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A fuzzy model for evaluating airport security screeners' work

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ABSTRACT

A baggage screening system is one of the factors that determine air transport security. It prevents objects and materials that could be used to commit an act of unlawful interference from being placed on board an aircraft. The aim of this paper was to present a model and a computer system supporting the management of a security screening checkpoint's organisation at an airport. This model was to take into account the role of the human factor in this process, in particular of many subjective factors that influence the effectiveness of an airport security system, such as an employee's experience, level of training or attitude to the work he/she does. The studied process involves numerous dependencies which are intuitive and subjective in character and which cannot be unequivocally described. Therefore, a fuzzy model and a fuzzy inference system were created because they are suitable for analysing decision-making processes in the context of uncertainty. The model was parameterized based on expert assessments as well as measurements and experiments that had been carried out at the Katowice-Pyrzowice airport. The model and the computer system that have been developed make it possible to evaluate the effectiveness of airport security screeners in detecting prohibited items in baggage. The experiments made it possible to evaluate individual employees and groups of employees working during the same shift. The tools that had been obtained allowed us to make a recommendation that comprehensive training sessions should be organised every 12 months and ongoing training sessions should be held every 6 months.

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1. Introduction

The security of an airport depends on many factors, which are discussed in more detail in the literature (Gerstenfeld and Berger, 2011; Uchroński, 2011; Skorupski and Uchroński, 2014a). In most general terms, these factors can be divided into technical (Skorupski and Uchroński, 2014b) and human ones. People play different roles in an airport management system (AMS) and appear at many different levels of its functioning. At the operational level, a human being takes on the role of a person screening passengers and their luggage as well as patrolling airport premises in search of people who might have unlawfully entered the restricted area at an airport. At the tactical level, a human being assumes the role of the organiser and controller (supervisor) of the activities carried out by all services, whereas at the strategic level, he or she establishes regulations and legal standards. On the other hand, it is also the human being that constitutes the main source of risk, which is to be

counteracted by airport security (Price and Forrest, 2013).

1.1. A human being as an element of an airport security system

The role that the human factor plays in civil aviation, in particular in civil aviation security, became a subject of research not long ago, i.e. in the 1970s. The events that occurred in the US on 11 September 2001 gave a direct impetus to the intensification of activities and to creating new, more restrictive regulations (Seidenstat and Splane, 2009). Attention was also directed to training the personnel in threat detection skills and in reacting appropriately to any kinds of non-standard behaviour on the part of passengers (Alards-Tomalin et al., 2014; Dąbrowska, 2011). This is because human error, which is caused by deliberate action or deficiencies in training, may have catastrophic consequences for an airport, a carrier and passengers (Price and Forrest, 2013). The awareness that a human being is a factor that may significantly influence the level of air transport security causes this factor to be treated with special care in civil aviation security. This care is manifested, for example, in the checks that are carried out by

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national quality auditors, who secretly test airport security systems. These tests involve, among other things, provocation, i.e. an attempt to bring a prohibited or dangerous item hidden in the luggage on board an aircraft. The results of such tests provide a basis for evaluating the work of a particular security screener (Schwaninger et al., 2004).

Apart from content knowledge, an employee's psychophysical abilities that allow him/her to effectively carry out his/her tasks are also important. A person who is unable to distinguish between colours or has significantly reduced visual acuity cannot work as a security screener, if only because of the very nature of the image that is generated by an X-ray source (Flitton et al., 2013). What is also important for this job is employees' experience because it allows them to carry out their tasks independently and effectively as well as an attitude that guarantees that they will work conscientiously and diligently.

The mechanism of the civil aviation security system is based on the principle of limited trust. Any activities that are undertaken with regard to a passenger and his/her luggage are aimed to detect prohibited items, which a passenger-terrorist could use to commit an act of unlawful interference (Butler and Poole, 2002). Although the specialised equipment for the screening of people and baggage that security screeners have at their disposal is becoming increasingly more advanced, it will always be the human being who will constitute a link between technology and a decision-making process, whereas equipment will always be merely an element supporting a human being in his/her work.

This paper analyses various aspects of the activity of a human being, i.e. a security screener, with regard to that screener's effectiveness in eliminating threats.

1.2. Literature review

The screening of checked baggage is largely carried out automatically (Wells and Bradley, 2012). A human being, however, constitutes an important element of this process since the human ability to think analytically and assess the risk while considering all the factors that are specific to a particular case makes a human being an integral part of the security system. On the other hand, the effectiveness of an airport security system, including the checked baggage screening system, depends on a human being's psychophysical abilities, level of training and motivation. Schwaninger et al. (2004) pointed out that a security screening system at an airport is as effective as the employees who carry out the screening. The paper presents two methods of testing security screeners' effectiveness: the prohibited items test (PIT) and the object recognition test (ORT). These methods are aimed to determine the relationship between the type of a prohibited item, its location in the baggage and the possibility that it will be detected by a security screener. The authors of the present paper expand this approach by directing more attention to the characteristics of a particular security screener him-/herself than to the baggage he/she is inspecting. The article by Feng et al. (2009) presents an attempt at analysing the relationship between the reliability of a baggage screening system and its effectiveness. Two kinds of errors committed by security screeners were taken into account and principles of conduct were proposed for a two-level screening system. However, the assumptions that were made about the probability of security screeners committing an error were unrealistic. In the present paper the authors examine the actual probabilities that were obtained based on measurements.

In their paper, Graves et al. (2011) analysed the factors that influence the effectiveness of baggage and passenger screening systems at an airport while taking account of the fact that such systems should be designed by considering security screeners as a

critical factor in their performance. The authors of the present paper supplement these studies with quantitative analyses of the relationships between the factors in question and the effectiveness of a baggage screening system. McCarley's (2009) paper points to the important role of any kind of aids, even minor ones, that indicate that special attention should be paid to a particular item of luggage in increasing the effectiveness of security screeners' work. In their article, Wales et al. (2009) used the Threat Image Projection (TIP) system to assess a security screener's competence. A linear relationship between the response time and the number of images of prohibited items that had been detected was established. The authors of the present paper also employ the statistics of the TIP system to evaluate a screener's experience, which makes it possible to achieve the paper's aim, i.e. to quantitatively determine a given security screener's effectiveness in detecting prohibited items.

In general, it can be stated that the following are the basic factors that influence the errors made by security screeners which are analysed in the literature: the complexity of an image that is being assessed, a prohibited item's position relative to the person who is carrying out the screening as well as the extent to which different images of objects that are adjacent to the image of the prohibited item overlap (Michel et al., 2010). The approach that has been adopted in the literature focuses on looking for the relationships (mainly qualitative ones) between particular features of luggage and the type as well as number of errors made by security screeners. This paper presents a quantitative analysis of the relationships between a security screener's individual characteristics and his/her effectiveness in detecting prohibited items. Such an approach makes it possible to practically apply the obtained results in the process of managing the organisation of a security screening checkpoint at an airport by selecting the appropriate employees (a group of employees) to carry out particular tasks. The method that is presented in this paper can also be used to improve the training programme.

When analysing the literature with regard to particular research methods one can notice several trends. This brief review will only include those which were also adopted for the purpose of the present paper. Many of the relationships that exist within the analysed system are intuitive and subjective in character and they cannot be unequivocally described. It is therefore necessary that decision-making processes should be analysed in the context of uncertainty (Dubois and Prade, 1992). As a result, fuzzy methods or methods using the rough set theory must be adopted (Greco et al., 2001). The article written by Akgun et al. (2010) presents an interesting model that examines the vulnerability of critical infrastructure's elements, including airports, to terrorist attacks. The proposed approach is referred to as the fuzzy integrated vulnerability assessment model (FIVAM). It is based on the fuzzy set theory and aimed to search for hidden loopholes in the system, which result from the internal, functional relationships within that system. Liou et al. (2011) proposed that dominance-based rough sets should be used to examine service operating systems at airports. This model is based on a set of "if..., then..." decision rules. Similar rules were used in this paper but they were expressed in the form of fuzzy conditional statements.

Wu and Mengersen (2013) suggest that there is a need to analyse airport security systems by adopting a two-criterion approach, i.e. by taking both the processing time (throughput) and the effectiveness of security screening into account. The processing time and security costs have been analysed, for instance in (Hainen et al., 2013; Kirschenbaum, 2013; Stewart and Mueller, 2014). This paper presents an attempt to provide tools for describing the second of these criteria. Generally speaking, there are no analyses of the checked baggage security system's effectiveness in the literature, especially with regard to the human

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