Applications of Cost-Benefit Analysis in Designing Security Strategies for Aviation Systems

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Abstract: The proposed cost-benefit model for counterterrorist investment transforms the difficulty of the implementation of the reduction in resources allocation into an opportunity to reform the aviation security system. 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. The applications presented demonstrate that the cost-benefit analysis is a decision-making support tool created to evaluate and compare the costs and benefits of security measures against terrorist threats.

Key-words: security, aviation system, cost-benefit analysis, terrorism risk.

1 Introduction

Given that security is no longer just a set of protection systems, but also a function of system and a process in a complex, dynamic and unpredictable environment, the economic dimension of security gains in the same time necessity and obviously valences [1].

If economic security regards to ensure the conditions for maintaining economic activity in normal parameters, the economic dimension of security is an extension of economic security in terms of organization/system functionality. The main research directions in the field of analysis of investment return in the security of the critical aviation infrastructure are represented in Table 1. A variant of economic security architecture is shown in Figure 1.

The allocation of a budget in order to defend critical complex infrastructure from a palette of dynamic threats is an important task and at the same time a difficult one for decision-makers. The problem of optimal resource allocations must be built to cover both the cost of security investment and uncertainties faced by protected system related to possible targets [2].

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The cost-benefit analysis determines the effectiveness cost of the proposed solutions in terms of consequences attenuation and risk mitigation associated with a critical infrastructure of aviation. Benefit-cost ratio for an alternative investment may be calculated relative to a monetary unit and an interval of time, usually one year [3].

The cost-benefit analyses associated with the terrorism risk in aviation failed to exceed two major limitations: difficulty in assessing the terrorism risk and the inability to anticipate a reaction of terrorists to changes in the security environment [4]. If the costs, particularly those for reducing the risk of terrorist attack, may be relatively easily quantified, but the benefits, expressed by reducing the probability of successful attacks and diminishing the consequences, are difficult to evaluate in quantitative terms. For the cost-benefit analysis to be a tool to explain reasoning decision, it must seek both qualitative and quantitative methods, as well as data from experts. The cost-benefit approach does not provide unique responses, but it defines the decision space of the possible security choices in certain conditions.

2. The cost-benefit analysis in dedicated investments to reduce terrorism risk

2.1 The cost-benefit model

Airport revenues are divided into two categories: aeronautical (resulting from the aircraft operation and the processing of their loads) and non-aeronautical (commercial activities, rents for airport space and land). Unlike income, operating costs structure is more complicated, due to the lack of a standardized reporting system and different weight of the three main categories of costs: costs related to labor, capital and other costs (outsourced services, consulting services, utilities, travels and repairs and so on).

The cost-benefit ratio for a security investment can be calculated using equation (1).

$$R_{\text{cost-benefit}}^A = \frac{C^A}{B^A} = \frac{C_{\text{aq}} + C_{\text{op}} + C_{\text{maint}}}{\sum_{i=1}^{n} \sum_{k=1}^{s} B_{ik}^A}$$  \hspace{1cm} (1)$$

where the benefit $B$ is the difference between the level of risk assessed initially and the level of risk assessed after the implementation of the security solution, expressed in a monetary unit, within the time limit, and $C$ is the equivalent cost to the same period of time required to implement and support risk mitigation measures.

The expected net profit estimate according to introduction of a security measures package of at the level of an infrastructure component $A$ is based on the effect/impact on the level of risk (eq. 2):

$$B_{ik}^A = \left( w_{ik} \cdot w_{i} \right) \frac{ICRT_{ik}^A - ICRT_{i}^A}{ICRT_{ik}} \cdot CCA^A$$  \hspace{1cm} (2)$$

where $w_{ik}$ is the weight of $k$ element in the subsystem $i$, $w_{i}$ is the weight of the subsystem $i$ in the system $T$, $ICRT$ is the composite index of terrorist risk calculated before and after the
implementation of the package of measures $A$, and $CCA^A$ is the cost of avoided consequences.

All the above parameters can be found in the extreme risk assessment methodology (ERAM) [8], with the exception of $CCA^A$, which can be determined by equation (3):

$$CCA^A = CCA^A_H + CCA^A_P$$

In the equation (3) $CCA^A_H$ represents the cost of the lives saved through the implementation of the package of measures $A$. Assigning a monetary value to each life saved is one of the challenges of cost-benefit analysis. The most approved estimate [6] recommends for security analysis the value of 6.3 million $ (equivalent to the level of 2008). Adapted to the national context, the cost per life saved (CVS) could be estimated in relation to the gross domestic product (GDP) per capita [13], as follows (eq. 4):

$$CVS \approx \frac{V_{Robinson}}{GDP_{is} / \text{cap}} = 2.5 \text{ mil.}$$.  

The expected net benefit has indirect component, expressed as a deterrent ability of attackers or increased confidence in the air transport system. For this study, indirect component, difficult to quantify, was not taken into account.

The probability of achieving a cost-benefit report $0 < \alpha < 1$ can be determined with the relationship (5) [14].

$$p\left(\frac{C}{B} \leq \alpha\right) = 1 - p(C - \alpha B \geq 0)$$

The selection of the best alternative by the decision-makers for reducing the risk is based on maximizing the probability of achieving an optimal cost-benefit ratio, in terms of security objectives with limited resources.

2.2 Applications of cost-benefit model

The consequences of exposure to the terrorism risk represent an estimate of the loss of human life and damages, expressed in monetary units. Choosing a terrorism risk mitigation solution (countermeasure) implies two aspects: a cost of investment and an estimate of the percentage of risk reduction. Estimation of the parameters in equation (1) is not simple. There are not still models for calculating the financial risk associated the events with catastrophic consequences or the effectiveness of considered solutions in risk reduction (fig. 2).
In order to demonstrate the applicability of cost-benefit analysis, we chose for example the following two security systems: armoring doors to cockpit for civil transport aircraft with a capacity of more than 60 passengers and multi-sensor monitoring system to avoid placing any dangerous object in the air side of an airport (ATOM). Measure of armoring doors to cockpit for civil transport aircraft with a capacity of over 60 passengers has emerged as a standard and recommended practice of the International Civil Aviation Organization (ICAO), regulated in Annex 6 to the Chicago Convention.

The total cost of this measure was estimated (only for USA) at about 40 million $ annually [15]. The cost-benefit analysis for this system is accomplished by reporting to the consequences of 9/11 attack on the Pentagon. Replacing the parameters in (2) and (3) equations, results in:

\[
C^A = 40 \text{ mil.} \$; \quad \left( w_{s_3} \cdot w_{t_1} \right) = 0.2;
\]

\[
\frac{ICRT_{t_3} - ICRT^A_{t_3}}{ICRT_{t_3}} = \frac{400 - 93}{400} = 0.76;
\]

\[
CCA^A = (125 \cdot 6,3\text{mil.}\$) + 700\text{mil.}\$ = 1487,5\text{mil.}\$.
\]

Thus, with a probability of 80%, the cost-benefit ratio for this example has the value of 0.18 without considering the indirect benefits of the measure application. Calculated for a single scenario, hijacking, and one critical element of infrastructure, aircraft, the model can be easily extended to the entire system.

The second example performs an evaluation of the benefits of the introduction of a multi-sensor monitoring system to avoid placing any dangerous object in the air side of a medium-sized airport.

The ATOM system, now in the prototype stage, without an estimate of the production, implementation and operation costs, can be calibrated in terms of costs using the cost-benefit analysis, in order to prevent the recurrence of an attack scenario, such as Burgas (July 18th, 2012), on the national territory.

The consequences of this suicide bomb attack occurred in the area of public facilities (parking) from Burgas airport, with the loss of six human lives and the destruction of three buses [16].

The ATOM system, consisting of two radar, according to the laboratory technical data [17], has a probability of detection possible threats (weapons, explosive, inflammable or toxic substances) of over 80%. The performance of risk analysis after a possible integration of such a system provides a reduction of the bomb attack risk in the area of public facilities by 90%. Data for the evaluation of the benefit are as follows:

\[
\left( w_{s_2} \cdot w_{t_3} \right) = 0.28 \cdot 0.37 = 0.1;
\]

\[
\frac{ICRT_{t_3} - ICRT^ATOM_{t_3}}{ICRT_{t_3}} = \frac{200 - 19}{200} = 0.9;
\]

\[
CCA^ATOM = (6 \cdot 2,5\text{mil.}\$) + 450000\$ = 15.450.000\$.
\]

Annual net benefit for this counterterrorist system, considered for a single risk scenario associated with a single component of critical infrastructure, is 1.4 million $. To this it can add indirectly benefit, represented by very good passengers’ perception about security, reducing waiting time and the degree of satisfaction of security staff. Thus, the total maximum annual cost has the value of 1 million $.

Calculating return on investments in security critical infrastructure cannot be done without a prior evaluation of risk, which involves the analysis of vulnerabilities for each subsystem/component element in connection with the threat and the occurrence probability of the scenario. The cost-benefit analysis follows the risk analysis as a tool for decision support: adoption of a solution for the prevention the attack or mitigation the consequences.

The method has the advantage of providing a simple tool, but particularly useful for comparing security solutions based on relative values or estimates of the losses involved in the calculation of the return on security investments for prevention of similar problems in the future.

This model is easy to implement but it has a number of limitations, such as: difficulty of separation of the countermeasures effects; multiple sources of unpredictability; it is difficult to implement in a system in real time; difficulty in assessing the security investment depreciation, in the context of reduced number of events.

3. Conclusion

The protection of such infrastructures, as well as components of the 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.
analysis that emphasizes efficiency and how resources can be optimal allocated to maximize the security and safety of the air transport.

The cost-benefit model is based on the extreme risk assessment methodology (ERAM) that was built to evaluate and compare the level of risk for different scenarios of terrorist threat associated with systems/subsystems/components critical in aviation infrastructure. The cost-benefit model complements the analysis presented and offers decision-makers a new indication in connection with the variety of risk scenarios considered, with the level of risk and the allocation of resources to mitigate the risk.

The examples presented demonstrate, on the one hand, that the cost-benefit analysis is viable for allocation of resources decisions for acquisition of security equipment/procedures, and on the other hand, calibrates research results in the field of airport security in terms of cost for systems placed in the prototype stage.

This model is a decision-making support tool created to evaluate and compare the costs and benefits of security measures/procedures against terrorist threats. It can be improved by the inclusion of some elements of game theory or artificial intelligence to capture and social, political, or environmental aspects.

References: