COUNTER-TERRORISM: PROTECTION RESOURCES ALLOCATION

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PART I. MINIMAX CRITERION

Abstract

A concept of optimal resources allocation to protect an object against terrorists attack is presented. Under assumption of uncertainty of terrorists' intentions, minmax criterion is suggested. Goal functions for cost-effectiveness analysis are given.

I. INTRODUCTION

For decades, the United States has focused its military and intelligence capabilities on potential enemies beyond its own borders. After September 11th, 2001, it has become increasingly clear that our enemies have the ability and determination to reach through our defenses and strike at critical assets here at home.

Modern terrorism has gone from the frame of simple intimidation to the active destruction of the chosen country: terrorists' attacks goal is to cause the maximum possible material damage and/or human casualties. It is obvious that the terrorist activity is getting more and more organized and modern counter-terrorism is a real war with an invisible enemy.

The problem of protection of human beings, material values and political/historical subjects of possible terrorists' attacks arose. A defender usually spends more resources then terrorists, so optimal allocation of these resources is very important. It is clear that terrorists have many advantages: they choose the time of their attack, they choose the object for the attack, and they choose the weapon of destruction. In general, a defender does not know what are terrorists' intentions.

The proposed mathematical model is developed for optimal allocation of defender's resources for best protection of the defended objects.

This approach is based on [*Ushakov*, 2005]. and [*Gnedenko & Ushakov*, 1995].

II. VERBAL DESCRIPTION OF THE PROBLEM

Types of counter-terrorism actions

What kind of actions of the country protection against terrorists do we suppose to consider? They are in general as follows:

1. Safety: complex of measures permitting to create “counter-terrorist environment” in the country.
2. Survivability: complex of measures permitting to develop special measures to minimize the loss if the strike has been done.
3. Pre-emptive measures for destroying the terrorist’s abilities to attack.

Safety includes a set of measures permitting to prevent terrorist’s acts (check points at airports, checking cargo, profiled visa control, registration of foreign visitors and control of their staying in the country, control the purchase of dangerous components for composing bombs, etc.). Objective of these measures is to prevent the possibility of organizing the terrorists acts by limiting penetrating suspicious people in the country and by eliminating a possibility of collection/creation WMD.

Examples:

(1) *A soft visa control in the USA permitted a number of 9/11 terrorists to enter the country and to stay within it easily.*

(2) *Absence of document control permitted a group of foreign terrorists to get training in jet piloting that led to hijacking civil planes and directed them to Twin Towers in New York and Pentagon in Washington.*

(3) *Lack of control for purchasing of suspicious materials give to Americans McVeigh and Nichols a possibility to make an extremely destructive bomb and blast a Governmental building in Oklahoma City, killing many innocent people including children in a kindergarten.*

Survivability includes a set of measures, which help the society to lose fewer lives, to get less loss, to prevent public panic.

Examples: *In October of 2002, when Chechen terrorists hold hostages at the Moscow theater, Russian counter-terrorists forces using poisonous gas against them but did not supply the scene with the anti-dots that led to severe loss of hostages.*

Pre-emptive measures include political steps and economical steps.

Examples:

(1) *UN inspections of countries with possible cradling of terrorists,*

(2) *embargo for states supporting terrorism,*

(3) direct military attacks on terrorists’ bases like it has been done against Al-Qaeda in Afganistan.

Of course, some unjustified actions (like Bush’s war in Iraq) could even increase terrorists’ activity.

Our belief is that all these sides of the terror-fighting problem must be combined in an aggregated model, which can be used by decision makers of various positions.

Here, at the first step of modeling of counter-terrorism resources allocation, we will focus on the measure of protection of a single object, i.e. on the safety problem. For this problem, one can formulate the following problems:

Direct Problem:
Optimally allocate available limited resources that guarantee the maximum possible level of safety of defended objects against terrorists' attacks.

Inverse Problem:
Optimally allocate resources that guarantee the desirable level of safety of defended objects against terrorists' attacks with minimum possible expenses.

Thus, there are two objective functions:

- Cost of protective measures, and
- Guarantee level of the object safety.

Different objects have different priorities (or values). For instance, a terrorists' attack on a stadium during performance might lead to huge human lives loss; an attack on a large bridge might create a serious communication problem for a relatively long time; a destruction of a National symbol might be a strong hit on the country prestige.

It is assumed that counter-terrorism experts are able to formulate measures of priority, or "weights" of defended objects because without such priority objects defense is rather amorphous.

III. DEFINITION AND NOTATIONS

Let us assume that there are three distinct layers of objects safety protection: Federal, State and Local (individual). All input data are assumed to be given by counter-terrorism experts. Introduce the following notations:

$F_i(\varphi_i)$ – subjective probability that an object within the country will be protected against terrorists' attack of type i under condition that on Federal layer one spends φ_i resources. (Notice that this type of protection might be not applicable to all objects. For instance, increasing control of purchasing chemical materials for WMD design has no relations to possible hijacking.);

$S_i^{(k)}(\sigma_i^{(k)})$ – subjective probability that an object within State k will be protected against terrorists' attack of type i under condition that on the layer of this particular State one spends $\sigma_i^{(k)}$ resources;

$L_i^{(k,j)}(\lambda_i^{(k,j)})$ – subjective probability that particular object j within State k (denoted as pair "k, j") will be protected against terrorists' attack of type i under condition that one spends $\lambda_i^{(k,j)}$ resources;

$W^{(k,j)}$ – "weight" (or "measure of priority") of object (j, k).

IV. MATHEMATICAL MODEL: Evaluation of expected loss

On this stage, we consider a single object *j*, located in State *k*. Assume that only set $G_{k,j}$ of possible types of terrorists' attacks is possible against object (*k*,*j*). Under condition of uncertainty, we have to assume that terrorists choose the most vulnerable type of strike. In this case, Federal protection delivers to this particular object the level of safety is equal to:

$$F^{(k,j)} = \min \{ F_i , i \in G_{k,j} \}.$$

Now consider State *k* layer. Using the same arguments, we can write for object (*k*,*j*) the level of protection delivered by the protective measures on the State layer:

$$S^{(k,j)} = \min \{ S_i , i \in G_{k,j} \}.$$

Assume that on a local layer object (*k*,*j*) protection is equal to $L^{(k,j)}$. (Postpone for a while, how this value is obtained.) Then we can assume that measures of protection on all three layers (Federal, State and local) influence independently.

Let us, for the sake of concreteness, consider safety of a stadium: Federal measures are usually relatively rough and non-specific (like general visa control, etc.), State measures are more specific (traffic control, attention to local communities behavior, etc.), and local measures are focused on specific sides (police blocking of transportation, stronger patrolling, using dynamite sniffing dogs, etc.). It is possible to say that Federal layer nets "large fish", State layer can net "smaller fish", and, finally, local layer nets even smaller though "very poisonous fish". So, the total probability of possible terrorists attack will be lessened by all three layers practically independently, i.e. the probability of successful protection of object (*k*, *j*) can be found as:

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$$P^{(k,j)} = 1-(1-F^{(k,j)}) \cdot (1-S^{(k,j)}) \cdot (1-L^{(k,j)}).$$

Hence, the expected loss, $w^{(k,j)}$,of possible attack in this case is equal to

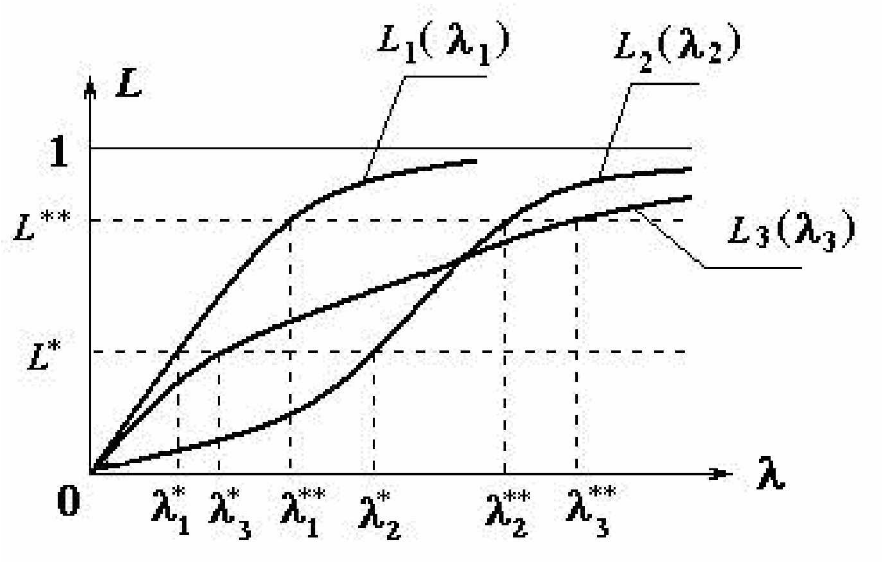
$$w^{(k,j)} = W^{(k,j)}(1 - P^{(k,j)}).$$

V. MATHEMATICAL MODEL: Algorithm of resources allocation

Now we return to calculation of $L^{(k,j)}$ and to the problem of optimal allocation of resources for object (*k*, *j*) protection.

Consider $G_{k,j}$, a set of possible terrorists actions against object (*k*, *j*). Let on the local layer we know functions $L_i(\lambda_i)$ – subjective probability of protection of object

(*j*, *k*) depending on spent resources λ_i for all possible types of terrorists' attacks, where superscripts (*k*, *j*) are omitted, for the sake of simplicity . These functions are presented in the figure below where for illustration purposes only we depicts only three such functions. (They should be defined by counter-terrorism experts.)



First, consider the Inverse Problem: obtaining the desired level of safety due to measures on the local layer. If the chosen level is L^*, then each of functions $L_1(\lambda_1)$, $L_2(\lambda_2)$, and $L_3(\lambda_3)$ has to have its value not less than L^* because inequality

$$\min\{ L_1(\lambda_1), L_2(\lambda_2), L_3(\lambda_3)\} \geq L^*$$

has to be held.

It is obvious that for the minmax criterion to have any $L_i(\lambda_i)$ larger than L^* has no sense. So, the problem of protection resources allocation is solved: the local safety level L^* can be reached if all $L_i(\lambda_i) = L^*$, and in this case one spends total

$$\lambda^* = \lambda_1^* + \lambda_2^* + \lambda_3^*$$

resources. This amount of resources is minimum for reaching safety level L^* .

In analogous way, if one needs to reach the safety level L^{**}, the expenses related to this level of safety are

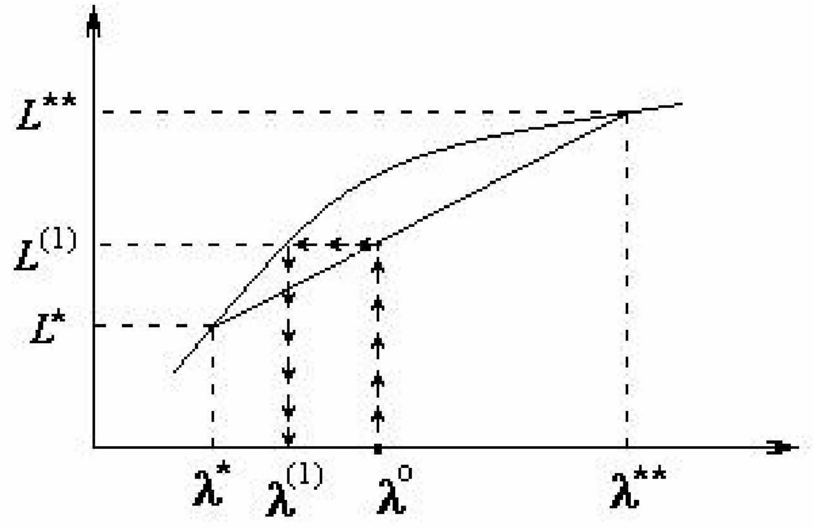
$$\lambda^{**} = \lambda_1^{**} + \lambda_2^{**} + \lambda_3^{**}$$

and also are minimum for this case.

Direct problem (maximization safety under limited total resources) can be solved with the use an iterative process of numerical extrapolation. For instance, let total resources λ° be given. One can find two arbitrary solutions of the Inverse Problem, say, L^* and L^{**} with corresponding values λ^* and λ^{**}. Let all three values satisfy condition

$$\lambda^* \leq \lambda^\circ \leq \lambda^{**}.$$

Applying linear extrapolation, one finds value $L^{(1)}$ and then, having solved the Inverse Problem for this value, finds a new value $\lambda^{(1)}$, which is used on the 2nd step of the iterative process instead of value λ^* , used at the beginning (see figure below).



If initially found values λ^* and λ^{**} satisfy conditions $\lambda^* \leq \lambda^{**} \leq \lambda^{\circ}$ or $\lambda^{\circ} \leq \lambda^* \leq \lambda^{**}$, obviously, the iterative process is absolutely similar.

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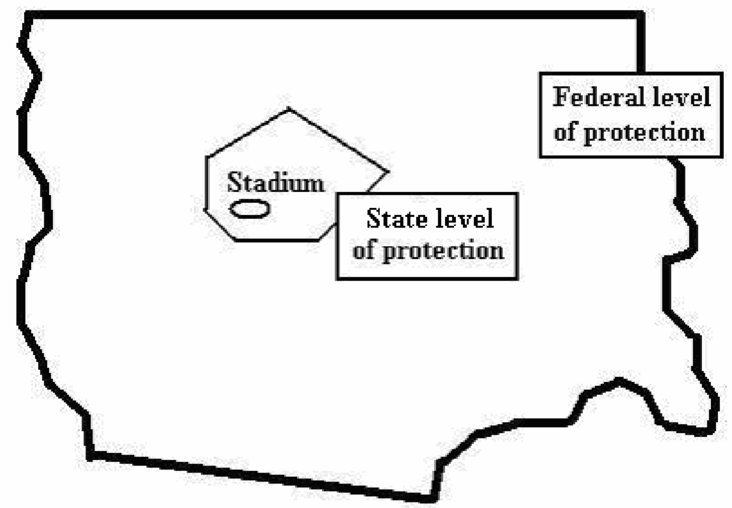
EXAMPLE.

For the sake of transparency, consider a conditional example with a stadium safety that give us a possibility to explain everything not so abstractly. Assume that protection measures on Federal and State layers (for instance, attentive visa issuing with profiling nationality and country of applicant, checking pilot schools attendees, observation abnormal activity within specific communities, etc.) have been already undertaken.



Assume that three possible types of terrorists attacks are considered:

(A) Suicide bombing;
(B) Track with explosive entering the stadium zone;
(C) Crash of a private plane.

Assume that there are the following protection measures:

A_1 – Visual checking suspicious bags, dresses, etc;
A_2 – Sample checking suspicious persons;
A_3 – Using explosive-sniffing dogs;
B_1 – Police block up of traffic on neighbor streets;
C_1 – Copter, armed with anti-plane missiles, barraging in the stadium area.

Fictional numerical input data (expenses of these protective measures) used in this illustrative example are given in the table below.

	LEVEL OF PROTECTION				
	0.9	0.95	0.99	0.995	0.999
A_1	1	2	5	8	12
A_2	5	10	25	40	60
A_3	-	2	-	5	10
B_1	1	-	10	-	20
C_1	50	75	125	200	300

Here symbol "**-**" means that the protection level is absent, i.e. for instance, if one begins to use measure A_3 , after applying 2 cost units the protection level jump to 0.95, though there is no level 0.9 at all.

For given example, expenses related to the protection level 0.95 are equal to 2+10+2+**10**+75=99 conditional units (numbers in the table are taken from up to down). Expenses related to level 0.995 are equal to 8+40+5+**20**+200=273 conditional units. Here bold fonts denote "jumps" described above, i.e. one is forced to "overkill" protection since otherwise the required protection is not delivered.

CONCLUSIONS

We have outlined very general theoretical approach that can be used for the assessing, planning, modeling, and managing of cost-effective counter-terrorism measures. The second phase of the proposed approach deals with aggregated model for sets of defended objects within the states and in the country as whole. Of course, due to terribly increasing dimension of the problem on the higher layer it is possible to make only computer model.

Having that computer model, one can formulate much more complex and realistic problems to include various "what-if" scenarios and additional information: known gaps in security system, counter-terrorism intelligence, impact of preemptive strike against terrorist groups, fuzzy (or not enough reliable) information about terrorist plans and capabilities, etc.

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