Transportation Research Part D 63 (2018) 769–785

Contents lists available at ScienceDirect

Transportation Research Part D

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

Visualizing aviation impacts: Modeling current and future flight trajectories with publicly available flight data

Max Z. Li[a], Daniel Y. Suh[b], Megan S. Ryerson[a,b,*]

[a] Department of Electrical and Systems Engineering, University of Pennsylvania, Philadelphia, PA, United States
[b] Department of City and Regional Planning, University of Pennsylvania, Philadelphia, PA, United States

ARTICLE INFO

Keywords:
Airport expansion
Trajectory visualization
Regression-based trajectory extraction
Terminal airspace models
Critical cartography

ABSTRACT

As the demand for air travel continues to grow both nationally and internationally, airports seek airfield expansions and new infrastructure to accommodate new aircraft movements. However, airport expansion initiatives – runway extensions and/or new runway construction – directly impact terminal airspace operations. A change in flight paths near the airport affects the population living proximate to the airport, increasing noise levels and exposure to pollutants emitted by low-altitude departures and arrivals. While airspace procedures and their impacts are well-understood by aviation stakeholders, they are often convoluted and technical in nature. To this end, we propose a methodology to visualize terminal airspace trajectories leveraging publicly available data and commonly-used software. The trajectories are extracted via polynomial regression and hyperbolic tangent interpolation is applied to reflect accurate final approach maneuvers. Final visualizations are rendered in ArcGIS, a geographic information system used by many Metropolitan Planning Organizations. These trajectory visualization modules can also be combined with external models that provide noise contour projections and emission level estimations. We present a case study of Chicago O'Hare International Airport (ORD) due to the contentious O'Hare Modernization Program. The resultant interactive and dynamic three-dimensional trajectory airspace maps for ORD rendered via ArcGIS are easy to understand and customize, allowing MPOs to package them into downloadable online modules. MPOs armed with these modules will bridge the critical gap between the technical knowledge presented by authorities touting airport expansions and the residents who are impacted by the expansions.

1. Introduction

1.1. Background

Local governments and other sub-state jurisdictions that serve as the owners and operators of major airports are constantly seeking to grow the footprint and reach of aviation in their cities. From 2000 to 2013 in the United States, 19 of the top 35 airports (by passenger volume) either built or completed planning for new or expanded runways. During the same period, airport sponsors operating airports of all sizes and levels of operation provided millions of dollars in air service incentives to airlines to increase their air services (Ryerson, 2016; Ryerson & Woodburn, 2014). The motivation for new runway infrastructure and for new airport operations is driven by economics, as it is well established that urban and regional economic growth is highly correlated with air service

* Corresponding author.
E-mail addresses: lizhaoyu@seas.upenn.edu (M.Z. Li), dansuh@design.upenn.edu (D.Y. Suh), mryerson@design.upenn.edu (M.S. Ryerson).

https://doi.org/10.1016/j.trd.2018.07.009

(Baker et al., 2015; Bilotkach, 2015; Brueckner, 2003; Mosbah & Ryerson, 2016; Tittle et al., 2013).

The process through which airport sponsors plan for new and extended runways begins with the Airport Master Planning process and leads to the development of an Environmental Impact Statement (EIS). The EIS, and the Airport Master Plan that proceeds it, detail the preferred new runway design, alternative designs, and polices to manage and promote airport demand (Federal Aviation Administration, 2006; Wyatt and Schneck, 2014). Each alternative is evaluated for operational impact and environmental impact, including local pollutants and noise. An important feature of EIS development is the gathering of public input; the airspace is not only shared by flights utilizing various arrival and departure procedures, but also by the citizens living in the neighborhoods directly underneath the procedures. Public input is gathered through "workshop-style" meetings where the Federal Aviation Administration (FAA) and airport officials meet with members of the public, as well as state and federal entities, to comment on current and future EIS developments. (Federal Aviation Administration, 2015a). Despite regular public meetings during the airport planning process, the public faces barriers to providing input and having their voices heard regarding airport expansions. The complexity of airspace planning oftentimes sidelines the general populace, leaving them with little say and little to say during the planning process (Hansen et al., 2013).

1.2. Problem and motivation

Even though attempts to address the lack of communication and synchronization between the airport and the public are made during public hearings and meetings regarding the impending expansions, a clear disconnect still persists. While airspace procedures and their impacts are well-understood by airport operators and air transportation researchers, they are highly technical and require a large prerequisite of knowledge to fully comprehend (Cidell, 2008; Hansen et al., 2013). In addition, noise contours presented to the public are representative of the way airports plan to use the newly extended or constructed runway, but this can be very different from the actual usage of the new infrastructure (Woodburn and Ryerson, 2014). In fact, the EIS that airport sponsors prepare regarding infrastructure expansion typically includes only a few possible airport configurations, but not all possibilities that could be utilized. A particular *airport* or *runway configuration*, or *configuration* for short, refers to the set of runways assigned as departure or arrival runways for a specific time period. Proponents of airport expansion projects typically only showcase models with a limited set of runway configurations to highlight capacity improvements, but other useable configurations with possible negative impacts on surrounding neighborhoods are overlooked. The issue of configuration modeling selection and others such as noise exposure estimation biases results in eroded trust in the planning process (Suau-Sanchez et al., 2011).

With this in mind, our research empowers citizens to utilize visualization modules distributed via their respective Metropolitan Planning Organization (MPO) to run whatever configuration scenario they would like and examine the impacts of such configurations on the surrounding neighborhoods. MPOs are well-positioned to be the mediators between technical aviation knowledge and community empowerment due to two main factors: (1) the FAA provides funding to MPOs in order to prepare and disseminate regional airport system plans that cover future expansions and capital projects (Delaware Valley Regional Planning Commission, 2014; Metropolitan Transportation Commission, 2018a; Regional Planning Association, 2017; Southern California Association of Governments, 2018a), (2) MPOs maintain data repositories that include geographic information system (GIS) data and end-user maps (Delaware Valley Regional Planning Commission, 2018; Metropolitan Transportation Commission, 2018b; Southern California Association of Governments, 2018b).

Furthermore, the work presented in this paper has already been applied to modeling the potential airspace impacts caused by initiating operations at newly constructed airports within pre-existing multi-airport systems (Li and Ryerson, 2017). This demonstrates not only the flexibility of our methodology, but also international applicability as the world-wide demand for air travel ignites a new wave of airport construction and expansion – along with intense policy debates and contention over these capital projects (Arputham and Patel, 2010; May and Hill, 2006; van Eeten, 2001).

1.3. Contribution of work

Efforts at generating three-dimensional maps that encapsulate succinct details regarding the impacts of flight and airspace procedural changes due to an impending airfield expansion are hindered by difficulties and accessibility issues in producing such visualizations. Current trajectory generation techniques, while they produce very detailed and analyzable trajectory plots, are often computationally complex and require specialized software to render and visualize. The predecessor data sets are also often proprietary and provided through nonpublic channels. We argue that this gap can be partially bridged by empowering the public with visualization modules produced from a data-efficient trajectory visualization method, one that can be extended by incorporating projected noise level contours and atmospheric emission estimates. The scope and contributions of our work can be broken down into four components: we aim (1) to highlight the disconnect between the technical knowledge presented by the supporters of airport expansion and the citizens impacted by the expansion, (2) to emphasize the role that MPOs should play in bridging this gap, now aided by our methodology and resultant modules, (3) to present the mathematics behind our data-efficient methodology, and (4) to present examples of visualization modules produced via our methodology using Chicago O'Hare International Airport (ORD) as a case study.

1.4. Paper organization

The remainder of the manuscript is organized as follows: The literature review in Section 2 provides a survey of relevant studies