A fuzzy system to support the configuration of baggage screening devices at an airport

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ABSTRACT

An airport is a complex engineering system; it is composed of many elements interconnected with numerous internal relations with a strongly pronounced role of the human factor. One of the specific tasks carried out by the airport managing entity (AME) is to configure the airport security system (ApSS) so that to attain the expected level of confidence in the airport safety and security. This task consists in selection of infrastructure, technical equipment, allocation of personnel and financial means that are necessary to perform all functions of the ApSS. One of the aspects of the configuration of the ApSS is the allocation of available X-ray baggage screening devices searching for items prohibited for transportation. To make this allocation, we need to know how effective these devices are (in terms of detecting prohibited items). This assessment is dependent on several factors which are treated as linguistic variables and are input to fuzzy inference system: the ability to detect explosives, the number of detection lines, the effectiveness of the TIP (Threat Image Projection) system and the age of the machine. Some of these elements are difficult to objective assessment, as they are heavily dependent on the human factor or the information is uncertain or incomplete. So fuzzy ApSS analysis is proposed. The output from the fuzzy inference system is linguistic variable *Device evaluation*. The meaning of this variable is the ability to protect the aircraft against prohibited items. The proposed new method of assessing the airport baggage screening system involves the construction of a hierarchical fuzzy inference system. The usefulness of the method is exemplified for Katowice–Pyrzowice International Airport, for which an assessment of devices has been performed. The results show that not only allocation of specific devices for specific control points is important for the security of passengers. Also important are the locally accepted principles of their work, which so far are not specified by international regulations. This applies for instance to the selection of the number and frequency of TIP images. Experiments show that the proposed approach can be effective as part of an expert system for supporting the airport operator in configuring ApSS.

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1. Introduction

Airport is a public use facility used for commercial flights. It is a dedicated area on land, water or other surface, partly or entirely devoted for take-offs, landings and ground or water traffic of aircrafts, with the permanent buildings and facilities, entered into the airports register (Aviation Law, 2002). An airport consists of numerous elements which are linked with various internal relations with a strong impact of the human factor. It is therefore a complicated socio-technical system. Operational availability of an airport may be defined as an exploitation state, where (Kozłowski, Skorupski, & Stelmach, 2008):

– it is possible to continue approach to landing and landing,
– aircraft ground handling is possible including pre take-off handling of an aircraft, passenger service related to accepting passengers on board of an aircraft, as well as disembarking after landing and accepting and receipt of baggage,
– it is possible to execute the departure procedure after finishing the ground handling in accordance with a plan, procedures and air traffic provisions.

The correct operation of an airport requires providing the appropriate level of security by the airport managing entity (AME). One of the aspects involved in providing security is protection against the acts of unlawful interference (ICAO, 2010).

1.1. Literature review

The consequences of admitting the baggage with prohibited content to transport (as a result of misjudgement or carelessness of

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security personnel) can be catastrophic (Pettersen & Bjornskau, 2015; Price & Forrest, 2013). Security of civil aviation can be analysed with the standard risk assessment methods (Tamasi & Demichela, 2011; Wong & Brooks, 2015). However, the probabilities are difficult to assess quantitatively, so these considerations are usually conducted at a high level of generality. In our paper we suggest a different approach. We resign from defining the probabilities to the benefit of assessing the efficiency of screening devices with the use of expert judgements. Among papers that are strictly related to the problems of airport security it is worth to note the works of Gkritza, Niemeier, and Mannering (2006) and Alards-Tomalin et al. (2014), which indicate the need to provide the proper security level at an airport but at the same time minimize the nuisance caused by the security control process to the passengers. The new way of meeting the requirements for security control were suggested by de Lange, Samoilovich, and van der Rhee (2013), where considerable savings were found by using the "virtual queues". However, in the work of Liou, Tang, Yeh, and Tsai (2011) it has been proposed to use dominance-based rough set approach to an airport service survey. The basis for the prepared model is the set of decision-making rules in the "if … then …" form. Similar rules but in the form of fuzzy conditional sentences has been used in this article.

In this work we show that the airport security (protection) system is an element of preventive actions intended for preventing a situation, where the airport will not be able to realise its function. It is therefore, an important area of an effective strategy for keeping the airport system in operation. As there would be no purpose in the attempts of optimisation of the strategy for keeping the technical part of the system in order, if there are unlawful actions from the side of the passengers or terrorists - the airport will not be able to fulfil its functions. In our work we assume that it is not possible to fully evaluate the operational readiness of the system without the prior evaluation of the protection system (airport security system). In (Wells & Bradley, 2012) the relationship between the screening efficiency, and both the human factor and the X-ray equipment were mentioned. However, these two elements were analysed separately. In our paper we extend the analysis by looking at the X-ray devices from the human (operator) perspective. The issue of the security screener's capability to properly interpret the image generated by X-ray devices was taken up by Michel, Mendes, de Ruiter, Koomen, and Schwaninger (2014). In the work of Akgun, Kandakoglu, and Ozok (2010) an interesting model has been presented allowing for multi-criteria evaluation of vulnerability of critical system (such as airports) to a terrorist attack. In (Nie, 2011) a method for baggage risk assessment was presented and sequences of using the particular X-ray scanners were suggested. This work refers to three main areas of research on the issue of improving the efficiency of the baggage security control system: discrete optimisation techniques, simulation methods and cost-effectiveness analyses. In our work we suggest a different approach consisting in considering the human factors in the assessment of screening devices. Our paper suggests an evaluation of an airport security system based on a hierarchical model of fuzzy reasoning. The layers in a hierarchical security system will not always combine as straightforwardly as our intuition would suggest, making the evaluation of a layered security effort difficult (Jackson & LaTourrette, 2015). This results from the fact that the tested system is heavily influenced by the human factor and other elements, which are not subject to unequivocal and precise description. It is impossible to detect the functional relationships between the various factors which influence the effectiveness of the security system and an evaluation of the security level. In such cases it is required to use expert opinions. As we have to deal with expert opinions, it is a known fact that very often they are formulated in a descriptive and an imprecise way. We must therefore view the decision making problem in context of uncertainty related to decision making (Dubois & Prade, 1992). All this locates the decision making problem in an area described by e.g. the theory of fuzzy

sets or rough sets (Greco, Matarazzo, & Slowinski, 2001). In (Wu & Mengersen 2013) the necessity to analyse the airport security system in terms of two criteria (capacity and efficiency of control) was suggested. The former can be expressed as numerical values and the latter as linguistic values. The present paper constitutes an attempt to deliver a tool to determine the latter. The issue of making decisions in similar conditions by many decision-makers is presented in (Chen, 2013; Park, Cho, & Kwun, 2011; Skorupski, 2014).

1.2. Design of the paper

This paper focuses on fuzzy reasoning. A similar approach, although related to the evaluation of an aircrew status, was presented in the work by Skorupski and Wiktorowski (2015). This paper is a follow up to the work (Skorupski & Uchroński, 2015a), where the general structure of interaction model in the airport security system is discussed. The extension involves the specification of effectiveness of the whole set of X-ray equipment used, together with their configuration on each security check points. We also present the analysis of equipment age and number of installed TIP images influence on the decision making regarding the possible replacement or change of devices configuration. The analysis of the efficiency of the alternative equipment configuration has been made. The subject of security screening assessment is continued in (Skorupski & Uchroński, 2015b, 2015c) where the efficiency of cabin and hold baggage screening is determined.

The paper considers some of the elements affecting the assessment of an airport security system. So far, no tools have been provided for an objective quality assessment of security control at airports, as we lack the knowledge about the prohibited objects that have been carried on board. Otherwise, we would not have permitted such objects on board. Because of this, airport managers may be unaware of the need to introduce changes that would adequately protect passengers from the acts of unlawful interference. Any changes actually taking place are based solely on the decision makers' intuition rather than on measurable values. Our paper presents a method that helps to intentionally achieve the expected effectiveness of a selected part of a security control system. This is about reaching a predefined effectiveness and not maximising it at any cost; the latter approach might bring airport traffic to a complete standstill. The presented method is primarily intended to assess the effectiveness of baggage screening devices depending on their properties.

The basic benefit from using the proposed solution is the ability to obtain a quick and effective answer regarding the use of the given device at a specific baggage control checkpoint, taking into consideration the fact that it is only a tool used by the operator. Alternatively, the proposed expert system may aid the ongoing directing of passenger streams to security checkpoints with specific equipment. The use of the fuzzy inference system in conjunction with access to expert knowledge in the form of a fuzzy rules set allows obtaining a strong practical tool. What is particularly important, most of the input variables of the fuzzy inference system come from measurements, which eliminates the subjectivity of this system component.

The paper presents the basis for building a decision support system which can draw conclusions and make decisions consisting in indicating a solution (screening devices' configuration) with the highest degree of accuracy. This system uses a knowledge base provided by experts who express it in the form of fuzzy rules. Such expert systems are extremely necessary in practice, especially when final evaluations are not known precisely, and there are no known functional relations describing them. An example from the field of aviation security belongs to a class of problems for which there is no formal mathematical model of a problem solving algorithm. Parts of the knowledge, necessary to build the knowledge base for the expert system, are available and expressed precisely (from observations and measurements), especially most input variables. Hence, within the