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Fuzzy inference system for the efficiency assessment of hold baggage security control at the airport

Jacek Skorupski [a,*], Piotr Uchroński [a,b]

[a] Warsaw University of Technology, Faculty of Transport, 00-662 Warszawa, ul. Koszykowa 75, Poland
[b] Upper Silesian Aviation Group, 40-161 Katowice, al. Korfantego 38, Poland

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ABSTRACT

One of the factors determining the aviation safety and security is the baggage security control system. It constitutes protection against placing objects and materials that could be used to perform an act of unlawful interference on board of an aircraft. The aim of this work was to create a model for assessment of airport baggage security control efficiency understood as the capability of detecting items prohibited in transport. Especially the human factor and the technical factor had to be taken into account collectively in the assessment of efficiency. Including many subjective factors such as operator's assessment, tendency to make mistakes and the control process organisation method required using means adequate to the present informational uncertainty. In this case a hierarchical fuzzy inference system was used and it was implemented as the RBES computer system. Its important element is the completely new method of assessing the actual detectability of the prohibited items. The method is based on the analysis of the frequency of mistakes (called type A mistakes) consisting in not indicating a baggage, in which the screened image showed a prohibited item, as dangerous. The equally important element is including a few possible control process organisation options, so far not mentioned in the literature, in the analysis. The experiments on the model allowed to assess the baggage security control efficiency in real conditions and indicate the right control process organisation option.

1. Introduction

The hold baggage security control, i.e. the control of a baggage put in the hold of an aircraft, is performed according to the regulations (European Commission, 2010) and is carried out in order to detect (and then remove) items and substances which cannot be transported on the board of a passenger aircraft. These include explosive and incendiary materials: ammunition, blasting caps, detonators and fuses, mines, grenades and other military explosives, fireworks and other pyrotechnics, smoke-generating canisters and cartridges, dynamite, gunpowder and plastic explosives.

The hold baggage security control is one of the most important elements determining the aviation safety and security. This is due to the fact that the items prohibited in the hold baggage may pose a serious threat to the flight operation being carried out. The consequences of admitting the baggage with prohibited content to transport (as a result of misjudgment or carelessness of security personnel) can be catastrophic (Price and Forrest, 2013; Pettersen and Bjørnskau, 2015). A classic example of such an incident is flight No. 103 of a passenger aircraft of the Pan American World Airways that took place on 21 December 1988. As a result of the explosion of a bomb placed in a hold baggage Boeing 747 aircraft flying from London to New York with 259 passengers on board fell down in a small town Lockerbie in Scotland. All the passengers were killed and the falling elements of the wreckage of the airplane killed 11 residents of the town (Smart, 1997).

1.1. The process of baggage security control

Baggage security control takes a variety of forms and is implemented with the use of various technologies. It depends from technological equipment, infrastructure or the requirements connected with providing proper capacity of an airport. The method of performing the security control affects its efficiency in terms of capability to detect prohibited items. Therefore it will be included in our method. In this chapter only the possible airport security points (ASP) operation schemes will be discussed. The assessment of its influence on the efficiency of control will be presented in Section 2.5 where the linguistic variable *Control organisation option* will be defined.

* Corresponding author. Tel.: +48 22 234 7339.
E-mail addresses: jsk@wt.pw.edu.pl (J. Skorupski), puchronski@gtl.com.pl (P. Uchroński).

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The easiest solution for the hold baggage security control is to perform the whole control by a security control operator (SCO), who analyses the image of the inside of the baggage generated by a conventional X-ray equipment. This method is not efficient, the practical capacity of such a system is assessed to be 200–300 bags per hour and therefore it can be used exclusively on small, local airports.

On airports with larger traffic the used solution consists in carrying out the control with an X-ray scanner equipped with EDS (Explosive Detection System), blended in the system of conveyors BHS (Baggage Handling System) feeding the baggage to the right place. The general structure of this solution consists in carrying out four different levels of baggage control with different automation ranges (Fig. 1).

The first level of control consists in fully automatic analysis of the baggage scans. When the baggage is accepted by the system it receives status "cleared" which allows to carry it to the sorting area where it is sorted to the assigned chute. According to the data collected at the Katowice-Pyrzowice International Airport about 70% of bags are given the "cleared" status at this stage of control. It is obvious that the efficiency of the algorithm used for image recognition is very important for the safety (Kirschenbaum et al., 2012; Maloof and Michalski, 1997). In this paper we assume that the algorithm is completely safe and it will not be taken into account in our evaluation method. We assume that the used solution resolves negatively even the slightest doubts, which means such a baggage does not get the "cleared" status. The technical, operational and decision-making issues referring to the X-ray control of hold baggage are in more detail presented in Wells and Bradley (2012) and Blejcharova et al. (2012).

In case of the lack of automatic approval of the baggage for further transport its image is passed to the operating station to be decided by the SCO. This is the second level of control. The time for making the decision given to the operator is limited, it is usually about 30 s. This time is determined individually and is not the result of legal regulations. When the baggage is accepted by the SCO it receives status "cleared" which allows to carry it to the sorting area where it is sorted to the assigned chute.

The third level of control takes place when the baggage is not accepted by the SCO. It consists in further control of the baggage and the SCO has additional time of about 30 s. It is also possible to hold the baggage at the decision-making point longer in the case when SCO finds it difficult to make a decision.

When the SCO at the third level of control is not able to determine if the baggage can be given the "cleared" status, it is passed to the fourth level of control which is manual baggage security control. For this purpose the owner of the baggage is called upon as according to the regulations (ICAO, 2010; European Parliament, 2008) they must be present during the manual control. At the operating station of the fourth level the screened image of the baggage taken at previous levels of control is also displayed.

The bag in which in the course of manual control dangerous items were detected is placed in a safe pyrotechnic container and usually it is taken outside the terminal area to be neutralised. At the same time the evacuation alarm in the sorting area and within the so-called safe zone is announced.

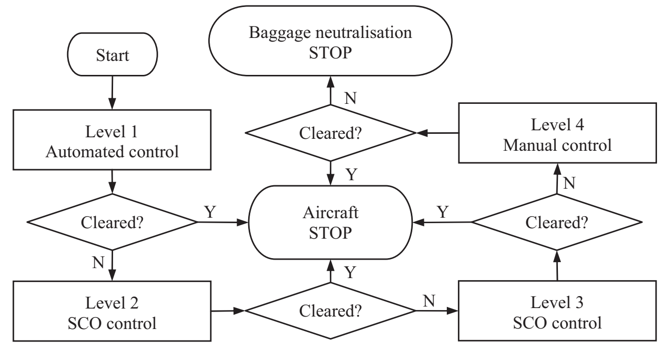

Fig. 1. The general scheme of the baggage security control at ASP algorithm.

1.2. Overview of the state of research

The important role of the airport manager is assessing the efficiency of the Airport Security System (ASeS). The system includes: baggage security control and personal security control as well as the external monitoring against the intrusion and actions of unauthorized persons at the airport. These can be analysed with the standard risk assessment methods (Tamasi and Demichela, 2011). Unfortunately due to the difficulties in quantitative assessment of probability, these considerations are 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 control with the use of expert judgements. We deal only with hold baggage security control. The method of evaluating the efficiency of cabin baggage screening was presented in our previous paper (Skorupski and Uchroński, 2015a).

In Feng et al. (2009) an attempt to analyse the relationship between the reliability of the control system of hold baggage and its effectiveness was made. Two types of SCOs' mistakes were taken into account and rules of conduct for 2-level control systems were suggested. Our paper constitutes an extension of this research as it includes as many as four levels of control used in the contemporary systems. They define five different options for organising the control process (Section 2.5). Additionally, in contrast to (Feng et al., 2009), where the adopted assumptions as for the probability of the operators' mistakes were unrealistic, in our paper the probabilities considered are realistic and come from measurements.

Since the 1980's the main focus of the organisation of the aviation safety and security system was placed on preventing hijacking of aircrafts (Seidenstat and Splane, 2009) or mitigating the risk connected with airport operations (Jonkman and Verhoeven, 2013; Ayres Jr. et al., 2013). However, since the attacks on 11 September 2001 most attention is being paid to issues of terrorist threats, particularly acts of unlawful interference with the use of small quantities of very strong explosive substances. This issue was discussed in Wells and Bradley (2012). In this paper the relationship between the efficiency of control and both the human factor and the X-ray equipment was signalled. However, the main focus was the technological aspect and these two elements were analysed separately. In our paper we combine the human and technological factor and we also extend the analysis with the manual control.

An extensive overview of the contemporary systems and methods of detecting explosives, also in aviation, can be found in Caygill et al. (2012) and Singh and Singh (2003). Whereas the analysis of the modern approach to the aspects of the integrated baggage security control is presented in Butler and Poole (2002). These studies, however, do not make attempts to assess quantitatively the effectiveness of the individual methods.

In Nie (2011) a method of analysing the efficiency of the control system based on grouping baggage in terms of the class of threat was presented. For the particular classes a risk assessment was performed and sequences of using the particular X-ray scanners were suggested. It is worth noting that this work refers to three main strands of research on the issue of improving the efficiency of the baggage security control system: discrete optimisation techniques, simulation methods and cost and effectiveness analyses. In our work we suggest a different approach consisting in considering the human factor in its numerous aspects.