Transportation Research Part D 32 (2014) 373–386

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Comparing the impact of future airline network change on emissions in India and the United States

Antony D. Evans *

UCL Energy Institute, University College London, 14 Upper Woburn Place, London WC1H 0NN, United Kingdom

ARTICLE INFO

Keywords:
Airline flight network
CO_2 emissions
Simulation
Network optimization
Game theory

ABSTRACT

In this paper we use simulation to analyze how flight routing network structure may change in different world regions, and how this might impact future traffic growth and emissions. We compare models of the domestic Indian and US air transportation systems, representing developing and mature air transportation systems respectively. We explicitly model passenger and airline decision-making, capturing passenger demand effects and airline operational responses, including airline network change. The models are applied to simulate air transportation system growth for networks of 49 airports in each country from 2005 to 2050. In India, the percentage of connecting passengers simulated decreases significantly (from over 40% in 2005 to under 10% in 2050), indicating that a shift in network structure towards increased point-to-point routing can be expected. In contrast, very little network change is simulated for the US airport set modeled. The simulated impact of network change on system CO_2 emissions is very small, although in the case of India it could enable a large increase in demand, and therefore a significant reduction in emissions per passenger (by nearly 25%). NO_x emissions at major hub airports are also estimated, and could initially reduce relative to a case in which network change is not simulated (by nearly 25% in the case of Mumbai in 2025). This effect, however, is significantly reduced by 2050 because of frequency competition effects. We conclude that network effects are important when estimating CO_2 emissions per passenger and local air quality effects at hub airports in developing air transportation systems.

Introduction

The demand for air travel is widely projected to continue its strong historical growth of about 5% per year in worldwide revenue passenger and freight tonne kilometers over the next 20–40 years (e.g. Airbus, 2013; Boeing, 2013). While this growth carries a range of societal and economic benefits, it also creates challenges. One of the most important of these is the growing environmental impact of this sector, both on a local scale (e.g., noise, air quality) and a global scale (e.g., climate change). The IPCC (1999) report that growth in air traffic may have significant environmental impacts. Nitrogen oxides (NO_x) and particulate emissions in the vicinity of airports have significant impacts on local air quality, resulting in negative health effects and premature mortality (Graham et al., 2009). Aircraft noise in the vicinity of airports also has negative health effects (Cohen et al., 1980), while also reducing property values and affecting children's abilities to learn (Haines et al., 2001). Carbon dioxide (CO_2) is a greenhouse gas that impacts the atmosphere for hundreds of years, increasing radiative forcing and

* Tel.: +44 (0)20 3108 9356.
E-mail address: antony.evans@ucl.ac.uk

http://dx.doi.org/10.1016/j.trd.2014.08.009

ultimately causing the global average temperature to rise. Non-CO_2 climate effects from aviation are also significant – NO_x emissions at aircraft cruise altitudes lead to the production of tropospheric ozone, which has a regional warming effect (IPCC, 1999), while contrails from aircraft engines can increase high altitude cloud cover. This tends to also produce a regional warming effect.

Such impacts require effective policy responses that account for effects on the environment, on national and international economies, on the airline industry, and on the flying public. This is particularly true in high growth developing regions such as India, China, the Middle East and South America. In these regions growth in aviation is key to economic development, but it is also making a rapidly increasing contribution to the environmental impact of aviation. Air traffic in India, for example, although starting from a small base, is projected to grow by greater than 7% per year, compared to growth in the United States, which is forecast to be between 2.5% and 4% per year (Airbus, 2013). Even more critically, recent climate research (Köhler et al., 2013) suggests that certain emissions from aircraft (particularly NO_x) at latitudes closer to the equator (such as over India, China, the Middle East and South America) have a greater impact on climate change than emissions in more northerly regions (such as over Europe and North America), due to latitudinal effects.

Despite this increasing impact of air traffic in developing regions, the vast majority of research in aviation and the environment is focused on industrialized regions, particularly the United States and Europe. It is, however, essential that, in the development of policies to mitigate the environmental impact of aviation, careful consideration be given to air traffic growth in developing regions as well. This is particularly essential given the desire for strong economic growth from the governments of developing economies, which is partly enabled by growth in air transportation. This leads to reluctance on the part of policy makers in developing economies to restrict air traffic growth. Careful policy assessment is therefore required to identify policies that will enable growth, but limit environmental impact.

While mature air transport systems, such as those in the United States and Europe, do not undergo significant structural changes as they grow, as demonstrated by Evans and Schäfer (2011), less mature systems such as those in India, China and South America are expected to undergo more significant structural changes, particularly in terms of flight network routing. The networks currently in place in these less mature systems are strong hub-and-spoke networks, concentrated around two or three hub airports in the largest cities. However, as other cities grow in importance and regulatory structures in these regions become increasingly liberalized, these networks will start to shift towards increased point-to-point routings, more closely resembling the networks in the United States and Europe. These structural changes may have a significant effect on environmental impact, particularly at the local level, and in enabling economic development.

Development of policy responses to traffic growth requires the use of integrated policy assessment tools. Three such tools exist: the Aviation Emissions and Evaluation of Reduction Options Modelling System (AERO-MS) (Pulles et al., 2002); the Aviation Environmental Portfolio Management Tool (APMT) (Waitz et al., 2006); and the Aviation Integrated Modelling (AIM) project (Reynolds et al., 2007a,b). Each of these models simulate aviation, environment and economic interactions at local and global levels by simulating different elements of the air transportation and environmental system. They permit important feedback and data flows between the key system elements and provide the capability to assess different policy measures. However, until now, no policy assessment tools simulate network change in any world region, meaning that the future traffic simulated in high growth regions may be different from what is likely to occur in reality. It is unclear how large an effect this has on global and local environmental impacts forecast, or on forecast economic benefits.

As part of the AIM project, a model was developed of airline operational responses, including flight network change, to changes in operating costs (Evans and Schäfer, 2011, 2014). This model is based on the overriding principle of airline profit maximization within a competitive environment. Flight frequency competition is modeled by simulating a strategic best-response game between airlines competing for market share. The model has been applied to simulate traffic growth in the United States under a series of airport capacity scenarios (Evans and Schäfer, 2011, 2014). However, because the United States is a mature system, simulated network change in the modeled airport set was small, suggesting that simpler existing modeling approaches may be adequate. This may not be the case, however, for less mature systems, where network change is more significant.

In this paper we use simulation to estimate the extent to which flight routing network structure is likely to change in India, a developing air transportation system, through 2050, and how this impacts traffic growth and emissions. This is done by comparing traffic growth and emissions under a scenario in which network change is simulated, to a scenario in which the network structure remains fixed to that of the base year (2005). This provides an indication of the importance of capturing network change in high growth developing regions. These results are compared to similar results for the United States, a mature air transportation system. India is chosen for the analysis because it represents one of the more liberalized air transportation markets of those developing regions that are seeing high growth, and is already showing a shift from the dominant hub-and-spoke network concentrated around the Mumbai and Delhi hub airports (Chhatrapati Shivaji International Airport and Indira Gandhi International Airport, respectively) to more point-to-point routings between other airports in the country, a number of which have been newly upgraded or developed. Because the model developed by Evans and Schäfer (2011, 2014) was developed for a liberalized market (the United States), it can be applied to the Indian air transport system with relatively little modification. The modeling approach is described below, followed by the model validation results, model simulation results, and conclusions.