CONSIDERATIONS ON OPTIMUM RESOURCE ALLOCATION IN AVIATION SECURITY

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This paper proposes a framework description for the implementation of a simple tool to the problem of optimal allocation of resources in the aviation security system, in the context of terrorist threats. The analysis shows that even when the uncertainties are large, plausible hypothesis with regard to the conditions in which the security systems could produce benefits can be developed, on the basis of well founded risk analysis. Amid the current economic climate, but also with the more evident trend to transfer airport administration to private management, decision-makers need to understand and to respond to the acute need of financial efficiency for airport activities, without negatively affecting the safety and security of passengers.

Key words: *security, aviation system, resource, economic resilience.*

1. INTRODUCTION

Security in general and aviation security in particular is a subject of growing interest. Today, in an unpredictable security environment characterized by a degree of instability, it is unanimously accepted that, in a complex socio-technical systems such as aviation, deployed on a large area, it is difficult to talk about security in absolute terms.

Aviation security can be implemented in terms of: human solutions (procedures) and technical solutions (security systems). Relations and interference of these components are difficult to assess, particularly in the context of technological progress, which is characterized by sustained dynamism. The difficulty in prediction and detection of asymmetric threats requires substantial resources allocations for the protection and security of the aviation system and associated infrastructure. In the current context, the problem of efficient investment in security, in terms of adaptability to new technologies, and the ability to respond to future challenges, becomes urgent.

Decision-makers responsible for aviation security must prove responsibility, efficiency and liability in the resource allocation [1]. Both qualitative and quantitative analysis of asymmetric risks, using vulnerability-threat-consequence architecture, contributes to the definition of a strategy for resource allocation in aviation security technology.

After the attacks of 9/11, the costs for aviation security (especially for physical security and control and surveillance capacity) have increased about 10 times the initial estimates of the federal Government of the United States in fiscal years 2000 and 2001 [2].

The challenge is not just in determining the cost of security measures, but in determining the cost necessary to achieve the system resilience. Estimating losses should include parameters such as [3]: stopping the activity (e.g. closing the airport, airlines insolvency due to inability to ensure safety and security in air transport); the temporal dimension (e.g. the time required to recover the system after the attack); direct and indirect loss/damage (e.g., contamination with dangerous substances and the contagion effect); costs of mitigation, response and recovery. In practice, it is likely to get step-by-step investment (planned by decisional trees) able to mitigate the effect of irreversibility. The first issue of the resource allocation is to bring the risk to an acceptable level. **Figure 1** shows the typical relationship between the investment cost in the security and risk, which expresses the dynamics of security.

Quantifying risk-cost ratio for each element of the infrastructure and the system as a whole, in an analysis of "portfolio optimization", provides substantiation in security investment decisions. The specific analysis is used to determine the global level of risk, using specific analysis, to assess quickly developments and to provide information on the future dynamics. The interest is to reduce the global risk to an acceptable level, in accordance with budgetary restriction proposed/possible. The ability to influence the evolution of the system on the most favorable trajectory is also essential [4].

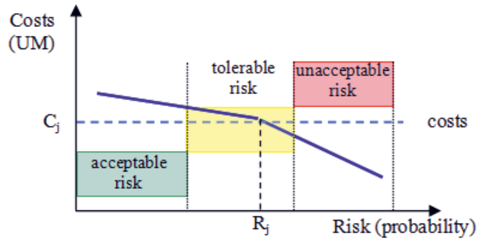

Figure 1. The relationship between the investments cost in security and risk

Performance measurement is essential to the success of any organization, because it creates the necessary behavior to improve competitiveness [5]. And in the case of security investment, especially in terms of budgetary restrictions, the determination of performance on the basis of efficiency indicators allows the finding of the desired way.

The research is important for designing an effective security system, based on maximizing the probability of achieving an optimal cost-benefit ratio, in terms of security objectives with limited resources. Also for Romania, where the airport infrastructure will be expanded considerably in the next period, airport management should consider designing security strategies with the help of such cost-benefit analyses.

2. OPTIMAL RESOURCES ALLOCATION PROBLEM

The allocation of a limited budget to defend critical infrastructure by the dynamic palette of threats is an important task and at the same time a difficult one for decision-makers. The problem of optimal dynamic resource allocations must be substantiated so as to include both the cost of investment and security uncertainties faced by the defended system related to the possible targets.

Air transport system is one of the 'favorite' terrorists' targets, therefore, questions such as *How many resources should be allocated in order to ensure the anti-terrorist protection of an airport? How to spend an international airport to the local one?* need to find the answer through the application of rigorous calculation models that to substantiate the optimal allocation decisions.

In modeling activities on the basis of costs (ABC), emphasis is on the veracity of the information related to the cost of services/processes or activities, but there is the danger of exclusion of indirect costs [6]. While not offering solutions to improve the current situation, the method is particularly useful for controlling the use of resources or periodical financial reporting [7].

In terms of the airports privatization and the new features of the external environment of the organization (enhanced competition or threats diversity), approaches such as the identification of the success parameters, the development of quantitative methods to assess the performance on activity areas or the planning and control of operations become extremely necessary.

Performance model based on costs (PBC) has been developed to move the centre of gravity of the analysis from activities to performance, both in financial and non-financial terms Estimating the precise costs starts from the identification of the areas that adds value to the organization [8].

The needs to achieve a high level of security within the air transport system, through a proactive, rather than reactive approach, and promoting agility, are some of the reasons for recommending the use of a PBC. Decision on implementation of the PBC should substantiate on the potential impact of the success parameters associated with each relevant area/field of activity.

Strategic game theory provides a solution to identify optimum allocation of budgetary security resources in a potential terrorist target system, in which players are: the attacked system and the attacker. The model was used by specialists [9] for investments in urban areas.

In the sequential game where the attacked system acts first, on the preventing principle, the main purpose is to minimize the potential consequences of an attack (eq. 1) [10].

(1)

$$\min C(H,D|b_T) = \sum_{j=1}^{l}\sum_{i=1}^{n}\sum_{k=1}^{s} p_{a_j}^{t_{ik}}(b_{t_{ik}}) \cdot p_{v_j}^{t_{ik}}(b_{t_{ik}}) \cdot w_{t_{ik}}$$

$C(H,D|b_T)$ represents the total consequences (human losses and material damages) estimated due to the terrorist attack, in any of the possible scenarios j; b_T represents the budget allocated to ensure the security of the system T, expressed in monetary units, calculated as a sum of the budgets allocated to the system components t_{ik}; s is the number of possible components/targets, and n is the number of subsystems associated to the assessed system *T*; $p_{a_j}^{t_k}(b_{t_k})$ represents the probability of a terrorist attack on the target t_{ik}, depending on the existing budget allocations; $p_{v_j}^{t_k}(b_{t_k})$ is the likelihood of success of a terrorist attack on the target t_{ik}, depending on allocated budget that targets; $w_{t_{ik}}$ is the value of the target t_{ik} within the system.

The attacked system does not know the attacker's evaluations related targets. In order to simplify calculations, we consider that the attacker's assessments $y_{t_{ik}}$ follow a triangular distribution which probable value is equal with $w_{t_{ik}}$.

The probability density function for the triangular distribution is given by equation 2.

If $y_{t_{ik}} = m \leq 0$, then we have a situation in which there is no attack. Also, we consider that an attacker will choose to attack a single target in the complex system.

$$f(y_{t_{ik}}) = \begin{cases} \dfrac{2(y_{t_{ik}} - m)}{(M-m)(p-m)}, m \leq y_{t_{ik}} \leq p \\ \dfrac{2(M - y_{t_{ik}})}{(M-m)(M-p)}, p < y_{t_{ik}} \leq M \\ 0 \qquad , y_{t_{ik}} < p; \quad y_{t_{ik}} > M \end{cases} \qquad (2)$$

The probability $p_{a_j}^{t_k}(b_{t_k})$ of an attack on the target t_{ik} is actually the probability that the target t_{ik} will achieve maximum expected value. In this way, the probability of attack on target t_{ik} considers both defenders uncertainties relating to evaluation of the targets by the attacker, expressed by *f* distributions and success probabilities of attack resulting from security investments of the system, expressed through $p_{v_j}^{t_k}(b_{t_k})$.

Optimum analysis in the resources allocation to investments in security against terrorism can cause transformation of possible targets in less attractive targets for attackers or offers capability of defense to a larger number of targets with the same initial resources.

3. THE IMPACT OF SECURITY INVESTMENT ON AVIATION INFRASTRUCTURE RESILIENCE

Economic resilience is the ability of the system to continue to operate in the context of events with catastrophic effects [11]. Regarding this study, the economic resilience refers to the ability to respond to the terrorist threat, which allows the system to avoid some of the potential losses.

For the exact description of this systemic feature, we associate two dimensions to economic resilience:

- *static*: efficient allocation of available resources for the time of the event management process;
- *dynamic*: the recovery speed of the system after the produced shock, including long-term investments associated with the reconstruction and recovery.

The ability of the system to achieve a certain level of economic resilience involves, in addition to the intrinsic component (developed before the disaster), and an adaptive component, which tries to maintain the basic function (e.g. substitution of damaged components). Thus, in terms of system performance, economic resilience comes from internal motivation and intensifies decisions of the pre and post-disaster (**Figure 2**).

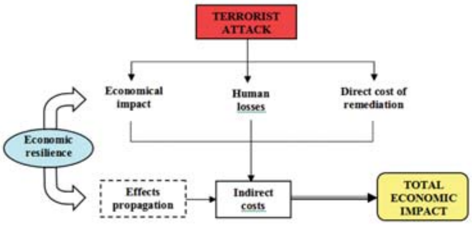

Figure 2. The modeling framework of the total economic impact in case of asymmetric extreme

The economic resilience study encounters numerous challenges: identifying actions, standardization of behaviors, or collection of data for building models.

In order to quantify the economic resilience, we considered the scenario of biological weapon attack in the land side of an airport. The number of canceled flights is estimated at an average of 70% of the total number of canceled flights in a year, direct economic losses were estimated to be only 45%. This difference results from the resilience actions (e.g. flights redistribution on unaffected terminals or other airports, the reallocation of passengers for other flights) associated with traffic disturbances.

Thus, the measure for direct economic resilience of system (REDS) can be expressed with the equation (3).

$$REDS = \frac{\%\Delta R^{max}_{cost-benefit} - \%\Delta R_{cost-benefit}}{\%\Delta R^{max}_{cost-benefit}} \quad (3)$$

where $\%\Delta R^{max}_{cost-benefici}$ is the maximum percentage of change to the cost-benefit ratio, and $\%\Delta R_{cost-beneficiu}$ is the calculated percentage. For this scenario, REDS has the value of 35%.

The usefulness of applying the concept lies in the ability of decision-makers to offer a rapid assessment of the situation, including the losses, which allows the improvement of recovery capacity of the system, efficient operating capabilities of the ad-vantage of resources dynamic reallocation, so as to minimize the effects of possible asymmetric attack.

4. CONCLUSIONS

It is a certainty that the terrorist attacks directed against aviation critical infrastructure cause significant human losses and damage. The protection of such infrastructures, as well as components as entire system should be based on rigorous analysis in order to provide decision-makers relevant knowledge indicators about the actual situation and a basis for dynamic adaptation of plans and actions. Understanding the dynamics of global risk can be achieved from the cost-benefit analysis that emphasizes efficiency and how resources can be optimal allocated to maximize the security and safety of the air transport.

The proposal presented offers a simple but effective method of understanding the relationship between losses resulting from asymmetrical extreme events and associated investment costs for security measures, through incorporating the principles of cost-benefit analysis in risk analysis. The method allows the incorporation of dynamic elements, which are essential in this type of approach, by developing unique recognized picture as a critical function for risk decisions in the medium and long term.

This analysis could be a decision-making support tool created to evaluate and compare the costs and benefits of security measures/ procedures against terrorist threats.

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