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Analysing and modelling some effects of solutions for matching the airport runway system capacity to demand

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The paper deals with analysing and modelling some effects of three solutions for matching the airport runway system (landing) capacity to corresponding demand. These are: i) charging congestion applied to the NY LaGuardia airport (New York, USA); ii) deployment of the innovative operational procedures supported by the new technologies developing in the scope of European SESAR (Single European Sky ATM Research) and U.S. NextGen (Next Generation) program applied to the system of two closely-spaced parallel runways at Dubai International airport (Dubai, UAE (United Arab Emirates)); and iii) building the new additional runway(s) applied to the runway system of three London airports - Heathrow, Gatwick, and Stansted (London, UK).

The results have shown that each of the considered solutions can contribute to more efficient and effective matching of the airport runway (landing) capacity to the current and expected (prospectively growing) airside demand under given (specified) conditions.

1. Introduction

A continuous growth of the air transport demand has created an enormous pressure on the runway system capacity at many airports worldwide. Such development has already and will require an efficient and effective matching of the existing and in combination with ensuring additional airport airside area (particularly the runway system) capacity in order to support the future medium-to long-term growth of demand in a sustainable way (ACI, 2002; Janić, 2007). One of the proposed economic-based solutions for matching the existing airport runway system capacity to demand has been charging (or pricing) congestion. The medium-term technical/technological/operational and the long-term building/economic solutions for matching this capacity to demand have been development and deployment of the innovative operational procedures supported by new technologies and building the new additional runway(s), respectively. Charging congestion does not increase but seemingly enables more efficient and effective utilization of the existing runway system capacity. The innovative operational procedures supported by the new technologies developing in the European SESAR (Single European Sky ATM Research) and the U.S. NextGen (Next Generation) research program are expected to increase the existing runway system capacity to the certain extent, i.e., marginally (FAA, 2013; http://www.sesarju.eu/). Building the new additional runway(s) at one of the airports of a given airport system can substantively increase the runway system capacity of one of the airports and of the entire airport system as well (AC, 2015; Janić, 2015).

This paper presents analysis and modelling of contributions of the above-mentioned solutions to matching the runway system (landing) capacity to the corresponding demand and their exclusive application to the selected airport runway cases according to the "what-if" scenario approach. In addition to this introductory section, this paper consists of four other Sections. Section 2 describes the main characteristics of the above-mentioned (three) possible solutions. Section 3 presents the main characteristics of the models of these (three) solutions. Section 4 illustrates application of the above-mentioned models to the selected airport runway systems: i) congestion charging to the New York LaGuardia airport (U.S.); ii) innovative operational procedures supported by new technologies to the Dubai International airport (Dubai, UAE), and iii) adding the new runway to the London airport system including three airports -

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Heathrow, Gatwick, and Stansted (London, UK). The last Section summarizes some conclusions.

2. Some solutions for matching the airport runway system capacity to demand

2.1. Short-term solution - charging congestion

Charging congestion at airports usually implies raising the landing fees during the congestion period for an amount called the charge for those aircraft/flights, which could presumably impose the excessive delays and related costs on the succeeding aircraft/flights. In such case, as a response, the airlines are forced to reschedule some flights to the off-peak periods, or, if this is not possible, to give up from accessing the airport. Thus, the objective of the charge is to deter (i.e., prevent) the new accesses to the already congested airport runway system(s). As such, this solution does not increase the existing capacity of a given airport runway system but just enables its more efficient and effective utilization by constraining access of too excessive aircraft/flight demand (Janić, 2005).

2.2. Medium-term solution — deployment of innovative operational procedures supported by the new technologies

The innovative operational procedures supported by the new technologies are expected, in addition to the case of single runway, to be particularly promising to increase the landing capacity of the closely-spaced parallel runways (separated laterally by less than 760 m (2500 ft; ft-feet)), which have been commonly operated as the single runway. The most recent rather complex medium-term practical endeavours in developing these new technologies have been the European SESAR and the U.S. Neaten research and development programs (EEC/EC, 2012; Janić, 2006; Kolos-Lakatos and Hansman, 2013; Tittsworth et al., 2012; http://www.sesarju.eu; http://www.faa.gov/nextgen). Table 1 gives a summary of some of these technologies developed by the NextGEN programme to be used for aircraft operations at and around airports (FAA, 2013; http://www.faa.gov/nextgen/).

The above-mentioned technologies are expected to increase the airport runway system capacity by enabling more flexible use of airspace in combination with application of the different ATC minimum separation rules under different weather conditions, just thanks to having more precise real-time information on the aircraft position in airspace. In particular, they will enable the following: i) New definition of the aircraft wake turbulence categories and their associated separation rules; ii) Pair-Wise Separation based on the distance and time based-separation of both arrivals and departures; iii) Dynamic Pair-Wise Separation allowing dynamic adjustment of the aircraft separation using the wake turbulence measurement, real-time weather conditions, and data from the air and ground systems; iv) Time-Based Separation using the time instead of the distance-based separation rules between arriving aircraft under strong headwind conditions; and v) Weather Dependant Separation aiming at optimizing the aircraft separation by taking into account all meteorological conditions (crosswinds, headwinds, turbulence and temperature) and the wake vortex behaviour (http://www.sesarju.eu). For example, the U.S. FAA (Federal Aviation Administration) has permanently evaluated operations at the closely-spaced (less than 760 m (2500 ft) apart) parallel runways aiming at reducing separation between arriving aircraft without compromising safety and consequently increasing the landing capacity. In August 2013, the FAA made effective the revised separation standards for independent arrivals at the parallel runways spaced for 1098 m (3600 ft) and less apart. The arriving aircraft separated by 1.5 nm have been allowed to carry out dependent (pair-wise) staggered approaches at 16 such parallel runway pairs at eight US airports: Boston, Cleveland, Newark, Memphis, Philadelphia, Seattle, San Francisco and Salt Lake City (FAA, 2013, 2014; Janić, 2006, 2008; 2015a).

Table 1
Some new technologies developed by NextGEN for supporting the aircraft operations at and around airports (FAA, 2013; http://www.faa.gov/nextgen/).

- ADS-B (Automatic Dependent Surveillance Broadcast) ground stations
- ASDE-X (Airport Surface Detection Equipment — Model X)
- CSS-W (Common Support Services-Weather)
- Data Communications
- GBAS (Ground Based Augmentation system)
- Integrated Departure and Arrival Coordination System
- Modernized AIM (Aeronautical Information Management) system
- SBAS (Satellite Based Augmentation System)
- STARS (Star Approach Routes) system enhancements,
- TFDM (Terminal Flight Data Manager),
- TFMS (Traffic Flow Management System)

2.3. Long-term solution — building the new additional runway

The long-term solution(s) for matching the airport runway system's capacity to growing demand has commonly been increasing of the existing capacity by building the new additional runway(s) at an airport operating individually or in the scope of an airport system consisting of few airports. In later case, the airports of a given airport system have been considered as alternatives for implementation of the solution - new additional runway. The preferred alternative airport has been usually determined by application of different single and/or multi-criteria evaluation methods (Janić, 2005). In some other cases, the considered solution has been building the new airport(s) with the number of runways (de Neufville and Odoni, 2003).

3. Modelling solutions for matching the airport runway system capacity to demand

3.1. Previous research

3.1.1. Charging congestion

A long time ago, the economic theory noted that optimal use of a congested transport facility such as, for example, an airport landing runway could not be achieved unless each user, in this case an aircraft/flight, was forced to pay the marginal delay cost it imposed on all other subsequent users (aircraft/flights) arriving by the end of the congestion period. This marginal delay cost was usually called the ‘congestion pricing’ or ‘congestion charging’. In the given context, congestion has recently been also considered as an externality together with the internalized costs of air pollution, noise, and air traffic incidents/accidents (Brueckner, 2002b, 2009; Janić, 2005; Odoni and Fan, 2002; Vickery, 1969). In general, the concept of charging congestion is considered as an economic tool to mitigate some types of congestion, delays, and related costs of users tending to use the scarce resources, such as for example the runway system landing and/or take-off capacity at congested airports. Under such circumstances, the fundamental principle behind the theory of congestion charging is that, one, let say a regulator, must impose a congestion toll on each user which is equal to the external cost, which it imposes on the others within the whole system (de Neufville and Odoni, 2003). In the economic terms, it was something forcing users to “internalize the external costs.” This implied that the airlines willing to pay the congestion charge (i.e.,

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