Air Traffic Incidents Analysis with the Use of Fuzzy Sets

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Abstract. In safety, reliability as well as risk analysis and management, information often is uncertain and imprecise. The approach to air incident analysis under uncertain and imprecise information presented in our paper is inspired by the possibility theory. Notably, in such analyses these are both: static and dynamic components that have to be included. As part of this work, static analysis of a serious incident has been performed. In order to do this, probability scale which is based on fuzzy set theory has been given. The scenarios of transformation of incident into accident have been found and their fuzzy probabilities have been calculated. Finally, it has been shown that elimination of one of premises for transformation of the incident into accident significantly reduces the possibility of this transformation.

Keywords: serious incident, fuzzy probability, events tree, fuzzy inference, air traffic safety.

1 Introduction

Air communication is commonly thought as the most safe transport type. Because passenger safety is the main priority of all subjects engaged in air transport, technical, organization, procedure barriers are established in order to avoid air accidents. Sometimes these facilities fail; in most cases because of human error. To learn lessons from these failures, accidents are investigated in order to find their causes. Such investigation is usually qualitative [8].

In the paper, a quantitative analysis of serious incidents is proposed. The "serious incident" is usually a very dangerous event when some barriers against accident have failed to meet their goal. They are very important sources of knowledge about safety assurance systems in air transport. We want to estimate the probability that a given incident would transform into accident. With that kind of study at disposal, one can conclude whether safety facilities are sufficient or have to be extended. In order to evaluate this probability, estimation of safety barrier reliability has to be carried out. Unfortunately, in most cases there are no sufficient data to infer statistically about the frequency of events for the accident scenario. Unfortunately, it is highly unlikely to find that data. There are two reasons of such situation. First is that some of these events occur very rarely, and additionally, in past the events without significant consequences were not usually recorded. The second one is human factor with such

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measures that are difficult to evaluate as different reactions probabilities and error activity probability. Such measures are charged with uncertainty and subjective estimations. Only methods to obtain such knowledge are expert estimates. These estimations are not precise and not sufficient to probabilistic analysis.

In safety, reliability, and risk analysis and management, information often is uncertain and imprecise. In book [10] three approaches to reliability and safety with uncertain and imprecise information are presented: probability and statistics, fuzzy set theory, possibility theory (inspired by the above).

In paper [1] the following approaches for representation of uncertainty are listed: probability, imprecise (interval) probability, probability bound analysis, possibility theory (foundations: probability, statistics, fuzzy sets), Dempster-Shafer evidence theory.

The approach to air incident analysis presented in our paper is inspired by the possibility theory.

In air incident analysis both types of components have to be included: static and dynamic. Static analysis can be executed by means of fault trees with fuzzy probabilities [16, 17] and event trees with fuzzy probabilities [7]. Fuzzy probability is called possibility. The Dynamic analysis is executed in the time domain. More precisely, the analysis may be carried out using minimal and maximal values of time parameters similarly to the safety study of some railroad crossing in [9]. The other approach is probabilistic when time parameters are represented by probability distributions as in [2] where time coordination of distance protections in high voltage power transmission line was considered. The next kind of analysis will be based upon fuzzy set and will become the topic of the paper.

In this paper, the serious incident which occurred at the Chopin airport in Warsaw in 2007 year would be analyzed. Only static analysis will be executed, while dynamic one will be the topic of the following paper. In order to find the probability that given incident would transform into accident, the analysis of event trees by fuzzy probabilities will be performed.

2 Serious Air Traffic Incident No. 344/07

An analysis of incidents using fuzzy inference is illustrated with the example of a serious air traffic incident which occurred in August 2007 at the Warsaw Chopin airport between Boeing 767 and Boeing 737 aircraft. Its cause was classified as a "human factor" and the causal group H4 – "procedural errors" [18].

2.1 Description of the Circumstances of the Incident

In the incident on 13th of August 2007 participated two aircraft – Boeing 737 (B737) and the Boeing 767 (B767), which more or less at the same time were scheduled for take-off from the Warsaw Chopin airport. As the first, clearance for line-up and wait on runway 29 was issued to B737. As a second, clearance for line-up and wait on runway 33 was given to the B767 crew. The latter aircraft was the first to obtain permission to take-off. A moment after confirmation of permission to take-off, both aircrafts began the start procedure at the same time. The B737 crew wrongly assumed