SCREENING DEVICE MODEL FOR AIRPORT SECURITY INFRASTRUCTURE

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The paper presents a description of an airport security system and screening devices deployment procedure. Its scope is the development of a model for the use of explosives detection devices in aviation security systems. One of the methods of examining airport security system efficiency is creation of a simulation process model that would allow the identification of critical points which are under normal circumstances difficult to determine and that would also facilitate the simulation of all the conditions affecting airport security systems.

K e y w o r d s: Screening device, airport security/aviation security, Nonlinear Integer Problem

1 INTRODUCTION

Every screening device within an aviation security system infrastructure has different features, such as data processing speed, operating costs, installation and threat detection probability. If multiple device types are required for a certain passenger class, the security system may become too costly and the time of passengers' check-in may be inconveniently prolonged. On the other hand, an insufficient number of screening devices may increase the aviation risks as the system becomes prone to failure in detection of attack threats. It is therefore crucial to allocate suitable types of screening devices to each passenger class and to determine the required number of devices in order to maximize the total security and to keep the costs within the defined limits.

In general, a range of technical equipment types is used for detection of various threats or screening of passengers, hand baggage and hold baggage. If specific equipment is used a number of devices will be needed, as screening for individual threats is performed at different locations. The topic of specifying technologies and devices designed for respective threat category detection may thus be divided into several separate sub-issues. This article will focus on the allocation of the hand (i.e. carry-on) baggage screening devices.

2 IDENTIFICATION OF ALGORITHM COMPONENTS

This section contains the marking used in the aviation security model.

M – number of passenger classes,

D – number of types of screening devices

A_i – average assessed value of passengers' threat in class i (i = 1,2, ... M),

B_i – number of baggage pieces in class i

(i = 1,2, ..., M),

B_T –total number of baggage pieces = $\sum_{i=1}^{M} B_i$,

F_j – fixed costs (€ per device) of the j type device (j = 1,2, ... D),

I_j – installation costs (€ per device) of the j type device (j = 1,2, ... D),

O_j – operating costs (€ per piece of baggage) of the j type device (j = 1,2, ... D),

C_j – capacity (pieces of baggage per hour) of the j type device (j = 1,2, ... D),

E_j – number of the j type devices in place

(j = 1,2, ... D),

P_j – conditional probability of threat detection by the j type device (j = 1,2, ..., D), assuming that a threat exists,

TB – total budget (€).

Decision variables:

X_{ij} – binary variable with X_{ij} = 1 if the j type device is used for screening of pieces of class i baggage,

otherwise X_{ij} = 0,

Y_j – required number of the j type devices

2.1 Devices deployment model

In the device deployment model the numbers and types of devices need to be assigned to each passenger class. As soon as a specific type of the required equipment is identified, the number of the devices to be installed must be determined. The number of the *j* type devices needed for installation may be determined as the number of the *j* type devices minus the number of the *j* type devices currently in place at the airport. The number of the *j* type devices to be installed will be marked as Sj, therefore

$$S_j = Y_j - E_j, \text{ for } j = 1,2, ..., D. \tag{1}$$

As the de-installation costs are disregarded here,

$$S_j = Y_j - E_j, \text{ if } Y_j > E_j \text{ and } S_j = 0 \text{ otherwise,}$$
$$\text{for } j = 1,2, ..., D. \tag{2}$$

Subsequently the total installation costs may be calculated as:

$$\sum_{j=1}^{D} I_j S_j \tag{3}$$

and the total fixed costs may be calculated as

$$\sum_{j=1}^{D} F_j Y_j \tag{4}$$

where I_j and F_j are the estimated hourly installation costs or fixed costs, irrespective of the volume of the screened hold baggage. The fixed costs include the yearly maintenance and lease costs. The installation costs include the purchase and preparation costs. These cost figures are set on the basis of the expected operating lifespan of the device and yearly number of the operating hours (daily x 365).

The operating costs for the *j* type device depend on the number of pieces of baggage in each class, screened by the *j* type device. They are calculated as

$$\sum_{i=1}^{M} O_j B_i X_{ij} \tag{5}$$

Thus the total operating costs are set by the equation:

$$\sum_{j=1}^{D} \sum_{i=1}^{M} O_j B_i X_{ij} \tag{6}$$

where O_j are the expected operating costs of the *j* type device.

For the total budget *TB* the cost limits are as follows:

$$\sum_{j=1}^{D} (F_j Y_j + I_j S_j) + \sum_{j=1}^{D} \sum_{i=1}^{M} O_j B_i X_{ij} \leq TB \tag{7}$$

where the first parameter consists of fixed costs and installation costs and the second parameter represents the operating costs.

It is desirable to determine the number of devices required for screening of the given number of pieces of baggage. The capacity of screening devices must therefore be considered. A number of screened pieces of baggage is set for each *j* type device.

$$\sum_{i=1}^{M} B_i X_{ij} \tag{8}$$

Then the total number of the required *j* type devices is equal to the total number of pieces of baggage screened (checked) by the *j* type device, divided by the capacity of the *j* type device.

$$\sum_{i=1}^{M} B_i X_{ij} / C_j \tag{9}$$

However, the number of devices is an integer. As the result of the above equation may not necessarily be an integral number, the bottom limit will be set by defining the following capacity range:

$$Y_j \geq \frac{\sum_{i=1}^{M} B_i X_{ij}}{C_j} \tag{10}$$

or

$$C_j Y_j \geq \sum_{i=1}^{M} B_i X_{ij} \text{ for } j = 1, 2, ..., D \tag{11}$$

Similarly defined are the upper capacity limits:

$$C_j Y_j < \sum_{i=1}^{M} B_i X_{ij} + C_j \text{, for } j = 1, 2, ..., D \qquad (12)$$

On the left side, the C_jY_j is the total capacity of all the *j* type devices, while the right side represents the overall requirements for the *j* device (sum of the pieces of baggage to be screened by the *j* device). The bottom capacity limits (11) ensure that the number of the *j* devices is sufficient for screening of the volume of baggage to be checked by the *j* devices. The upper limits (12) ensure that if the *k* device isn't in use in any passenger class, i.e. $X_{ik} = 0$, then Y_k is also zero.

The threat detection probability in each passenger class is defined as a probability that one of the device types in this combination can detect a threat. To simplify the calculation the P_j shall stand for a probability of detection by the *j* type device, given that a threat exists, and L_i will be used as a probability that the threat is detected by the combination of devices for class *i*, given that a threat exists; then the assumption of independence implies that

L_i = P {the threat is detected by one of the devices screening the passenger class *i* | threat is present}

= 1–*P* {the threat is not detected by any of the devices in passenger class *i* | threat is present }

$$L_i = 1 - \prod_{j=1}^{D} (1 - X_{ij} P_j) \text{, for } i = 1, 2, ..., M \qquad (13)$$

Fig.1 presents an example with three types of explosives detection devices for class *i*. A piece of baggage is supposed to be screened by all the three types of detection devices prior to boarding an aircraft. If one of the devices detects a threat, the baggage piece is removed.

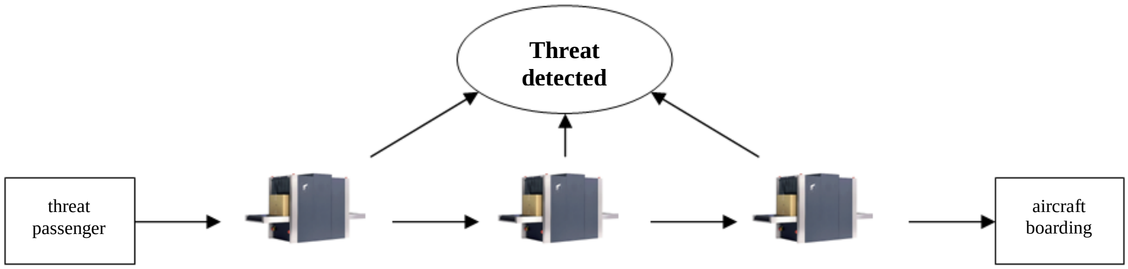

Figure 1 Example of combination of three device types

We assume that the number of pieces of baggage B_i and the average assessed threat value of passengers in every class A_i are known. The risk level of class *i* will be defined as a proportion from the total value of assessed threat assigned to class *i*

$$R_i = A_i B_i \frac{1}{\sum_{i=1}^{M} A_i B_i} \qquad (14)$$

Alternatively, the risk level is a conditional probability that class *i* contains a threat, under assumption that the system contains a threat. To make it more specific and clear, the following cases will be defined:

T_i = class *i* contains at least one threat,

S_T = the system contains at least one threat.

Then the *Ri* risk level of class *i* can be also expressed as $P(T_i \mid S_T)$.

The true alarm rate of a screening device is the probability that the device detects a threat, given that a piece of baggage contains a threat. Likewise, the true alarm rate of a devices type combination in passenger class *i* is a probability that at least one of the device types can detect a threat, given that passenger class *i* contains a threat. Then the total security is defined as a probability that a threat is detected, given that a threat exists in the system.

The following shall apply to identification of the total security:

D_i = threat is detected in passenger class *i* (i.e. a piece of baggage of class *i* contains a threat which is detected under assumption that the system contains a threat).

The $P(D_i)$ may thus be calculated as: (probability that class *i* contains threat) x (probability of threat detection by combination of device types for class *i*) or:

$$P(D_i) = P(\mathrm{T_i} \mid \mathrm{S_T})\, L_i = R_i L_i \qquad (15)$$

The result is the total security as:

$$\sum_{i=1}^{M} P(D_i) = \sum_{i=1}^{M} L_i R_i \qquad (16)$$

The model of deployment of explosives detection devices can be regarded as a nonlinear integer problem as the objective function, the maximization of total security, is nonlinear and the decision variables, the number of screening devices and the binary variables of deployment/non-deployment are integers.

5 CONCLUSION

The main objective of the methods used and the methodology developed is the solution of the issue of maximizing the security level and designing a model for deployment of explosives detection devices to maximize the screening process security. The basic and applied research in the field of aviation security is focused on the theory and taxonomy of processes and their placement in the security system with regard to the risk type applicable to the given group. The deployment of selected tools optimizes the management of security processes not only through quantified credibility and authenticity of the input variables, but also through modification of elementary functions of management tailored to the current level of risk of the particular process in the aviation security system.

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