DEFENSE RESOURCES MANAGEMENT USING GAME THEORY

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Game theory provides a number of analytical tools designed to assist in developing a more comprehensive understanding of phenomena emerging when decision-makers interact. A game describes the strategic interactions between players who act guided by their interests and with the consciousness that their actions affect each other. The basic entity in all game theory models is the player. A player may be understood as an individual, group of individuals or any kind of organization, even countries or alliances facing decisions-making challenges and opportunities. In this respect, the concept providing the dimensions and variables informing on the planning "game" elements required for an optimal defense resource allocation is that of 'capabilities'. The model developed in this paper is focused on allocations of the available defense resources over the assumed capabilities in order to achieve the best response to national security. I consider as a game the competition between strategic decision-makers involved in defense resource management and the threats to the national security.

Key words: *defense resources, game theory, defense capabilities, optimal resource allocation, effectiveness, efficiency.*

1. INTRODUCTION

Warfare is a costly economic activity that combines inputs as varied as those employed in any ordinary economic activity.[1]

Game theory provides a number of analytical tools which are designed to assist in a more comprehensive understanding of phenomena occurring when decision-makers interact. A game describes the strategic interactions between players who act guided by their interests and with the consciousness that their actions affect each other. The basic entity in all game theory models is the player. A player may be understood as an individual, group of individuals or any kind of organization, even countries or alliances that need to make decisions.

In order to describe a theoretic game we need to specify four essential elements: players, actions, payoff and information. Rasmussen refers to these by the PAPI acronym [2].

To develop a model based on game theory capable to describe an optimal defense resource allocation, and identify the planning "game" elements, a thorough conceptual understanding of 'defense capability' is required.

The Australian Defense Force defines the 'defense capability' as "the power to achieve a desired operational effect in a nominated environment, within a specified time, and to sustain that effect for a designated period"[3]. This comprises the combined effect of multiple inputs such as: personnel, organization, training, major systems, supplies. The Department of Defense of US defines as a military capability "the ability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks" [CJCSI/M 3010 series]. It includes four major components: force structure, modernization, readiness, and sustainability.

Both definitions are built around the notion of 'effect'. This leads us to the question *"what decisions can be taken to maximize the general security effect, having designed certain capabilities to encounter certain threats, under the pressure of limited available resources (such as the allocated defense budget)?"*

The model developed in this paper is focused on allocations of the available defense resources over the assumed capabilities in order to achieve the best response to the national security. I consider as a game the competition between strategic decision-makers involved in defense resource management and the threats to the national security.

2. MILITARY EXPENDITURES IN NATO COUNTRIES

A military force is "only as effective today as current capabilities allow. And, in future, it will only be as effective as investments in new capabilities made today will allow" [4].

In the opening of the NATO Parliamentary Assembly annual session, Dubrovnik, 11 October 2013, the president, Hugh Bayley stated that "Without strong capabilities, our ambition to defend our interests and the values we stand for will be unfulfilled, and our response to crises will be narrow, limited and possibly ineffective".

Against a background of economic austerity, delivering NATO Forces 2020 will only be possible if the Allies spend smarter. This means spending more efficiently, including more multinational cooperation, and spending more effectively, that is making sure that their militaries retain their ability to operate together as they have done on NATO-led missions. [5]

2.1. An analysis of defense expenditure structure

Military expenditures are made in order to assure inputs for national defense. These comprise in acquiring manpower, fuel, food, buildings, weapons, and so on. The relationship between these inputs and defense capabilities is a very important and yet a very difficult area to study for a single country or to compare across countries.

NATO publishes an annual compendium of financial, personnel and economic data for all member countries. Since 1963, this report has formed a consistent basis of comparison of the defense effort of Alliance members based on a common definition of defense expenditure.[6]

Analyzing the 13 April 2012 report related to defense financial and economical data among alliedthere are four main categories in which military expenditures are structured:

- Personnel expenditures;
- Equipment expenditures;
- Infrastructure expenditures;
- Operations and Maintenance expenditures.

Table no. 1 Distribution of total defense expenditure by category

Category of expenditure	The average per countries (%)		Maximum average percentage (%)	Minimum percentage (%)
	1990-2011	2011		
Personnel*	57.14	59.84	75.4 Belgium	31.55 Estonia
Equipment**	15.38	13.54	27.47 Turkey	6.72 Belgium
Infrastructure***	3.62	3.25	13.72 Estonia	1.04 Portugal
Other expenditures ****	23.86	23.37	39.73 Estonia	11.47 Albania

* Personnel expenditure include military and civilian personnel expenditures and pensions;

** Equipment expenditures include major equipment expenditures and R&D devoted to major expenditures;

*** Infrastructure expenditures include NATO common expenditures and national military constructions;

**** Other expenditures include operations and maintenance expenditures, other R&D expenditures and expenditures not allocated among above-mentioned categories.

The personnel expenditure between 1990-2011 has increased reaching in 2011 about 60% percent from total defense expenditures.

The investments in major equipments have fell by nearly 2%, in 2011, from the average along the time.

The infrastructure expenditures were maintained at around 3.62%, as average over the time. The largest percentage of total defense expenditure was allocated by Estonia for infrastructure, over 13% every year, starting 2004 when it joined NATO.

In conclusion we observe that the largest cost for defense, among NATO countries, is given by personnel expenditures and the relationship between equipment expenditures and the cost for operation and maintenance is about 1:1.6.

2.2. The defense effectiveness function

The main objective which is taken into consideration by strategic decision-makers when planning to develop a defense capability is to achieve the best response against possible and probable threats to national security. The evaluation of effectiveness of a particular capability is hard to do. We cannot evaluate its performance only based on how this acts individually. To have a complete evaluation we need to see a military capability in a more complex environment, integrated in the defense capability as a whole and in connection with other capabilities.

To evaluate the military power of a country does not simply mean looking at its defense capabilities, and their performance. This has to be viewed in a global context, geographical, political, demographical, and to identify the available resources to support the defense system.

A broad analysis of military

power is made by Global Firepower [7], which has come with a ranking system using over 40 factors to determine each nation's Power Index ("PwrIndx") score. Along the specific military capability (land system, total aircrafts, and total naval strengths) they also count the financial factors, the resources indicators, the logistic infrastructure, even the geographical characteristics such as square land area, coastline, shared border, waterways. The lower "Power Index" ranks show countries with higher military power.

In order to see how military spending is reflected in the effectiveness of a country's military power we transformed the IndexPower into an effectiveness parameter, on a scale between 0 and 100; a lower IndexPower shows a higher effectiveness parameter. The transformation formula is as follows:

$$Efectiveness = \frac{\max(Indexpower) - IndexPower}{\max(Indexpower) - \min(IndexPower)} \quad (1)$$

Table no. 2 The relationship between the effectiveness parameter and defense expenditure in NATO countries

NATO countries	Defense expenditure 2011 (billion dollars)*	Power Index*	Effectiveness
Croatia	0.97	1.7413	1.41
Romania	2.38	1.6555	7.07
Portugal	3.61	1.7627	0.00
Denmark	4.52	1.616	9.68
Belgium	5.54	1.7266	2.38
Greece	6.43	1.6527	7.26
Poland	8.91	0.9518	53.52
Spain	13.98	1.1847	38.15
Canada	23.69	0.8638	59.33
Italy	30.22	0.6838	71.21
France	53.44	0.6163	75.66
Germany	48.14	0.6491	73.50
United Kingdom	63.57	0.5185	82.11
United States	731.88	0.2475	100.00

* Source: http://www.globalfirepower.com/ - Global FirePower;

** Source: http:/www.nato.int/ Current price and exchange rate.

The correlation coefficient between the effectiveness parameter and defense budget (Table 2) is 0.46, which means that we have a moderate relationship between these variables, and also shows there are others variables which influence the effectiveness parameter of military power.

In this research it is not important the absolute values of parameters, we need only to see the path in which they influence each other. If we denote E the relative effectiveness parameter of military power, calculated with the formula (1), and B_d the budget allocated to the Ministry of Defense, we can assume for the function $E=E(B_d)$ the following properties:

- It is an increasing function: $dE/dB_d>0$
- It is strictly a concave function on the interval $(0,\infty]$:

$$E(B_{d1}\theta + B_{d2}(1-\theta)) > \theta E(B_{d1}) + (1-\theta)B_{d2}$$

for any $B_{d1} \neq B_{d2}$, and $\theta \in (0,1]$;

- It is upward limited: there is an effectiveness limit above which the defense power cannot increase regardless the allocated budget.

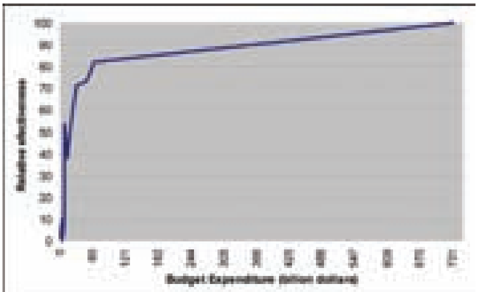

Figure 1. The path of Effectiveness-Defense Expenditure function

One type of function which can meet the above conditions is the logistic function which can take the following form:

$$E(B_d) = \frac{E_{max}}{1 + Ae^{-kB_d}} \quad (2)$$

where A and k are parameters which determine the path of function.

3. GAME THEORY FUNDAMENTALS

Game theory is an area of mathematical study with direct applications in economics, sociology, and psychology. The theory was first formulated by John Von Neumann, and later was developed by John Nash, A. W. Tucker, and others.

Game theory consists of a set of analytical tools designed to help us understand the phenomena that we observe when decision-makers interact.

3.1. Definitions and game elements

A game describes a strategic interaction between players who have to choose between a series of actions respecting a series of rules (constraints on the actions in order to maximize their interest). A solution is a methodical description of the outcomes that may come out in a family of games.

A strategic game is a model of a situation in which each player chooses his plan of action, and all players' decisions are made simultaneously (that is, when choosing a plan of action each player is not informed of the plan of action chosen by any other player). By contrast, the model of an extensive game specifies the possible orders of events; each player can consider his plan of action not only at the beginning of the game but also whenever he has to make a decision. [8]

The basic entity in all game theoretic models is the player. A player may be interpreted as an individual or as a group of individuals making a decision. Once we define the set of players, we may distinguish between two types of models: those in which the sets of possible actions of individual players are primitive and those in which the sets of possible joint actions of groups of players are primitive. Sometimes models of the first type are referred to as "noncooperative", while those of the second type are referred to as "cooperative" (though these terms do not express that well the differences between the models).

The central concept in non-cooperative game with two or more players is the Nash equilibrium. This defines a solution concept in which the rational players having chosen a strategy cannot gain anything by changing unilaterally their own strategy.

The Nash equilibrium is used to analyze the outcome in strategic decision-makers interaction.

3.2. Contest success function

In game theory the contests are games in which each a player exerts effort in order to increase his or her probability of winning a prize. The contest is a very useful tool to study phenomena in economics, warfare and other social domains.

The main components of a contest are the players' probabilities to win or lose given their level of effort. These probabilities described as functions of efforts are called contest success functions.[9] Regarding their use, an analogy with production functions from production theory can be made. But there are two important differences between production functions and contest success function. Related to outputs, the production functions provide deterministic results as to contest functions probabilities. Looking at the inputs, contest functions take into consideration the efforts of the participating players to determine the probability of winning. These efforts are combined adversarially, "so that a player's probability of winning is increasing in her or his effort but is decreasing in the efforts of all the adversaries" [10].

Contest success functions, which show how probabilities of winning depend on resources devoted to a conflict, have been widely used in the literature addressing appropriative activities (economics), international and civil wars (political science), and group conflict and selection (evolutionary biology). Two well-known forms of contest success functions predict contest outcomes from the difference between the resources of each side and from the ratio of resources.

Consider two adversaries or contestants, labeled 1 and 2. Denote their choice of efforts as x_1 and x_2. We suppose that efforts are themselves outputs of production functions of different inputs. These production functions can be the same for the two adversaries or they can be different. Associated with them are cost functions $c_1(x_i)$ and $c_i(x_2)$. Since we are solely concerned with how pairs of efforts translate into probabilities of wins and losses and not how efforts might be chosen, we will keep these cost and production functions in the background. For any given combination of efforts, each rival has a probability of winning and a probability of losing. Denote the probability of party *i*=1 winning as $p_1(x_1, x_2)$ and the probability of party *i*=2 winning as $p_2(x_1, x_2)$.

The properties of those probabilities need to be as follows:

- $0 \le p_i(x_1, x_2') \le 1$ for $i = 1 \cdots 2$;
- $p_2(x_1, x_2) = 1 - p_2(x_1, x_2)$.

The general form of these probabilities that has been widely examined is as follows:

$$p_i(x_1, x_2) = \begin{cases} \dfrac{f(x_i)}{f(x_1) + f(x_1)} \text{ if } \sum_{i=1}^{2} f(x_i) \\ \dfrac{1}{2} \text{ otherwise.} \end{cases} \quad (3)$$

There are two main forms which are commonly used for the function *f*. One of them takes the exponential form as $f(x) = x^{\lambda}$, where $\lambda > 0$ (and often, for technical reasons of existence of pure-strategy Nash equilibrium, $\lambda \le 1$). This form provides probabilities of winning which depend on the ratio between the efforts of two parties, and looks as follows:

$$p_1(x_1,x_2)=\frac{x_1^{\lambda}}{x_1^{\lambda}+x_2^{\lambda}}=\frac{1}{1+(x_1/x_2)^{-\lambda}} \quad (4)$$

$$p_2(x_1,x_2)=\frac{x_2^{\lambda}}{x_1^{\lambda}+x_2^{\lambda}}=\frac{1}{1+(x_2/x_1)^{-\lambda}} \quad (5)$$

Another well-know form of function f uses the "logit" specification as $f(x)=e^{\lambda}$, where $\lambda>0$, and the probabilities for winning become as follows:

$$p_1(x_1,x_2)=\frac{e^{\lambda x_1}}{e^{\lambda x_1}+e^{\lambda x_2}}=\frac{1}{1+e^{\lambda(x_1-x_2)}} \quad (6)$$

$$p_2(x_1,x_2)=\frac{e^{\lambda x_2}}{e^{\lambda x_1}+e^{\lambda x_2}}=\frac{1}{1+e^{\lambda(x_2-x_1)}} \quad (7)$$

4. MODELS TO PLAN DEFENSE RESOURCES

4.1. The main elements of the models

In the following game models we have defined, on the one hand, the main player under the fictitious name 'defender', who tries to defend as much as possible a series of valuable targets. On the other hand we have an 'attacker' who tries to attack the targets and determine as much losses as possible.

The notion of 'attacker' does not define a specific country or terrorist organization that interacts with national security; it takes into consideration the effect of its action as a 'threat' against national security. This threat is evaluated in terms of probability of occurrence and the level of impact over the target on which is directed. I assume that the attackers (as well as their generated threats) are neither static, or fixed, nor immutable.

When I refer to a target I mean a complex system which can be conceived to have economic value, human value, and/or symbolic value, and could generate an interest for a potential aggressor. As an example, a target such as The U.S Statue of Liberty has substantial symbolic value, and no human value. I do not want to insist with more details what a target comprises and how this can be evaluated. For my purpose I take into consideration a theoretical target which has a different value from a defender's and attacker's perspective.

The first and foremost approach to modeling a player's interest is utility theory. This theoretical methodology deals with measuring the degree of preference across a set of available options. The purpose of this paper is not to evaluate the targets, but we need to set the theoretical values for each target, measured in money. Further research will explore in details the ways of evaluation.

"The functionality or successful operation of each target depends on the relative investments in defense versus attack. The defender seeks functionality of the system while the attacker seeks non-functionality. The approach allows analyzing the phenomenon from both the defender and attacker's point of view."[11]

The assumptions concerning the defender and attacker are that they both think at strategic level and are capable to adapt optimally their own actions to the opponent's actions by spending defensive/offensive resources for each target.

4.2. Resources allocation over defense capabilities

The main purpose in defense resource allocation is to assure such level of readiness of existing capabilities in order to respond optimally to a set of threats against national security.

We assume that the defender has developed a series of capabilities, noted $C_i, i=1\cdots n$ to defend, independently, a specific 'target' with a specific value, against the attacker. For this step of research, we assume that the readiness level of a capability does not have any influence over the level of readiness of other capabilities.

Each target $T_i, i = 1 \cdots n$ has an evaluation from both the defender's and attacker's point of view. The defender evaluates the target *Ti* with the total value 'v_i' (economic, human and symbolic). From the attacker's perspective, the same target has different evaluations. We denote V*i* the value of the target T*i* from the attacker's perspective.

In order to defend the target T_i, the defender needs to spend the resources x_i for the capability C_i to assure a certain level of readiness. The total cost of allocated resources is constrained by the defense budget B_d.

$$\sum_{i=1}^{n} x_i = B_d \quad (8)$$

In the same way we consider that the attacker exerts a resource effort y_i to attack each target T_i. The total costs of allocated resources are also constrained by the budget of the attacker B_a.

$$\sum_{i=1}^{n} y_i = B_a \quad (9)$$

The defender's aim is to save as much as possible from the total value of the defended targets, through resource allocations for each developed capability.

The total value expected to be saved by defender if a confrontation with the attacker occurs is:

$$S\left(x_i, y_i, v_i, V_i^j\right) = \sum_{i}^{n} p_i \cdot v_i \quad (10)$$

where $p_i = \dfrac{x_i^{\lambda}}{x_i^{\lambda} + y_i^{\lambda}}$ is the probability to have success in defending the target T_i .

The objective function for the defender is to maximize the total value expected to be saved:

$$\max_{x_i} S\left(x_i, y_i, v_i, V_i^j\right) \quad (11)$$

If the attacker chooses to launch an attack against the defender, the total value expected to be caused is:

$$L\left(x_i, y_i, v_i, V_i^j\right) = \sum_{i}^{n} q_i \cdot V_i \quad (12)$$

where $q_i = \dfrac{y_i}{x_i + y_i} = 1 - p_i$ is the probability of the attacker to have success on the target T_i.

The aim of the attacker is to cause as much damages (lost value) as possible to the defender (targets).

$$\max_{y_i} L\left(x_i, y_i, v_i, V_i\right) \quad (13)$$

4.3. Multi-year expenditures. The investment plan

When defense planners decide to invest in a new capability in order to improve the effectiveness of national defense, it is compulsory to be also aware of how much resource remains to operate the existing capabilities.

In this model the defender has not only to analyze the status of the current security environment every year but also to anticipate how this evolves. In this respect, the defender has to decide how much resource has to be allocated to assure the optimum level of readiness of current capabilities and how much is needed to be invested in order to have a better defense in the future.

Let us denote $x_0(t)$ the expenditures allocated by defender to operate the existing capabilities, and $x_i(t)$ the expenditure invested in developing the new capabilities, where $t = 1 \cdots n$, a specific fiscal year.

Without missing the general aims of this paper we assume that the defense budget is spent only to develop new capabilities and to operate the existing ones.

The budget constraint can be

written as follows:

$$x_o(t)+x_i(t)=B_d(t) \text{ for each } t=1 \dots n \quad (14)$$

We assume that the effectiveness of the defense capability as a whole is given by the total value of the inventory at each time I(t):

$$I_d(t)=I_d(0)+\sum_{t=1}^{n} x_i(t) \quad (15)$$

Taking into consideration the function form (2) of the effectiveness we can write:

$$\lambda(t)=\frac{1}{1+Ae^{-\frac{I_d(t)}{I_d(0)}}} \quad (15)$$

where $0<\lambda<1$ is the effectiveness of defense capability, and *A* parameter.

In the same way we can analyze the attacker, at time *t*:

$$y_o(t)+y_i(t)=B_a(a) \text{ for each } t=1 \dots n \quad (16)$$

$$I_a(t)=I_a(0)+\sum_{t=1}^{n} y_i(t) \quad (17)$$

$$\varphi(t)=\frac{1}{1+Ae^{-\frac{I_a(t)}{I_a(0)}}} \quad (18)$$

where:

- $y_o(t)$ and $y_i(t)$ is the expenditure invested by the attacker to operate the existing capabilities and to invest in new ones;
- $I_a(t)$ t=0…n the total value of the capabilities inventory of the attacker;
- φ(t) is the effectiveness level of the attacker's capabilities;

Both the defender and the attacker use long term analysis, check the probabilities of success if confrontations occur, and evaluate what the level of total saved (total damages) value will be if a confrontation occurs.

The probabilities of success at the *t* moment take the following forms:

$$p(x_o^t,y_o^t)=\frac{(x_o^t)^{\lambda(t)}}{(x_o^t)^{\lambda(t)}+(y_o^t)^{\varphi(t)}} \text{ for defender } (19)$$

$$q(x_o^t,y_o^t)=\frac{(y_o^t)^{\varphi(t)}}{(x_o^t)^{\lambda(t)}+(y_o^t)^{\varphi(t)}} \text{ for attacker } (20)$$

If we consider a target which is defended by the defender against the attacker and is evaluated with the *v* respectively *V* value by the defender, respectively attacker, then the value expected to be saved (to be de damaged) at the *t* moment is as follows:

$$s(t)=p(x_o(t),y_o(t))\cdot v \quad (21)$$

$$l(t)=q(x_o(t),y_o(t))\cdot V \quad (22)$$

The total value expected to be saved (damaged) after "n" fiscal years can be expressed as follows:

$$S=\sum_{t=1}^{n} s(t) \quad (23)$$

$$L=\sum_{t=1}^{n} l(t) \quad (24)$$

The objective for the defender and the attacker is to maximize the total value expected to be saved (damaged) over a period of the time *n*:

$$\max_{x_o(t),x_i(t),y_o(t),y_i(t)} \left(S(x_o(t),x_i(t),y_o(t),y_i(t))\right) \quad (25)$$

$$\max_{x_o(t),x_i(t),y_o(t),y_i(t)} \left(L(x_o(t),x_i(t),y_o(t),y_i(t))\right) \quad (26)$$

5. NUMERICAL RESULTS

Let us imagine a virtual country, XLand (defender), in a security environment posing a series of threats from a virtual enemy, YLand (attacker). The Ministry of Defense has to develop a series of capabilities, with a limited budget, in order to counter these threats.

In the process of capability based planning it was assumed that three types of capabilities are necessary: A - land defense, B- air defense, and C – maritime defense. Each of these capabilities is developed to defend, against the virtual enemy, three virtual independent targets (having human value, economic value and also symbolic value): T_1 - land territory, T_2 – airspace, T_3 – maritime territory.

It is assumed that both the defender and the attacker have different evaluations of the three targets as described in Table 3. Their actions (defending and attacking) against three targets are limited by the budget allocation: B_d = \$300 billion – the defender's budget, B_a = \$400 billion – the attacker's budget.

The defense planning specialists evaluate the cost- effectiveness of both their own and attacker's capabilities through the following parameters: $\lambda_d = 0.3$, and $\lambda_a = 0.1$

To estimate the probability of success both the attacker and defender use the different form of CFS.

Taking into account all of the above assumptions and evaluations, and with the help of Excel solver, it can be found out that the model rapidly converges to the Nash equilibrium, and there is a single optimal solution in resource allocations to defend/attack the targets for both defender and attacker (Table 4). This solution assures the "maximum saved value" – **4662 billion dollars** (from the defender's perspective) and "the maximum lost value" – **2032 billion dollars** (from the attacker's perspective), if a conflict between the defender and the attacker occurs. Any other allocation of resources will conduct to less output for both the defender and the attacker.

Table no. 3 Defender's and attacker's target evaluations

Capability	Targets	Defender's target evaluation (billion dollars)	Attacker's target evaluation (billion dollars)
A. Land Defense	T1. Land Territory	3000	2800
B.Airspace Defense	T2. Airspace	2000	2500
C. Maritime Defense	T3.Maritime Territory	1500	1700

Table no.4 Defender's and attacker's resource allocations

Capability	Targets	Defender's target evaluation (billion dollars)	Attacker's target evaluation (billion dollars)
A. Land Defense	T1. Land Territory	134	155
B.Airspace Defense	T2. Airspace	94	145
C. Maritime Defense	T3.Maritime Territory	72	100
TOTAL RESOURCE ALLOCATION		300	400

The second problem which is faced by the defender is how to choose the proportion between the operation expenditures and the investments in new capabilities in order to achieve a best response to the threats generated by the attacker.

The main data on which the defender develops his plan is described in **Table 5**.

Table no.5 Plan details

Details	Defender	Attacker
Defense Budget (billion dollars)	300	400
The total value of existing inventory (billion dollars)	3000	3000
The total estimated value of the targets (billion dollars)	6500	7000

The period of time which is taken into consideration for analysis is 6 years. Every year the defender updates his capabilities inventory by investment expenditure in order to increase the effectiveness. The rest of the budget is spent to operate the existing capabilities.

This model for planning the defense expenditure reaches very fast the equilibrium and provides a unique optimum solution for defense expenditure in every year. To solve the model Excel,and its feature solver, is used again. The results are given in the table below.

As we observe, the defender, in order to have an optimum response against the attacker's threats chooses to invest a part from the budget to improve the effectiveness of the capabilities, and increase the value of the inventory. For a 6 year period of analysis, the defender has to invest only in the first three years, with the main effort in the first fiscal year. The ratio between the expenditure on operation and investments, in the first fiscal year, is ***1.60.*** The analysis has to be made by the defender in order to adapt his strategy to any changes in the attacker's strategy.

Table no.6 Defense expenditures by FY

Fiscal Year	Operation expenditure	Investment expenditure	The value of current inventory	Effectiveness	Probability of success
2014	185	115	3114	0.51	0.47
2015	222	78	3190	0.52	0.47
2016	275	25	3212	0.52	0.46
2017	300	0	3212	0.52	0.46
2018	300	0	3212	0.52	0.46
2019	300	0	3212	0.52	0.46

6.CONCLUSIONS

These models, developed based on game theory, can become a powerful tool for defense planning makers who need to design the structure of resource allocation over the capabilities.

The major problem faced was in defining the elements of the games in such ways in which the equilibrium can be reached, and provide a solution to defense capability planners. In this respect, Rasmunsen states that *"lack of a unique equilibrium is a major problem in game theory"* [2].

Even some parameters of the game are hard to be evaluated (the value of the targets, the cost effectiveness parameters. In this respect, the models can provide a structure of resource allocation over available capabilities. Knowledge of the absolute values of the parameters does not necessarily need to be known. It is very useful if we have relative evaluations and if we could establish ratios between them within a certain tolerance limit.

Also, the results can show that it is not necessary to know how the attacker allocates resources over his capabilities. To take an optimum decision knowledge of the budget, of the nature of attacker's capabilities (in order to estimate the cost-effectiveness parameter) and threat estimates (the value of the targets from the attacker's perspective) is enough.

If we choose the logistic form, with a proper parameter (A=2.7), for calculating the effectiveness parameter (considered in Chapter I), we can obtain results very close to the reality. The ratio between operational expenditure and investments is 1.6, the same as the average in NATO countries.

These simplified models can be the first step in a more complex analysis of defense capability planning based on resource allocation.

Interesting future research can include: sensitivity analysis and identification of the important parameters which have the most influence over resource allocation; how the cost-effectiveness parameter influences resource allocation, and the probability to win against an attacker. In this respect, the guiding research question could be: "What are the circumstances under which the planners decide to acquire a new capability instead to maintain an older one?"; developing a more complex model with multi-purpose capabilities in a security environment with more independent and/or dependent enemies; consider the enemies who act both strategically and non-strategically.

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