludes the additional information, the set of strategies will coincide with the X set. The X set is the poorest set of strategies possible.

So, in the static model, the efficiency criterion W is a function of $\tilde{x}$ and Y:

$$W=F(\tilde{x},y)\ \tilde{x}=\tilde{x}.y.Y$$

The static form of the operation model W is used for calculating specific results and making certain conclusions.

Finally, it should be noted that the working hypothesis of this research has been proven by use of a mathematical model of the operations for risks assessment of critical infrastructure protection.

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