Transportation Research Part D 44 (2016) 199–210

Contents lists available at ScienceDirect

Transportation Research Part D

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

Fueling for contingencies: The hidden cost of unpredictability in the air transportation system

Lu Hao [a,*], Mark Hansen [a], Megan S. Ryerson [b]

[a] *Institute of Transportation Studies, Department of Civil and Environmental Engineering, University of California, Berkeley, Berkeley, CA, USA*
[b] *Department of City and Regional Planning, Department of Electrical and Systems Engineering, University of Pennsylvania, Philadelphia, PA, USA*

ARTICLE INFO

Article history:
Available online 17 March 2016

Keywords:
Aviation
Fuel loading and consumption
Flight predictability impact
Benefit analysis

ABSTRACT

The aviation community is increasing its attention on the concept of predictability when conducting aviation service quality assessments. Reduced fuel consumption and the related cost is one of the various benefits that could be achieved through improved flight predictability. A lack of predictability may cause airline dispatchers to load more fuel onto aircraft before they depart; the flights would then in turn consume extra fuel just to carry excess fuel loaded. In this study, we employ a large dataset with flight-level fuel loading and consumption information from a major US airline. With these data, we estimate the relationship between the amount of loaded fuel and flight predictability performance using a statistical model. The impact of loaded fuel is translated into fuel consumption and, ultimately, fuel cost and environmental impact for US domestic operations. We find that a one-minute increase in the standard deviation of airborne time leads to a 0.88 min increase in loaded contingency fuel and 1.66 min in loaded contingency and alternate fuel. If there were no unpredictability in the aviation system, captured in our model by eliminating standard deviation in flight time, the reduction in the loaded fuel would between 6.12 and 11.28 min per flight. Given a range of fuel prices, this ultimately would translate into cost savings for US domestic airlines on the order of $120–$452 million per year.

Introduction

The Federal Aviation Administration (FAA), as an air navigation service provider, continuously seeks to better understand and address customer requirements and improve the quality of air traffic management service provided. Metrics for quality of service have long been centered on delay. Recently, however, the concept of predictability has received more attention in service quality assessments. The FAA is seeking to define a new predictability metric so that this aspect of system performance can be monitored. Operationally, reliability or predictability is inversely related to the dispersion of travel times between individual origin–destination (OD) pairs or on specific routes, metrics for which include variance, standard deviation, mean absolute deviation, and inter-quartile range. Although flight predictability is still a relatively new concept, the FAA's aspiration to improve air navigation service through better predictability is part of its Destination 2025 plan. The specific flight predictability performance goal in Destination 2025 is to "Improve flight predictability by reducing variances in flying time between core airports based on a 2012 baseline" (Destination 2025, 2012). The International Civil Aviation

* Corresponding author.
E-mail address: haolu@berkeley.edu (L. Hao).

http://dx.doi.org/10.1016/j.trd.2016.02.016
1361-9209/

Organization (ICAO), which oversees international aviation under the United Nations, also endorses predictability as a key performance metric (ICAO, 2005).

In light of this, it is important to understand the benefits of predictability and how these benefits can be monetized. Previous studies focus on the relationship between flight time dispersion and scheduled gate-out to gate-in time (also called block time), which is a major airline cost driver (Hao and Hansen, 2014; Wojcik et al., 2013). In this study, we investigate an additional benefit mechanism from improved predictability—fuel savings. We conjecture that when flight times are less predictable, airline dispatchers load extra fuel. The amount of fuel uplifted, or loaded, to an aircraft for a flight adds weight to the aircraft throughout the flight, which in turn increases its fuel burn. Federal regulations stipulate minimum fuel reserves that must be uplifted to each flight, and in some conditions also require sufficient fuel to fly to an alternate airport. In addition to reserve and alternate fuel, contingency fuel may also be uplifted. The amount of contingency fuel loaded is discretionary, and reflects the airline dispatcher's assessment of the "downside" risks that may lead to additional fuel burn beyond what is projected by the flight plan. Contingency fuel, together with the decision of carrying extra fuel to fly to an alternate airport when it is not required by federal regulation, thus represents the dispatcher's hedge against unpredictability (Ryerson et al., 2015).

Recognizing the link between fuel consumption and predictability allows for both the monetization of predictability and the identification of new strategies for reducing aviation fuel consumption. There is intense focus on reducing fuel consumption from all stakeholders both to preserve the financial health of the airline industry and minimize environmental impact. Airlines are moving aggressively to reduce fuel consumption because of rising fuel costs, which have gone from $21 billion in 2009 to $31 billion in 2012, and now account for 27% of airline operating costs, based on Bureau of Transportation Statistics data (BTS, 2009; 2012). Higher fuel costs force airlines to increase their ticket prices, which in turn suppresses demand. While fuel prices decreased in 2014, the price fluctuation only showcases the instability of the international fuel market. Consider that in 2008, jet fuel prices reached levels more than three times those of 2004, followed by a sharp decrease in 2009. Many interpret the current 2015 period as a "bust" and argue that the long term trend is still toward higher prices (The State of the Global Markets Report, 2015). In addition to issues with supply and prices, in the future, climate change policies and environmental attitudes of potential air travelers may further increase or destabilize effective fuel prices (Ryerson and Hansen, 2013). Thus, by economizing on fuel airlines reduce their exposure to an economic "wild card."

In this paper, we investigate the relationship between predictability and fuel consumption for a major US carrier. Building on the direct physical relationship between fuel uplift and fuel consumption, we will show evidence that the fuel uplift determined by dispatchers is affected by the flight time unpredictability. To do so, we exploit a large and recent flight-level dataset provided by a major US airline and merge this dataset with other publicly available datasets that incorporate National Airspace System (NAS) operating characteristics. The data included for each flight are the amount of loaded fuel, fuel burn, scheduled, planned, and actual flight times, and delays. We measure unpredictability of a flight by the standard deviation of airborne time among all the flights between a specific OD pair, departure time bank, and month. This dataset enables us to estimate the relationship between unpredictability and fuel uplift, while controlling for other relevant factors such as terminal weather and traffic. Then by exploiting established relationships between fuel uplift and fuel consumption, we are able to evaluate the value of predictability in terms of cost savings from less consumed fuel.

The remainder of the paper is organized as follows: Section 'Literature review' provides a review on recent literature regarding measuring predictability, monetizing predictability, and fuel saving practice. Section 'Fuel loading practice' describes fuel loading practice for a representative US carrier. Section 'Data and modeling' presents our modeling approach, wherein predictability is quantified and related to fuel uplift, and the estimation results. Section 'Cost-to-carry analysis' presents methods and results for estimating the cost to carry additional fuel loaded as a result of flight unpredictability, and Section 'Conclusion' provides summary and conclusion.

Literature review

To investigate the impacts of flight predictability on fuel loading or any other aspect of airline behavior, the first step is to define and measure flight predictability. The idea of reliability or (inversely) variability as an equivalent to predictability is not new in the field of ground transportation, where (un)reliability mainly refers to the unpredictable variations in travel time and is thus directly related to uncertainty of travel time (Carrion and Levinson, 2012). As a measure of travel time variability in ground transportation, most studies have used either the standard deviation or the average delay relative to scheduled arrival time (Börjesson et al., 2012). Some studies include both topics, while fewer use percentiles of the travel time distribution (Brownstone and Small, 2005). The most common approach for non-scheduled services with relatively high travel time variability, such as car trips and urban high-frequency transit trips, seems to be the so-called "mean–variance" approach, where the formulation (with a linear-additive form) contains only the mean and standard deviation of the travel time (Noland and Polak, 2002; Hollander, 2006). Hollander (2006) further argues that "mean–variance" formulation may in practice not be able to capture the full disutility of travel time variability.

For low-frequency scheduled services with relatively low travel time variability, such as long-distance train or air trips, using the "average delay" as the variability measure seems to be the most common approach (Börjesson and Eliasson, 2011). By assuming that all travelers' preferred arrival times are equal to the scheduled arrival time, the form expressing variability with "average delay" can be derived. Wardman (2001), followed by Abrantes and Wardman (2011) include a meta-analysis