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From passenger growth to aircraft movements

Katrin Kölker [a,*], Peter Bießlich [b], Klaus Lütjens [a]

[a] German Aerospace Center (DLR), Hamburg, Germany
[b] Hamburg University of Technology, Hamburg, Germany

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ABSTRACT

Airlines are able to deal with passenger growth by either increasing the frequency or the aircraft size, which may entail different numbers of aircraft movements. Forecasting the latter is necessary for evaluating technologies, approaching future emissions or anticipating capacity constraints. Purpose of this paper is to forecast a typical fleet mix and the growth of aircraft movements on flight segments worldwide based on an assumed passenger growth. The methodology is implemented in a model called Forecast of Aircraft Movements. Basic approach is the assignment of each flight segment worldwide to a distance, passenger number and aircraft category. For each combination of distance and passenger numbers a typical fleet mix is defined. The forecasted worldwide growth of passenger demand and the empirically determined fleet mix is applied to all segments in order to derive a future scenario. Assuming a certain seat load factor, the frequency growth can be deduced from the aircraft movements generated for all segments. The paper includes a forecast for aircraft movements in a future scenario based on real schedule and passenger data and gives a detailed overview of the methodology and results considering airlines' behaviour.

1. Introduction

Air transport will be faced with a growth of passenger demand at an annual rate of nearly 5% over the next 20 years (Airbus (2013), Boeing (2013)). The suppliers on the market i.e. the airlines have to satisfy this market by extending the number of offered seats. Thus, the airlines adapt their capacities on the flight segments in order to handle the passenger growth by either increasing the frequency or the aircraft size, which may lead to different numbers of aircraft movements. However, the number of aircraft movements, which is the number of operated flights on one segment, has a major influence on different aspects of the air transport system. For example, one flight with a wide-body aircraft may induce less emission and less saturation of airports and air space than two flights with narrow-body aircraft carrying together the same number of passengers. Thus, for the assessment of these and other research questions it is inevitable to understand how the trade-off between increased frequency and increased capacity is described on a global scale.

For this reason, forecasting aircraft movements is necessary for evaluating future technologies and developments of the air transportation system. For example, the understanding of the determination of frequencies is required when investigating the introduction of new aircraft concepts (e.g. Blended Wing Body) as well as approaching future CO_2 and greenhouse gas emissions, which is assessed within the DLR project WeCare. Furthermore, future frequencies have crucial impacts on airport capacities. Today's airports are already congested and constrained in their infrastructure extension. Additionally, these forecasts are often used to justify the necessity of an infrastructure extension, for example the 3rd runway at Munich Airport. Therefore, the proposed approach is valuable for researchers assessing technologies in future scenarios but also for manufacturers and other stakeholders establishing different forecasts for example fleet forecast or emission forecast. Main purpose of this approach is the integration in a complex framework, where passenger demand is given and other models provide additional information.

2. Literature review

The methodology proposed in this paper is a frequency-capacity model which will be used within a complex framework. Similar parts are incorporated in other frameworks and also used to model the frequency and aircraft capacity. In several studies, the TAF

* Corresponding author.
E-mail address: katrin.koelker@dlr.de (K. Kölker).

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forecast of the FAA (2014) is utilized as input as it contains passenger and aircraft movement forecasts on airport level for the U.S. For example, Hassan and Mavris (2014) use the Fratar algorithm to distribute the given passenger and aircraft movements onto different routes between airport pairs within the U.S. air transport network based on the current network structure. This procedure bases on historical economic growths and the current state of flight operations as well as six aircraft classes, to which the growth of the demand is assigned proportionally.

Similar approaches building a global framework upon the data of the TAF forecast have been developed by Graham et al. (2009), Kotegawa and DeLaurentis (2011) or Viken et al. (2006). However, they build upon a given forecast of frequencies and distribute the given flight operations.

Other global concepts to model the demand and supply in the air transport use qualitative models to describe the choice of aircraft type and to derive the frequency from these results. Thus, the flight mix is a function of passenger volume, distance of the segment and other market parameters whereas the frequency is forecasted by applying a seat load factor on the passenger demand, e.g. Bhadra (2003a, 2003b) or Reynolds et al. (2007). Hollingsworth et al. (2008) use a model that assigns growth in passenger demand either to a growth in aircraft size or to growth in frequency depending on the extent of the growth. The same model is used for the framework to develop the forecast of Airbus (2013). With a slightly different approach, Schäfer et al. (2013) apply growth rates for passenger demand as a factor onto the monthly frequencies of current flights.

Despite complex models evaluating future air transportation network dynamics, the following literature on the parameters having an impact on airlines' choice of the aircraft size has been published. Givoni and Rietveld (2009) suggest that the airlines' choice of aircraft size is mainly influenced by route characteristics, like distance, level of demand and level of competition. Wei and Hansen (2005) state that airlines seek to increase frequency instead of increasing the size of aircraft in order to attract more passengers. Nevertheless, Hansen and Gosling (2001) show that economies of scale with respect to aircraft sizes exist. Furthermore, Pai (2010) considers operational aspects like airport and airline characteristics in order to assess determinants of aircraft size and flight frequencies in the U.S. market. He incorporates operational aspects without quantifying the demand on one route directly. Bhadra (2005) estimates flight frequency based on the parameters demand, distance, types of hubs, network and season.

2.1. Global approaches

The presented FoAM model describes the frequency and capacity on the flight segment based on the passenger volume, the distance and a given seat load factor. The model itself is not suitable to be used for assessing technologies or perform forecasts for the air transport system. For this, a global framework is required, which contains the model to describe the frequency. Global forecasts of e.g. Airbus (2013) and Boeing (2013) mainly predict one scenario with the passenger demand and the number of required aircraft. However, this does not suffice to assess new technologies for what different scenarios are important. Here, the presented FoAM model can also be integrated in a global flexible framework as presented in Ghosh et al. (2015). The input for the model is the forecasted passenger demand from an external passenger demand model described in Terekhov et al. (2015a, 2015b). FoAM does not generate new routes itself but the new routes shall be integrated in the demand model such that passenger demand is given on these new routes. The presented model does consecutively forecast a number of flights for these routes. The studies of Wenzel et al. (2014, 2015) show the integration of this frequency-capacity model in a more detailed approach. Here, the frequency for one airport is generated and put into the global context of forecasting the traffic at one specific airport.

The rest of the paper is organized as follows. A detailed description of the model is presented in chapter 2. Chapter 3 presents the results of the calibration process and a preliminary global forecast of aircraft movements. Chapter 4 concludes.

3. The forecast model

The forecast model, FoAM, has been developed to model the behaviour of the airlines when they are increasing their frequency and capacity on a global and generic basis. Therefore, it is essential to understand and dwell on the subject of balancing the size of an operated aircraft on the one hand and the frequency of an airline on a segment on the other hand. The distribution of different sizes of aircraft, called mix of aircraft size or fleet mix, is utilized for this and can be used to derive the frequency of an airline as well.

In this context, size of an aircraft is understood to be the available seats for passengers whereas frequency is understood to be the number of operated flights on any segment in a given time frame. A segment is a pair of two airports.

The prerequisite of the model is the categorisation of flight segments. Two different types of categories exist that classify the segments according to their distance and the monthly passenger volume. For every segment the aircraft movements are again categorized according to the size of the operated aircraft. The detailed categorisation is explained later. However, the main assumption of the model is that the fleet mix on one segment only depends on the distance of the segment and the yearly passenger volume. This means that a segment with a specific distance and a specific monthly passenger volume is assumed to have a similar fleet mix than another segment in the same categories. The results in chapter 3 reveal the fact that this holds for the last 10 years at last on an aggregate level. Additionally, as monthly data is considered, seasonality does not have to be considered implicitly. This approach allows predicting the fleet mix and the frequency by taking the average fleet mix of all segments in the same category.

Therefore, the model consists of two steps. For every pair of distance and passenger category, the average fleet mix of all segments in the past has to be calculated. The fleet mix describes the share of operated flights according to the size of aircraft. Hence, for every aircraft category, which is an interval of the size of an aircraft, the share of operated flights for the segment is retrieved and conducted with historical data only. Besides, the historical values are averaged and the basis for the following forecast. The first step is performed once and yields the fleet mix for every category of segments.

The second step is the actual forecast, in which the frequency is calculated for given future segments based on the fleet mixes of the first step. Thus, the input is segments with passenger volumes and the output is the frequency and the average capacity on this segments. The future passenger volume can also be retrieved by applying a given growth rate to the passenger volume of the base year. In this case, the passenger volume of the base year and the growth rates are the inputs.

3.1. Input data

The model uses two types of data: schedules and passenger volume information. These data are available on a monthly basis for worldwide flights and a time frame from 2003 until 2012 (Sabre (2014)) with around 70,000 airport pairs contained in the data. FoAM combines these two types of data and evaluates the following

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