Telematic Support of Baggage Security Control at the Airport

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Abstract. A key element of baggage security control at the airport is a human - the security screener. He/she performs some of the tasks remotely, and is supported by the telematic system, making the x-ray baggage screening. The aim of this paper was to analyze the dependence of the number of errors on the experience and the frequency of virtual threat images projection (TIP). The study was based on measurements under real conditions at the Katowice-Pyrzowice International Airport. In the framework of this research two basic types of errors made by security screeners were identified. The results show that the number of errors is dependent from both the experience and the frequency of the stimulus, represented by TIP images. As a result, it was possible to determine the boundary level of experience that entitles security screener to independent work. Also the recommended frequency of threat images projections was determined.

Keywords: telematic support, security control, baggage screening, airport, system operator's errors, air transport safety and security.

1 Introduction

Special procedures and devices that lead to a high level of safety and security are used in present air transport in two main areas. In the first one (safety) unintentional operational errors are considered. They consist in non-compliance to procedures, technical failures, making the wrong decisions and many more [9]. In the second area (security) acts of unlawful interference i.e. intentional acts of hooliganism and even terrorism are being analyzed [6,7].

In this paper, we focus on the second of these areas, in particular the issue of baggage security control at the airport. This is an extremely important issue, because people who plan actions against the security of air transport, very often tend to put onboard the aircraft objects (cold steel, explosives, corrosives, etc.) that can help them in hijacking the aircraft or carrying out a terrorist attack [2]. Such attempts are usually made by trying to hide these items in hand baggage or in hold baggage.

Considering the traffic volume on the average airport, the issue of passengers and staff security, and the time needed to control all the baggage, one can easily conclude

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that security screeners' work must be supported by a specialized telematic system [20]. It consists of an x-ray devices and software responsible for:

- generating high-quality image of baggage content [4],
- automatic image recognition of threats [19],
- delivering the image to a security screener, located at some distance from the control point,
- checking the screeners' work by: displaying TIP (Threat Image Projection) images, registering the remote detection of an image of prohibited object, detection performance analysis, archiving results [18].

The whole security check point (SCP) can be regarded as a complex socio-technical telematic system, supporting the maintenance of a high level of aviation security. A technical standard of the x-ray equipment used, control process organisation option and the technical condition of the equipment are some of the important factors that determine the level of safety and security [14]. However, the main factor is the quality of security screeners' work [13].

Analysis of the errors committed by the screeners, their causes and possibilities of their elimination [3] is the main research problem this study. Results are based on measurements made in 2014 at the Katowice-Pyrzowice Airport. Answers to the following questions that the existing literature does not answer were sought:

1. What experience of screener is needed to let him/her to work independently at the security check point, with the maximum possible level of security?
2. What is the dependence of the frequency of errors on the frequency of displaying TIP images? On this basis the best frequency of TIP's was sought.

The paper is structured as follows. Section 1 provides an introduction and formulation of the research problem. Section 2 presents the TIP system as a tool for telematic support of security screeners' work and at the same time for its assessment. Section 3 presents an analysis of the human factor as one of the key elements of the baggage security control at the airport. Special attention was paid to the types of errors and their possible causes. Section 4 contains the main part of the paper - analysis of the dependence of the number of errors from experience, expressed by working time and number of checked bags. Quantitative relation between the number of errors committed and TIP frequency was analysed, as well as possible actions that will minimize the number of errors. Chapter 5 provides a summary and conclusions.

2 TIP as a Telematic Support System for Security Screeners

The idea of TIP system is to project a virtual prohibited item on the image of the piece of baggage being screened. A database of images of items prohibited for air transport, that is included in TIP software, contains different images, depending on whether we are dealing with a hand baggage or a hold baggage. In the latter case, all kinds of explosives and pyrotechnics are prohibited. The catalogue of prohibited items is much broader in case of hand baggage. It includes also objects with sharp ends and liquids. Colloquially, we simply call these images TIP-s, and in the situation when the system displays an image from the database we can say that a TIP is displayed.

The operator's task is to detect the virtual object in the image and confirm this fact by pressing the button on the x-ray device. This increases the screeners' awareness, as they are forced to search for prohibited items in the baggage image more often than is the case when the TIP system is not used. If the response is correct, the system confirms that the screener has detected the TIP and records his/her reaction time. In case of no reaction, the system informs about an error and records this fact for further analysis. Such data is the basis for the research presented in Chapter 4.

The TIP system fulfils two important functions. On the one hand, it allows checking alertness, perceptiveness and knowledge of the screener. Depending on the number of mistakes, one can work out an opinion on the effectiveness of the employee. On the other hand, the system forces the screener to pay more attention to his/her work, thereby raising the level of safety of air travel. This kind of stimulation is beneficial for the effectiveness of the control. The issue of the impact of the frequency of these stimuli on screeners' work is the subject of analysis in Chapter 4.

3 Human as a Part of Baggage Security Control at the Airport

Technical solutions used for automatic image recognition of threats, made a great progress in the last decade. However, fully automated solutions do not apply so far. Around 30% of hold baggage and 100% of hand baggage is controlled with the participation of human - manually or remotely using x-ray devices.

3.1 Effectiveness of the Remote Control of the Baggage

The effectiveness of baggage control process performed remotely by the screener is affected by numerous factors. They can be divided into two main groups. The first one is related to the class of x-ray device used and was analysed in [15]. The second group is related to the human - the security screener and can include:

- an overall assessment of the screener's potential, depending on his/her experience, level of training and the overall attitude to his/her duties: restrictive or lenient,
- number of errors committed during baggage control,
- organizational factors, characterizing the degree of screener's involvement throughout the whole baggage security control process.

In this paper we deal with factors from the second group and in particular with the issue of screeners' errors.

3.2 Causes of System Operator's Errors

There are several groups of causes contributing to the errors made by the operator of a telematic system, an example of which is considered in this paper. These include:

- baggage characteristics: the complexity of the evaluated image, orientation of a prohibited object in relation to the screener and the degree of overlap between the different images adjacent to the forbidden item [12],
- technical factors : the type and condition of the telematic support equipment that generate and transmit x-ray images [8],
- environmental factors : workplace organisation, lighting, temperature,
- individual short-term factors: nervousness, lack of sleep, weariness (resulting from the monotony of work and lack of incentives), fatigue (due to the length of the work, work at night or due to an excess of stimuli) [17],
- individual long-term factors: level of training, experience, security culture [16].

3.3 Types of Screeners' Errors

Within the research measurements were carried out at Katowice-Pyrzowice International Airport from January to April 2014. Types and frequency of the errors were specified. We have established that screeners make the following types of errors:

- They do not point (notice) the virtual prohibited item located in the image of the scanned baggage. We called it the type A error. It is a very worrying situation. Because if the screener did not notice the image of the virtual prohibited item it can be assumed with the same probability that they will not notice a real prohibited item. A large number of such mistakes would mean that the whole security system of the airport is of poor quality. This is because the main purpose of the baggage security control, i.e. detecting the prohibited item, is not fulfilled.
- They point as dangerous the bags which in fact contain neither a virtual, nor a real prohibited item. We called it type B errors. This situation can be interpreted in two ways. We can assume that the operator had (due to the analysis of the image displayed on the screen of the x-ray scanner) reasonable concern and suspicion as to the content of baggage so he/she showed alertness, which undoubtedly is a positive feature. However, it is also possible that in order to get a good rating, he/she marked automatically, and without a thorough analysis of the image, many scanned baggage as suspicious.

From the security point of view, the most important are the type A errors. The essence of the security control carried out by an operator with the use of x-ray scanners is the ability to recognise the images of the prohibited items. The number of type A errors is the measure of this ability. In turn, type B errors can disorganize the screeners' work, resulting in the need for very frequent manual control of the baggage. This reduces the throughput of such a system, but more important is that a large number of false alarms weakens the screener's vigilance.

4 The Dependence of Errors on the Experience and Frequency of Stimulus

The theoretical knowledge that screeners acquire during training in civil aviation security establishes certain frameworks and patterns which they will use when performing their duties. However, just like in any other occupation that requires employees to operate equipment, assess the situation, relate facts to one another or make decisions, one cannot become theoretically prepared for all possible situations that can occur in real life. This is particularly true of non-standard situations or emergencies [1], [10], [13]. Such situations require solving unusual decision-making problems and being able to assess possible options for action in a factual, substantive and calm way as well as in the context of the current legal and organisational regulations or infrastructural limitations. An employee acquires these skills over time while working at a security screening checkpoint, thus gaining experience [5].

It is very difficult to assess experience of a security screener, i.e. the extent to which he/she is able to work independently or even supervise and train new employees. This is because it is a subjective matter and, additionally, an employee's performance depends on his/her personality as well as his/her ability to work in a group; therefore, it is hard to carry out an unambiguous assessment in this area [11].

4.1 Measurements of Errors Made by Security Screeners

The effectiveness of security screeners in detecting prohibited items was measured during the period from March 2013 to February 2014. The statistics of errors that had been recorded by baggage screening equipment with the TIP system were used for this purpose. Measurements were made of the number of TIP images which were not recognised by a security screener (type A error) and the number of identifications of a prohibited item that was not really there (type B error).

As a measure of type A errors we assumed the ratio of the number of unrecognized TIP-s to the total number of displayed TIP-s. As a measure of type B errors we assumed ratio of the number of false positives (the number of luggage mistakenly identified as containing prohibited items) for all checked baggage.

4.2 Analysis of the Number of Errors Depending on Experience

To find the relation between the number of errors and experience, measurements were carried out for three employees who had just begun working as security screeners. The results of the measurements are presented in Table 1, whereas their graphical representation is shown in Figure 1.

The measurement results clearly show that the number of errors (both type A and type B errors) committed by inexperienced security screeners during their first months of work is very large. The number of both types of errors decreases over time as the employees gain experience. It can be noticed that the error rate decreases to a level that is acceptable according to the regulations after about five months and it can be said that the rate stabilises after about eight months.

Table 1. Measurements of errors made by security screeners with respect to the number of months of work experience [own study]

Month	Number of TIPs	Number of bags	Number of type A errors	Percentage of type A errors	Number of type B errors	Percentage of type B errors
1	61	3185	38	62.30%	66	2.07%
2	261	10625	104	39.85%	172	1.62%
3	199	8577	50	25.13%	340	3.96%
4	218	9058	52	23.85%	217	2.40%
5	186	8271	39	20.97%	90	1.09%
6	242	10158	45	18.60%	101	0.99%
7	193	8060	47	24.35%	80	0.99%
8	195	8507	28	14.36%	99	1.16%
9	174	7198	30	17.24%	67	0.93%
10	188	8184	29	15.43%	61	0.75%
11	127	7809	23	18.11%	61	0.78%
12	85	6131	20	23.53%	28	0.46%

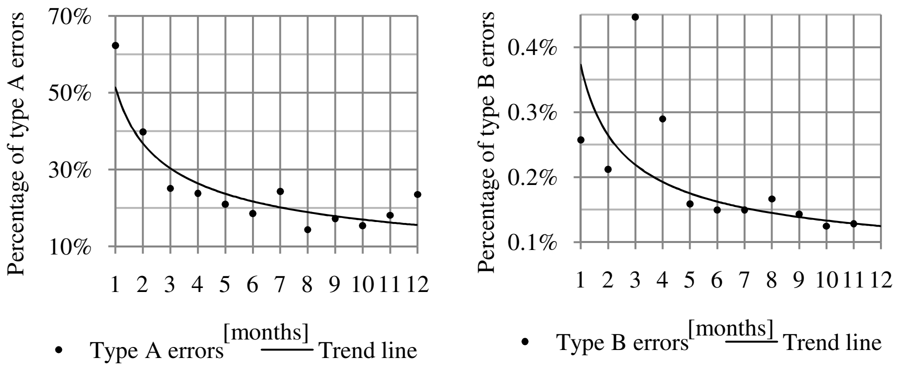

Fig. 1. The relation between type A and type B errors and one's work experience [own study]

4.3 Optimisation of the Training Process

A very important factor in the analysis of the training process is the number of errors, related to the cumulative number of screened bags, which parameterizes the training process. To examine this factor and to determine the appropriate moment at which an employee can be considered experienced enough for standalone baggage screening, moving averages were used for type A errors, using the following model.

Designations:

n - the number of the month,
N - the total number of months,
$x_t(n)$ - the number of TIP-s displayed during the *n*-th month,
$x_b(n)$ - the number of bags screened during the *n*-th month,
$x_{eA}(n)$ - the number of type A errors committed during the *n*-th month,
$y_{eA}(n)$ - the percentage of type A errors committed during the *n*-th month,

$y_b(n)$ - the cumulative number of bags screened during n months,
k - the number of periods considered in moving averages.

Moving average characterising the rate of the screener's errors can be determined from the following formula

$$y_{eA}(n) = \frac{\sum_{i=\max(1,n-k+1)}^{n} x_{eA}(i)}{\sum_{i=\max(1,n-k+1)}^{n} x_t(i)} \quad (1)$$

In turn, the indicator characterising the experience can be described as follows

$$y_b(n) = \sum_{i=1}^{n} x_b(i) \quad (2)$$

The graph of the rate of errors y_{eA} related to the cumulative number of baggages y_b averaged for one screener is shown in Figure 2.

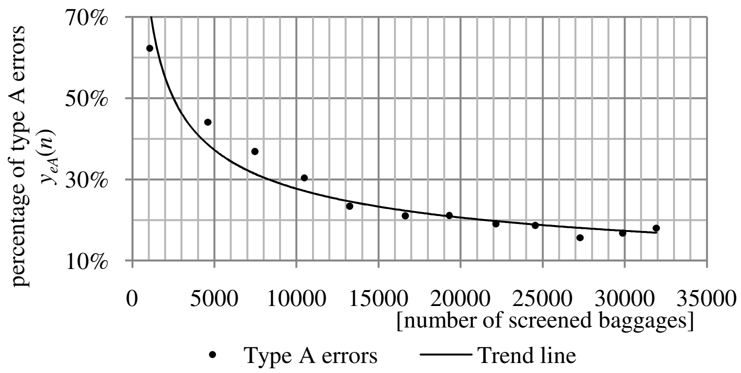

Fig. 2. Dependence of the rate of errors on the number of screened baggage [own study]

Empirically determined relation shown in Figure 2 specifies the moment after which the security screener may be allowed to work independently. Assuming a boundary error rate $y_{eA} = 0.2$, one can see that the screener has the appropriate skills after controlling about 22,000 bags. In turn, the maximum error rate allowed by the regulations $y_{eA} = 0.25$ is obtained after controlling about 13,000 bags. The study shows that the recommended number of controlled bags before the screener is allowed to work standalone should be set to 20 thousand.

4.4 Relation between the Screener's Errors and TIP Frequency

The frequency of the stimulus, defined as the TIP appearance in the x-ray image, has been listed in Section 3 as one of the causes of errors. In order to find the proper frequency of TIPs an experiment involving 93 security screeners from Katowice-Pyrzowice International Airport was conducted. Results averaged for all employees together, show no statistical relation between the frequency of errors and the TIP frequency. However, closer analysis of the results of measurements allows for the identification of four groups of screeners:

1. Those who commit few type A errors and few type B errors. These persons have an ideal profile for the security screener position.
2. Persons of a precautionary nature. They commit few errors of type A and a lot of type B errors. These screeners are carrying out a rational principle: 'better express doubts and proceed with manual baggage check than overlook the forbidden item'.
3. Persons restrained in identifying suspicious baggage. They commit a lot of type A and few of type B errors. Doing so may result from both a psychological determinants but also from difficulties in the perception of images of prohibited items.
4. Those who commit a lot of type A and type B errors. This type of person is the least useful in the security screener position. Employees in this group are those indicating baggage for manual control at random, without a deeper analysis of the image from the TIP system.

For the presentation of the dependence of the number of errors on the frequency of the stimulus, representatives of the above four groups of employees were chosen. Sample measurements from the period January-April 2014 are presented in Table 2 and in Figure 3.

Table 2. Characteristics of errors made by the screeners from different groups [own study]

Screener type	Number of TIPs	Number of bags	Number of type A errors	Percentage of type A errors	Number of type B errors	Percentage of type B errors
Group 1	161	9739	12	7.5	49	0.50
Group 2	172	10678	26	15.1	235	2.20
Group 3	185	11187	72	38.9	75	0.67
Group 4	257	16943	68	26.5	554	3.27

The graphs in Figure 3 show the results for the usable range of TIP frequencies, i.e. from 1% to 3%. Some interesting regularities can be observed:

1. Screeners committing a small number of type A errors (group 1 and 2) are characterized by an increase in the number of errors with increasing TIP frequency. For those who commit a large number of type A errors (group 3 and 4), this relation is reversed: the higher the TIP frequency the lower the number of errors.
2. Screeners committing a small number of type B errors (group 1 and 3) are characterized by an increase in the frequency of errors with increasing TIP frequency. Similarly, screeners with a high number of type B errors (group 2 and 4), record its' decrease with increasing TIP frequency.

Psychological analysis of the reasons of such screeners' behaviour goes beyond the scope of this work. The conclusion of this analysis is that in the general case neither very low nor very high TIP frequency is appropriate. Most preferred is the intermediate TIP frequency, about 2%. Only when we know to which of the four identified groups the screener belongs, we can select individual TIP frequency to him/her.

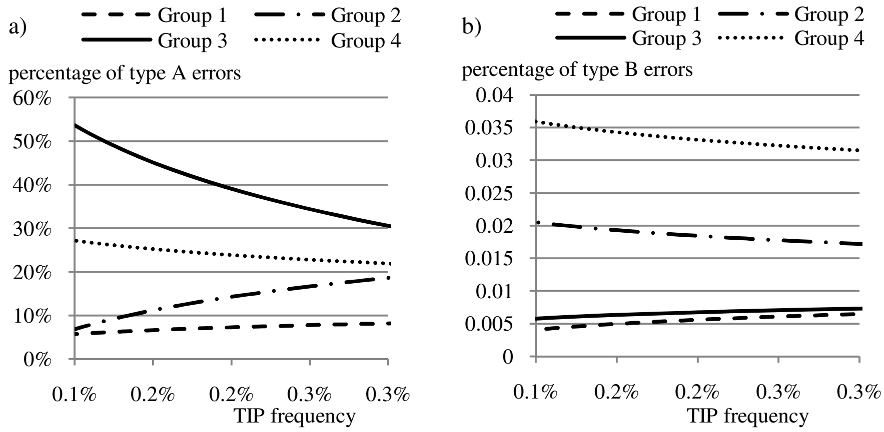

Fig. 3. Relation between the screener's errors and TIP frequency a) - type A errors, b) - type B errors [own study]

5 Conclusion

The paper presents an analysis of the dependence of the number and types of errors made by the security screeners on their experience and the frequency of the stimulus, represented by an image of a prohibited object. The basic material for analysis were measurements of errors committed by the screeners. They were recorded in real conditions, using the telematic support of Threat Image Projection (TIP) system.

One of the results of the research is finding the relation between the screeners' experience and the number of errors they commit. This allowed for an indication of the boundary number of 20,000 controlled bags, which may entitle the employee to work independently with screened image analysis.

The second result was to determine the relation between the TIP frequency and the number of type A and type B errors. This dependence on a general level does not exist. However, the identification of four groups of screeners, characterized respectively by low and high number of errors of type A and B, allows observing some interesting relations. This makes it possible to say that neither very low nor very high TIP frequency is appropriate in the general case. However, with the knowledge how effective the screener's work is (i.e. to which of the four groups he/she belongs) it is possible to select TIP frequency best for him/her.

References

1. Bazargan, M., Guzhva, V.S.: Impact of gender, age and experience of pilots on general aviation accidents. Accident Analysis & Prevention 43(3), 962–970 (2011)

2. Butler, V., Poole, R.W.: Rethinking Checked Baggage Screening, Policy Study 297, Reason Public Policy Institute (2002)
3. Feng, Q., Sahin, H., Kapur, K.C.: Designing airport checked-baggage-screening strategies considering system capability and reliability. Reliability Engineering and System Safety 94, 618–627 (2009)
4. Flitton, G., Breckon, T.P., Megherbi, N.: A comparison of 3D interest point descriptors with application to airport baggage object detection in complex CT imagery. Pattern Recognition 46, 2420–2436 (2013)
5. Fruhen, L.S., et al.: Safety intelligence: An exploration of senior managers' characteristics. Applied Ergonomics 45(4), 967–975 (2014)
6. Gerstenfeld, A., Berger, P.D.: A decision-analysis approach for optimal airport security. International Journal of Critical Infrastructure Protection 4(1), 14–21 (2011)
7. Gkritza, K., Niemeier, D., Mannering, F.: Airport security screening and changing passenger satisfaction: An exploratory assessment. Journal of Air Transport Management 12(5), 213–219 (2006)
8. Kirschenbaum, A., et al.: Trusting technology: Security decision making at airports. Journal of Air Transport Management 25, 57–60 (2012)
9. Le Coze, J.C.: What have we learned about learning from accidents? Post-disasters reflections. Safety Science 51(1), 441–453 (2013)
10. Malakis, S., Kontogiannis, T., Kirwan, B.: Managing emergencies and abnormal situations in air traffic control (part I): Taskwork strategies. Applied Ergonomics 41(4), 620–627 (2010)
11. Malakis, S., Kontogiannis, T., Kirwan, B.: Managing emergencies and abnormal situations in air traffic control (part II): Teamwork strategies. Applied Ergonomics 41(4), 628–635 (2010)
12. Michel, S., Mendes, M., Schwaninger, A.: Can the difficulty level reached in computer-based training predict the results in x-ray image interpretation tasks? In: 2010 International IEEE Carnahan Conference on Security Technology, pp. 146–155 (2010)
13. Schwaninger, A., Hardmeier, D., Hofer, F.: Measuring visual abilities and visual knowledge of aviation security screeners. In: 38th Annual IEEE International Carnahan Conference Security Technology, pp. 258–264 (2004)
14. Skorupski, J., Uchroński, P.: Rozmyty model oceny urządzeń systemu kontroli bagażu w porcie lotniczym. In: Skorupski, J. (ed.) Współczesne problemy inżynierii ruchu lotniczego– modele i metody, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa (2014)
15. Skorupski, J., Uchroński, P.: A fuzzy system for evaluation of baggage screening devices at an airport, European Safety and Reliability Conference, Wrocław (in press, 2014)
16. Stroeve, S.H., Sharpanskykh, A., Kirwan, B.: Agent-based organizational modelling for analysis of safety culture at an air navigation service provider. Reliability Engineering and System Safety 96(5), 515–533 (2011)
17. Wang, T., Chuang, L.: Psychological and physiological fatigue variation and fatigue factors in aircraft line maintenance crews. International Journal of Industrial Ergonomics 44(1), 107–113 (2014)
18. Wales, A., Halbherr, T., Schwaninger, A.: Using speed measure to predict performance in x-ray luggage screening tasks. In: 43rd Annual Carnahan Conference on Security Technology, pp. 212–215 (2009)
19. Wells, K., Bradley, D.A.: A review of X-ray explosives detection techniques for checked baggage. Applied Radiation and Isotopes 70, 1729–1746 (2012)
20. Wetter, O.E.: Imaging in airport security: Past, present, future, and the link to forensic and clinical radiology. Journal of Forensic Radiology and Imaging 1(4), 152–160 (2013)