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Air traffic assignment to reduce population noise exposure using activity-based approach

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ABSTRACT

Aircraft noise has been regarded as one of the major environmental issues related to air transport. Many airports have introduced a variety of measures to reduce its impact. Several air traffic assignment strategies have been proposed in order to allocate noise more wisely. Even though each decision regarding the assignment of aircraft to routes should consider population exposure to noise, none of the air traffic assignment strategies has addressed daily migrations of population and number of people exposed to noise. The aim of this research is to develop a mathematical model and a heuristic algorithm that could assign aircraft to departure and arrival routes so that number of people exposed to noise is as low as possible, taking into account temporal and spatial variations in population in an airport's vicinity. The approach was demonstrated on Belgrade airport to show the benefits of the proposed model. Numerical example showed that population exposure to noise could be reduced significantly by applying the proposed air traffic assignment model. As a consequence of the proposed air traffic assignment, overall fuel consumption increased by less than 1%.

1. Introduction

Aircraft noise imposes various problems to airports as well as to surrounding communities. Not only does it cause health-related problems and annoyance to residents living near an airport (Kaltenbach et al., 2016; Ozkurt et al., 2015), it also has detrimental effects on the airport's business (Upham et al., 2003). Considerable efforts have been invested in order to alleviate the noise nuisance. On the European level, the Environmental Noise Directive 2002/49/EC (END) relating to the assessment and management of environmental noise has been introduced (EC, 2002). In the framework of implementing the requirements set in this Directive, many airports have developed strategic noise maps and noise action plans (Glekas et al., 2016; Vogiatzis, 2014, 2012).

Over the past decades, airports have been implementing various noise abatement measures in accordance with the recommendations of the International Civil Aviation Organization (ICAO) (Ganić et al., 2016; Netjasov, 2012). In order to reduce the noise, airports often impose measures like (night) curfews or restrictions on flight numbers even though these have a negative influence on demand and airport business. Other measures such as noise preferential runways or noise abatement procedures reduce the noise impact without influencing an airport's capacity. Some innovative approaches for managing airport noise include also surveillance technologies such as ADS–B, GBAS or RNAV (Enge et al., 2015; Gagliardi et al., 2017).

Although most of the measures aim at achieving total noise load reduction, some of them simply aim at a geographical allocation of the noise that is somehow beneficial for the nearby community (Heblij et al., 2007). One such approach includes noise preferred

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departure and arrival routes that are designed to avoid highly populated areas. Prats et al. presented a multi-objective optimisation strategy for designing aircraft noise abatement procedures that took into account the actual populated areas, their type and distribution, the hour of the day where the trajectory was supposed to be flown and the aircraft type (Prats et al., 2011a). Since it is the responsibility of Air Traffic Control to select runway in use and to assign aircraft to routes, noise allocation as the consequence of such assignment could be achieved only with their cooperation.

Several air traffic assignment strategies have been proposed in order to allocate noise more wisely. Netjasov suggested the model that was based on the categorization of aircraft according to engine type and wake turbulence category and the assignment of specific runways for take-off and landing for each aircraft category (Netjasov, 2008). This model incorporates two basic goals: to increase airport capacity and to reduce the noise level in the airport's surroundings. Heblij et al. developed the Noise Allocation Planning Tool that maintained an equal noise level over a wider area, effectively reducing peak levels (Heblij et al., 2007). Zaporozhets and Tokarev formulated and solved several problems related to minimisation of aircraft noise impact, including a selection of optimum operations around an airport by distributing the aircraft between the routes (Zaporozhets and Tokarev, 1998). On a tactical level, Nibourg et al. have developed Runway Allocation Advice System (RAAS) which is currently in operation at Amsterdam Airport Schiphol (AAS) and Basel Euro Airport and which allows controllers to choose the optimal runway (combination) in any given situation with respect to noise preferential runway system in place (Nibourg et al., 2012). Kuiper et al. proposed an optimization approach that aims to minimize the risk of exceeding the limit at any predefined location in the vicinity of the airport by distributing flights over different runways (Kuiper et al., 2013).

Each decision regarding the assignment of aircraft to routes should consider the number of people who will be exposed to adverse noise levels, since it is the noise indicator used in many countries. Visser proposed a tool for analysis and design of noise abatement procedures around airports that, besides indices that are generic in nature, include also site-specific criteria which take into account density and distribution of population in the areas surrounding an airport (Visser, 2005). Following the current practice regarding noise exposure assessment, the number of people exposed to different noise levels, presented in noise contour maps, has always been calculated based on population census data. Despite the improvements made in census procedures over recent decades, it was recognised that for many applications, including environmental and health analyses, methods to model population distribution at the small-area level were needed (Briggs et al., 2007). Increase in spatial resolution of population data could be achieved by various dasymetric models (Nagle et al., 2014). Nevertheless, due to population daily migrations, number of people at some residential areas could significantly differ from census data, especially during the time of the day when employees go to work and pupils and students go to schools and faculties. Ott was one of the first researchers to spot the drawback when relying to census data, since it leads to overlooking the fact that some residents spend a long time far from the area, which is supposed to represent their exposure (Ott, 1982). The same was concluded in a paper that incorporated people affected at the workplace and places of education into the calculation of road traffic noise damages (Kaddoura et al., 2017). By taking into account temporal and spatial variations in population, Kaddoura et al. proposed a noise internalization approach that uses an activity-based road transport simulation and time dependent noise exposure tolls to which transport users can react by adjusting their route choice decisions. In that way, by changing individual travel behaviour it is possible to reduced overall noise exposure costs (Kaddoura et al., 2016).

Although the importance of analysis of daily migrations has been recognized in many transportation studies (Hao et al., 2010; Hatzopoulou and Miller, 2010; Jiang et al., 2017, 2012; Kaddoura et al., 2016; Novák and Sýkora, 2007), to the best of the authors' knowledge, none of the air traffic assignment strategies addressed these temporal and spatial variations in population in an airport's vicinity and the number of people exposed to noise when it comes to the assignment of aircraft to departure and arrival routes.

A first attempt to consider the above-mentioned problem is made by Ganić and Babić (Ganić and Babić, 2017). In their presentation at the ATRS 2017 conference, the authors identified the problem, proposed a solution and presented preliminary numerical results. This paper represents an extension of that research.

The idea presented in this paper is to tailor air traffic assignment of aircraft to departure and arrival routes taking into account temporal and spatial variations in population in an airport's vicinity (activity-based approach) in order to reduce the number of people exposed to noise, by assigning aircraft to a route that flies over the least populated area during the flight. For that purpose, a new noise abatement approach has been proposed based on a heuristic algorithm that chooses the preferred air traffic assignment. Also, for the selected preferred air traffic assignment, the influence of this assignment on the route length and consequently fuel consumption was analysed. The approach was demonstrated on Belgrade airport to show the benefits of the proposed model on a real data example.

This paper is organised as follows. Section 2 defines the mathematical model, explaining the necessary input data as well as the proposed (used) heuristic algorithm. Section 3 describes the Belgrade airport case study which is used to assess the capability of the proposed air traffic assignment model to reduce population exposure to noise as well as the influence of this assignment on the route length and consequently fuel consumption. The results are presented in Section 4. Finally, Section 5 provides the conclusion and ideas for the further research.

2. Model definition

The purpose of this model is to describe the process of assigning aircraft operations to routes. An aircraft operation is herein defined as one take-off or landing of some aircraft type according to air traffic schedule. It is important to emphasize that not every operation can be assigned to each route.