A Method For Managing A Security Checkpoint Through Multi-Criteria Analysis With Consideration Of Safety And Process Performance

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Abstract: The purpose of this paper is to develop a method for configuring a security screening lane at an airport. The method will be based on such personnel management that the most advantageous ratio of safety to process performance is achieved. The paper uses a fuzzy model on the basis of which a multi-criteria analysis is conducted. Two criteria are taken into account: safety and process performance. The model allows to select a team from a set of available individuals, to obtain the best system configuration. Inputs to the model will be based on an empirical study and the use of a computer simulation method. Such a model has not yet been developed in the scientific literature and can be of significant interest to the airport security control manager. The article is part of the work related to the project: "Development of an innovative desk of the primary and supplementary training of the security control operator at the airport".

1. INTRODUCTION

The International Civil Aviation Organization (ICAO), according to statistics, defines the air transport system as ultra-safe [1]. An ultra-safe system means a system in which there is less than one safety (catastrophic) failure per million cycles of the executed process. This is all a result of actions that are taken for the safety of air transport. Important issues that are related to this include safety management methods for technical failures of equipment as well as protection against unlawful interference by third parties. This paper addresses one such activity. The article discusses the screening process that is performed at an airport terminal.

The purpose of the screening process (SC) is to prevent prohibited items indicated in [2] from being brought into the airside. This process covers all passengers and the items they carry with them and in their hold baggage. The process also includes all cargo carried in the cargo hold of the aircraft as well as mail and airport supplies. In order to fill the high demand for the process, high systems performance is required. Especially, for passenger handling where long queues can form. Safety management activities carried out during PH have a negative impact on service levels. For many airports, SC is carried out using a centralized system [3]. This means that the process takes place between the landside and the airside of the airport. This is where the PH streams of each flight, which is executed at the same time, merge. The distribution of flights along the day is not homogeneous [4]. This results in the occurrence of several hourly peaks to serve a very large number of people in a short time interval.

At each screening lane, several screening operators (SO) perform different tasks. SO can be described by various characteristics. Two key characteristics include the time they perform their duties and the detection rate of prohibited items. For optimal operation of security checkpoint, it is good to choose the optimal task allocation to ensure safety while maintaining high process performance. This is not addressed in the literature because operator detection rates are not widely known, and so models accounting for this are lacking. This article is a part of research work that is conducted within the project: Development of an innovative desk of the primary and supplementary training of the security control operator at the airport. In this project, the developed training system will provide this data to a

model that will be responsible for assigning tasks to SOs in the security lane. It will increase the depth of knowledge because knowing the data directly from the system in which operators are tested will give the ability to manage it. It will give the opportunity to use them in a practical way.
This paper will present a hybrid method of using empirical testing, computer simulation and fuzzy logic to determine the optimal configuration for a security lane at an airport.

2. STATE OF THE ART

The screening process at an airport may follow different procedures and therefore the configuration of the technical system may differ from one airport to another. This is a major factor that affects the system performance at an airport. Consequently, many microscopic scale approaches have been developed to analyze the performance of a security screening system in terms of the structure of the process implemented. In this type of work [e.g., 5-7], a sensitivity analysis of the system to a change in selected parameters (number of operators, capacity of individual zones, number of devices used, etc.) is conducted. This enables the design of an appropriate system structure. An extensive collection of information on system analysis is presented in the report [8].

Related to performance is often the service quality parameter. The issue of the passenger's feeling of being under stress when undergoing the screening process is very important. On the one hand, the security check must be carried out accurately (the passenger must feel the safety of the transport system), on the other hand, the security check must also be carried out quickly so that the passenger can be on time for the plane. In the paper [9], the authors conducted a level of service (LoS) assessment for an airport passenger terminal. The need for the study was demonstrated and a research methodology was indicated to determine the relationship between LoS and the quantities affecting its assessment (e.g., distances traveled by passengers in the terminal). An analysis of the results obtained is presented. Then, in [10], the authors presented the LoS results for each subsystem of airport operation. An airport LoS evaluation model was presented as a weighted average of each airport subsystem (check-in, security screening, etc.). In [11], the authors presented the results, aimed at demonstrating passenger perceptions of individual airport subsystems using the Cronbach alpha index. The check-in counters, security screening system, etc. were analyzed. In the security screening system the following factors were taken into consideration: courtesy and helpfulness of security staff, thoroughness of security screening, waiting time at security checkpoint, feeling of being safe and secure.

The security screening process is also evaluated in terms of its efficiency in detecting prohibited items. The subject of efficiency is discussed in various detail in scientific papers. The influence of various factors on the efficiency of airport terminal security is discussed in [12]. The importance of individual activities carried out by security systems is given. The security of passengers and baggage is a priority in activities aimed at ensuring an adequate level of safety. Security checkpoints are very important. During this process, each passenger may follow a different screening path. These actions are dependent on the security class given to the passengers, requiring then the use of different screening methods. The work [13] shows the developed heuristic method to assign passengers to appropriate classes in order to ensure an appropriate level of safety. The paper [14] shows the benefits of using an additional screening system for a selected portion of passengers.

Another group of articles are those that directly analyze the effectiveness of airport equipment that supports the work of security screening operators. A direct evaluation of the screening process using fuzzy logic was conducted in the paper [5]. The evaluation of the passenger screening stream with the WTMD device and through manual inspection was analyzed. An analogous evaluation was carried out for the hand baggage screening process in combination with manual inspection [16]. In the paper [17], a fuzzy logic based evaluation model for X-ray equipment was presented. On the effectiveness of detection of prohibited items by operators was written in [18-20]. Scientific works have also addressed the reliability of ETD [21], or WTMD [22,23] devices.

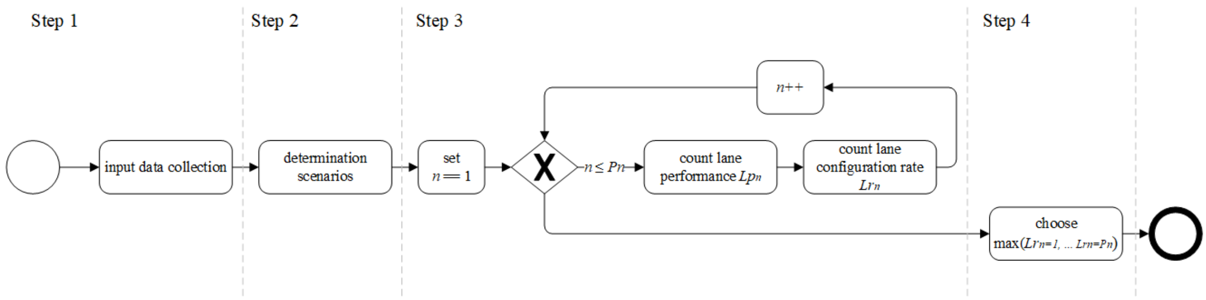
From the review of the state of the art presented here, it should be concluded that there are works that analyze aspects related to the performance and efficiency of the security screening system at the airport.

However, these works do not link this two issues together. In particular, it should be stated that there are no works that allow to select a team of operators to find the optimal solution to ensure an adequate level of safety, with good system performance. Thus, this is a research gap that this paper fills. In the next section, a task selection method for screening operators will be proposed.

3. CONCEPTUALIZATION OF THE SCREENING LANE MANAGEMENT METHOD

The main goal of the method is to select tasks in the security control team to obtain the best system configuration. Two factors are taken in this case, which influence the evaluation. The first one is the performance of the system. The second one is the safety level. The concept of the method is to solve the problem in 4 basic steps. The first step consists of input data. In the second step all possible configurations of the system should be determined. In step three the evaluation of the system for each of the possible configurations is calculated. In the last step the best solution is selected. A graphical concept of the method is shown in Figure 1.

Figure 1: Concept of the security lane management method



3.1. Step 1 - Input data collection

The concept of the method requires that data evaluations that are related to both performance and safety need to be entered into the model. A set of OS operators must be entered (1). Each operator should be assigned its features according to (2).

$$SO = \{SO_{i=1}; \dots; SO_n\} \tag{1}$$

$$SO_i = (e_b, e_{hb}, e_e, e_{hp}) \tag{2}$$

The parameters marked with the letter "e" belong to the group of parameters related to the efficiency of searching for prohibited items:

- e_b is the likelihood of detecting a prohibited item during an personal object screening,
- e_{hb} is the likelihood of detecting a prohibited item during a hand search of personal objects,
- e_e is the probability of detection of a prohibited item during an analysis with an explosives trace detection device,
- e_{hp} is the probability of detection of a prohibited article during a hand search of a passenger.

The second group consists of parameters related to the time of performed activities by the operator:

- t_{mcontr} is the probability density function of passenger inspection
- $t_{contBag}$ is the probability density function of the baggage screening
- $t_{mcontBAG}$ is the probability density function of performing extended baggage inspection.

3.2. Step 2 - Determination of scenarios

In this step, all possible combinations of system configurations must be determined. From the set of available operators can be selected 3 operators, each of which will be responsible for a different task:
- OS1 - performs manual control of passengers,
- OS2 - performs baggage screening
- OS3 - performs extended baggage inspection.

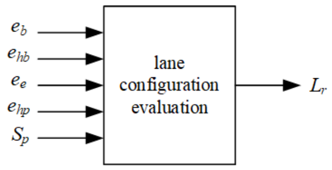
The number of available combinations *Pn* will follow equation (3), where *i* is the number of available operators in the set SO

$$Pn = \frac{i!}{3!\,(i-3)!} * 3! \tag{3}$$

3.3. Step 3 - Determination of system indicators

In this step, the main part of the analysis is implemented. The application of the evaluation model based on the fuzzy logic method is adopted. This model makes an overall evaluation of the system based on input variables that are related to both safety and performance of the system (Figure 2).

Figure 2: concept of fuzzy model for system configuration evaluation



Indicators determined from the screening operator's training system are entered directly as input variables: e_b, e_{hb}, e_e, e_{hp}. The last variable that is entered into the fuzzy model is its performance S_p. This parameter must be determined. It can be done by experimental studies on a real system if the operator teams under analysis have already worked in such configurations. However, in this paper it is proposed to use the computer simulation method. For this purpose, the variables t_{mcontr}, $t_{contBag}$, $t_{mcontBAG}$ can be added into a simulation model, which was developed by the authors of this paper and described in detail in the publication [24]. This simulation model will return a parameter *Sp*, which can be used directly in the fuzzy model.

To determine the values of the linguistic variables for the input and output of the evaluation model, an expert method was used in which 10 trainers for OS were surveyed. They have work experience of more than 12 years. With reference to the data they indicated, membership functions were developed as shown in Figures 3-8.

Figure 3: Membership function of the input linguistic variable e_b

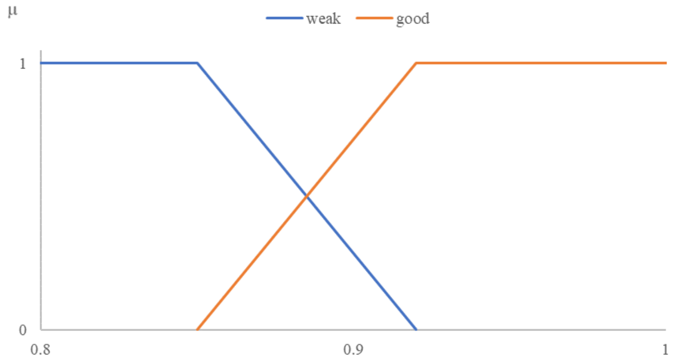


Figure 4: Membership function of the input linguistic variable e_{hb}

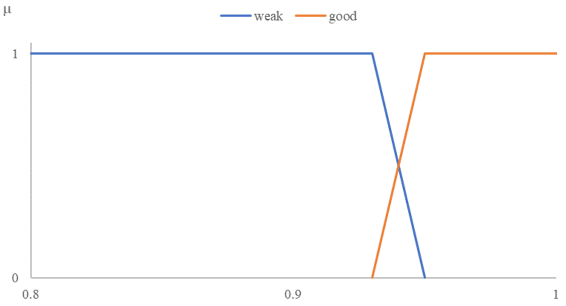


Figure 5: Membership function of the input linguistic variable e_e

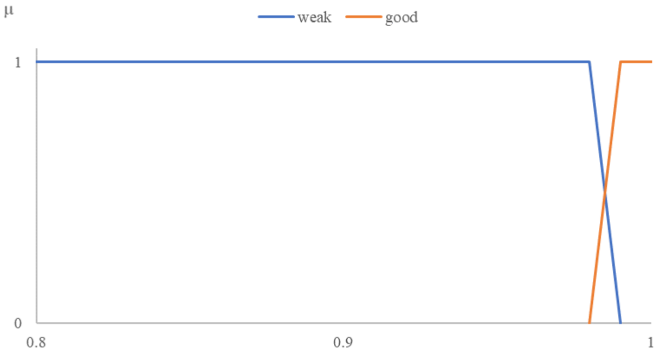


Figure 6: Membership function of the input linguistic variable e_{hp}

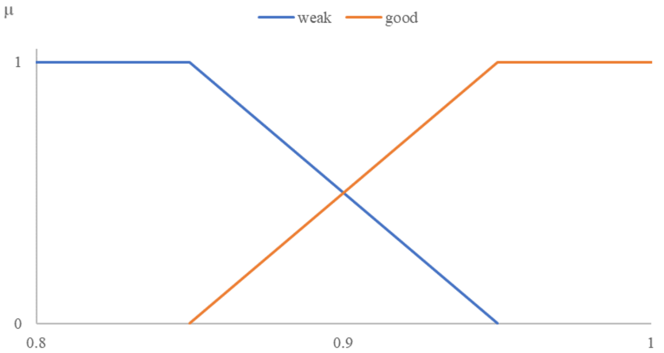


Figure 7: Membership function of the input linguistic variable S_p

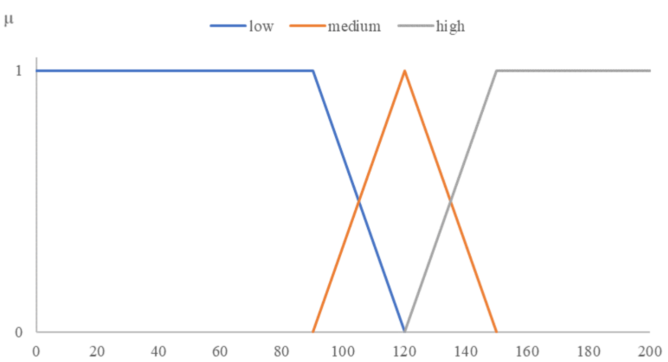
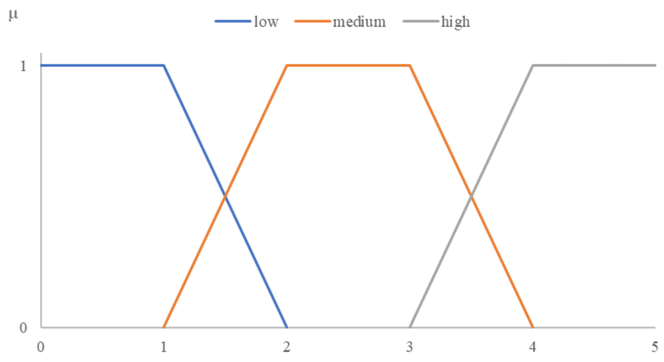


Figure 8: Membership functions of the output linguistic variable L_r



Fuzzy operators are used to define the method of performing a logical operation. The AND or OR operators can be used. For logical product A AND B the most commonly used function is min(A,B) which determines the smallest value of A and B membership function. A similar situation occurs in the case of the OR operator, where max(A,B) is the highest value of the membership functions A and B. Implication method application is realized in two steps. In the first step rules are developed. Each rule can be given a weight, which will determine its importance. In the presented example, for all rules the weight is the same. The set of rules is shown in Table 1.

Table 1: The set of rules

R1	if(e_b is	weak	) AND (	e_{hb}	is	weak	) AND (	e_e is	weak	) AND (	e_{hp}	is	weak	) AND (	S_p is	low	)	then	(	S_r is	low	)
R2	if(e_b is	weak	) AND (	e_{hb}	is	weak	) AND (	e_e is	weak	) AND (	e_{hp}	is	weak	) AND (	S_p is	medium	)	then	(	S_r is	low	)
R3	if(e_b is	weak	) AND (	e_{hb}	is	weak	) AND (	e_e is	weak	) AND (	e_{hp}	is	weak	) AND (	S_p is	high	)	then	(	S_r is	low	)
R4	if(e_b is	good	) AND (	e_{hb}	is	weak	) AND (	e_e is	weak	) AND (	e_{hp}	is	weak	) AND (	S_p is	low	)	then	(	S_r is	low	)
R5	if(e_b is	good	) AND (	e_{hb}	is	weak	) AND (	e_e is	good	) AND (	e_{hp}	is	weak	) AND (	S_p is	low	)	then	(	S_r is	low	)
R6	if(e_b is	good	) AND (	e_{hb}	is	weak	) AND (	e_e is	good	) AND (	e_{hp}	is	weak	) AND (	S_p is	medium	)	then	(	S_r is	medium	)
R7	if(e_b is	good	) AND (	e_{hb}	is	good	) AND (	e_e is	weak	) AND (	e_{hp}	is	weak	) AND (	S_p is	medium	)	then	(	S_r is	medium	)
R8	if(e_b is	good	) AND (	e_{hb}	is	good	) AND (	e_e is	good	) AND (	e_{hp}	is	weak	) AND (	S_p is	medium	)	then	(	S_r is	medium	)
R9	if(e_b is	good	) AND (	e_{hb}	is	weak	) AND (	e_e is	weak	) AND (	e_{hp}	is	good	) AND (	S_p is	medium	)	then	(	S_r is	medium	)
R10	if(e_b is	good	) AND (	e_{hb}	is	good	) AND (	e_e is	weak	) AND (	e_{hp}	is	good	) AND (	S_p is	medium	)	then	(	S_r is	medium	)
R11	if(e_b is	good	) AND (	e_{hb}	is	good	) AND (	e_e is	good	) AND (	e_{hp}	is	good	) AND (	S_p is	medium	)	then	(	S_r is	high	)
R12	if(e_b is	good	) AND (	e_{hb}	is	good	) AND (	e_e is	good	) AND (	e_{hp}	is	good	) AND (	S_p is	high	)	then	(	S_r is	high	)

On the basis of the developed rules and in conjunction with the input membership functions, the output membership function is determined for individual rules: $\mu_{out}^{R1}(z), \mu_{out}^{R2}(z), \dots, \mu_{out}^{R12}(z)$. Aggregate all output involves algebraically combining all output membership functions. For this purpose, the maximum functions for all output membership functions (4) are used. The last step is the defuzzification process. This process is usually based on determining the centroid of output membership function according to (5)

$$\mu_{out}(z) = max\{\mu_{out}^{R1}(z), \mu_{out}^{R2}(z), \dots, \mu_{out}^{R8}(z)\} \tag{4}$$

$$z^* = \frac{\int \mu_{out}(z) \cdot zdz}{\int \mu_{out}(z)dz} \tag{5}$$

The final result of this step is to determine the final system rating for each possible configuration. Based on this, an inference is made about the selection of the final configuration in the next step of the method.

3.4. Step 4 - Selecting the best configuration

This step consists of simply selecting the best solution Sr. From the set of system evaluation results L_r for all consecutive configurations from *n*=1 to *Pn*, the largest value of the obtained *Lr* is selected (6).

$$S_r = max\left(L_{r_{n=1}}, \ldots, L_{r_{n=P_n}}\right) \tag{6}$$

This gives a definitive indication of how to assign tasks to the screening operators at the security lane.

3.5. Method validation and discussion

The developed method combines several input variables and obtains a single output variable to answer whether a given configuration is better than others or not. This can significantly help in the management of the security control system. However, statistically proving such considerations is extremely difficult. To validate the model, a method analogous to the one carried out in the work [17] was proposed. In this method, a parallel evaluation using experts is conducted. The adopted input data should be shown to the experts. The experts give a rating for at their discretion and this rating is compared with that given by the model.

Table 2: Model validation

No.	configuration			entry parameters					output parameters		linguistic output parameters	
	(Operator No.)			e_b	e_{hb}	e_e	e_{hp}	S_p	L_{rm}	L_{re}	(fuzzy model)	(experts)
1	o2	o1	o3	0.95	0.94	0.97	0.88	145	4.20	4.35	high	high
2	o2	o4	o3	0.95	0.99	0.97	0.88	141	4.15	4.20	high	high
3	o1	o2	o3	0.92	0.96	0.97	0.88	144	4.07	4.20	high	high
4	o4	o2	o3	0.90	0.96	0.97	0.88	143	4.07	4.10	high	high
5	o3	o1	o4	0.87	0.94	0.94	0.94	140	3.76	3.95	medium/high	medium/high
6	o4	o1	o3	0.90	0.94	0.97	0.88	135	3.68	3.95	medium/high	medium/high
7	o1	o4	o3	0.92	0.99	0.97	0.88	130	3.51	3.80	medium/high	medium/high
8	o3	o4	o2	0.87	0.99	0.99	0.99	128	3.39	3.80	medium/high	medium/high
9	o2	o3	o1	0.95	0.95	0.98	0.86	131	3.27	3.60	medium/high	medium/high
10	o1	o4	o2	0.92	0.99	0.99	0.99	132	2.99	3.50	medium	medium/high
11	o1	o3	o2	0.92	0.95	0.99	0.99	125	2.86	3.15	medium	medium/high
12	o4	o3	o2	0.90	0.95	0.99	0.99	124	2.74	3.05	medium	medium/high
13	o4	o1	o2	0.90	0.94	0.99	0.99	123	2.64	2.80	medium	medium
14	o2	o4	o1	0.95	0.99	0.98	0.86	119	2.53	2.60	medium	medium
15	o2	o3	o4	0.95	0.95	0.94	0.94	118	2.51	2.55	medium	medium
16	o2	o1	o4	0.95	0.94	0.94	0.94	118	2.50	2.55	medium	medium
17	o3	o2	o4	0.87	0.96	0.94	0.94	116	2.50	2.50	medium	medium
18	o3	o4	o1	0.87	0.99	0.98	0.86	117	2.50	2.50	medium	medium
19	o4	o3	o1	0.90	0.95	0.98	0.86	116	2.50	2.35	medium	medium
20	o3	o1	o2	0.87	0.94	0.94	0.94	114	2.50	2.40	medium	medium
21	o3	o2	o1	0.87	0.96	0.98	0.86	124	2.30	2.50	medium	medium
22	o1	o3	o4	0.92	0.95	0.94	0.94	120	2.30	2.25	medium	medium
23	o1	o2	o4	0.92	0.96	0.94	0.94	118	2.13	2.00	medium	medium
24	o4	o2	o1	0.90	0.96	0.98	0.86	110	1.68	1.85	low/medium	low/medium

The authors performed the validation on real data, which were determined using the training system and the real system. However, these data are only for internal use and remain confidential because they involve data that are related to security and the authors did not obtain permission to present them. However, for publication purposes, an additional validation was performed in which fabricated data were used and were subjected to expert evaluation. Table 2 shows the inputs that were presented to the experts for evaluation.

The case of the validation was to select the best system configuration (3 operators) from a set of 4 available operators. Table 2 sequentially presents the analyzed scenarios, of which there are 24 in total. Next, the input parameters, discussed earlier in the paper, are presented. Next, the evaluation determined by the proposed fuzzy model L_{rm} is presented. Next to it, the average rating L_{re} given by all the experts is presented for comparison. Further, the linguistic variables of the evaluation determined by the system and that given by the experts are also compared.

The results obtained, through validation, indicate that there is a high correlation between the ratings proposed by the model and the average rating given by the experts. The average difference between the fuzzy model ratings and the experts' ratings is 0.19 which represents an error of magnitude of 3.5%. It should be mainly concluded that the experts indicated the same best solution according to the model. Analyzing the linguistic variables, a high convergence of results is noticeable here as well. There was a difference in only 3 of the 24 configurations. It is worth noting that these were configurations defined as medium or medium/high. They belong to the middle values on the point scale between the evaluation of 2 and 3. The middle range is always difficult to evaluate. However, satisfactory results were obtained anyway. More than 88% of the linguistic ratings from the fuzzy model agreed with the expert ratings.

4. CONCLUSION

This paper presents a method in which, given a known configuration of the technical system of an airport security screening lane, the best team can be selected from the set of available operators to perform particular tasks. This is important due to the fact that in addition to the direct tasks, which are related to the inspection of passengers and objects, security control operators must also perform other tasks such as: patrols, gate operation, video surveillance, etc. With the obtained method, it is possible to select a team that will combine the best aspects of security and system performance according to the experts' expectations. This paper proposes a method to select a team for one security control line. Satisfactory accuracy of the fuzzy evaluation model was obtained. This is new to the existing state of the art. Until now, this possibility has not been considered because there was a lack of knowledge about the actual efficiency of detection of prohibited items by screening operators. However, due to the construction of a training station that will collect such data, it will now be possible to analyze this.In the next stages of development of the method, it will be extended to include the possibility of simultaneously allocating all workers to handle all security control lines.

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