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Framework for airspace planning and design based on conflict risk assessment
Part 3: Conflict risk assessment model for airspace operational and current day planning

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ABSTRACT

This paper presents a natural continuation of author's previous work that deals with the development of a conflict risk assessment model for the purpose of airspace operational and current day planning under an airspace planning and design framework based on conflict risk and task-load assessment. The model is intended to support an air traffic manager's decision-making process during sectorization (for a given set of available sectors determined at tactical planning levels) through the evaluation of conflict risk and air traffic controller task-load. The model is based on the assumption that a conflict between a pair of aircraft exists when either horizontal or vertical separation minima are violated. Additionally, it was assumed that risk is a random variable. The developed model allows for estimation of the number of conflicts and the conflict probability, as well as their distribution at intersections and along an airway. It also allows for the determination of the air traffic controller's task-load for a given airspace and traffic load. The model is intended for use in en-route airspace. An illustration of the model application shows that in addition to airspace geometry, the total conflict risk also depends on aircraft speed, traffic demand and its spatial and temporal distribution in the airspace as well as the applied separation minima. Finally, it was shown that the results of the model could be used by the air traffic managers in order to help them decide the necessary grouping (aggregation) or collapsing (disaggregation) of sectors (sectorization).

1. Introduction

Air transport is generally growing despite constraints such as the global economic crisis, with a further increase with an expected average annual rate of about 4–5% (SESAR, 2006; EC, 2011). The increase of the air traffic in Europe 2050 is forecasted in the European Commission (EC) document "Flightpath 2050" (EC, 2011) to be an almost threefold increase relative to the year 2011 (25 million commercial flights in 2050 relative to 9.4 million expected in 2011). At the same time, an increased level of safety is required through both an 80% reduction in the accident rate for specific operations, and through a significant decrease of human error (EC, 2011). Similar objectives have been defined in the USA (JPDO, 2004). Objectives mentioned in the above documents are mutually conflicting and present a significant challenge for the research and scientific community since an increase in traffic should not lead to a decrease in safety. According to "Vision 2020" (OOPEC, 2001),

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development of new operational concepts in the air traffic system are expected as well as development of safety measures and system safety performance indicators.

Physically, and operationally, the air transport system is a rather complex system with the main components – airlines, airports and air traffic control services – all interacting in and across different hierarchical levels, which constitutes a very complicated, highly distributed network of human operators, procedures and technical/technological systems. In particular, the risk of accidents and the related safety in such a complex system is crucially influenced by interactions between the various components and elements (Netjasov and Janic, 2008a,b). This implies that the provision of a satisfactory level of safety, i.e., in the airspace context a low risk of an accident, is more than just assuring that each of the components and the elements function safely (Blom et al., 1998). Due to such an inherent complexity and the severe consequences of accidents, risk and safety have always been considered as issues of the greatest importance for the contemporary air transport system (Janic, 2000). Consequently, these characteristics have been a matter of continuous research from different aspects and perspectives ranging from the purely technical/technological to the strictly institutional. In general, the former have dealt with the design of safe aircraft and with other system facilities and equipment. The later have implied setting up adequate regulations for system design and operations (Netjasov and Janic, 2008a,b).

The system infrastructure – airports and the Air Traffic Control/Management (ATC/ATM) system, although in many cases acting as temporal "bottlenecks", are expected to be able to support such growth safely, efficiently and effectively. This research is concentrated on the ATC/ATM system, i.e., on airspace planning. Ultimately, unconstrained airspace capacity, given as the maximum number of aircraft going through any given geometrical airspace in a given time period (Majumdar et al., 2005), depends on the traffic flows on certain, or all of, the airways, as well as the applied aircraft separation minima. One of the possibilities to increase airspace capacity is to reduce the separation minima (ICAOa, 1988; ICAOb, 1988; Mosquera-Benitez et al., 2009).

An increase in airspace capacity is a prerequisite for satisfying the growing demand for air traffic, but it also affects safety of aircraft operations. This is why it is necessary to develop models that will help assess the safety of such a change and to find the balance between an increase in capacity and any unwanted decrease in safety at different planning levels. A review of these types of models is given in (Netjasov and Janic, 2008a,b).

The aim of the research described in this paper is to develop a framework for airspace planning at the operational and current day level as the natural continuation of research presented in (Netjasov, 2012a,b). A further aim was to develop a risk assessment model for airspace planning purposes as a first step towards implementing the proposed framework, considering airspace organization at the operational and current day planning level. Namely, the aim of this research is to develop a tool (a risk assessment model) that could be used by air traffic managers in real time in order to support their decision making process about necessary sectorization, i.e. sector grouping (aggregation) or collapsing (disaggregation) during airspace planning process based on a conflict risk and air traffic controller's (ATCo's) task-load assessment. Data regarding weekly and/or daily traffic, i.e., flight schedules with designated aircraft types, are used as traffic demand indicators. The supply side is represented by airspace geometry (number and length of airways as well as airway tracks) which was determined as most appropriate from a safety point of view at the tactical planning level. At the operational and current day level we were concerned with the exposure of air traffic controllers to conflict situations and total task-load (sum of task load for each ATCo sub-task type) which depend on sectorization.

The paper is organized as follows. Section 2 provides a description of the proposed framework for airspace planning and design based on conflict risk assessment. Section 3 explains the development of a conflict risk assessment model for airspace operational and current day planning. Section 4 illustrates the application of the developed model in the case of a hypothetic en-route sector and flight schedule example. Section 5 draws conclusions and presents further research directions.

2. Framework for the airspace planning and design based on conflict risk assessment

The basic idea of the research presented in this paper is that different planning levels in ATC/ATM require different models for risk assessment. Their main purpose is to support decision-making processes during system planning and development, through evaluation of risk and safety of proposed changes (either in the existing or a new system).

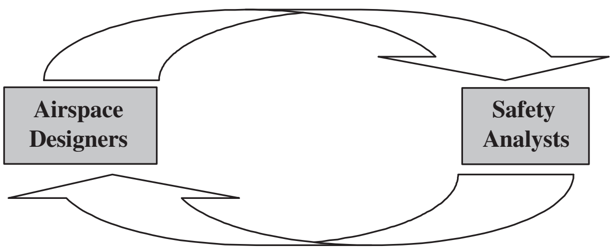

Fig. 1. Iterative process for airspace design and planning (compiled from Blom et al., 1998).