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Air freight hubs in the FedEx system: Analysis of fuel use☆

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A B S T R A C T

This paper provides a data based analysis of FedEx air freighter activities from selected hub locations. The basic idea is that air freighters have a set of range and payload parameters and their corresponding fuel burn depends on weight and distance. Data from 2011 to 12 (FlightAware) are used for 180,000 + flights on origin, destination and aircraft type. The particular aircraft vary widely in payload, but additional parameters may be derived from industry web sites and BTS. The research uses flight activity at hubs such as Memphis and Indianapolis (among others) and computes the aggregate distance flown on specific aircraft. The linkage between the hub and aggregate fuel use (assuming that the out bound flights are allocated to the hub) will give some quantifiable measures of the costs allocated to the hub. The paper examines particular aspects of the air freight system that are especially vulnerable to a spike in the costs of aviation fuel. These observations suggest that traffic to regional air express and air freight hubs is likely to respond in complex ways to fuel costs.

1. Introduction

Air freight networks of integrators such as FedEx and UPS represent a significant and well-studied component of US and global transport systems. An excellent overview of the challenges of moving freight by air is in Morrell (2011). All-cargo carriers and combination passenger/cargo carriers are also important for freight and mail, but these are not discussed here. The reader is referred to Morrell (2011) for a detailed comparison of these other forms of air freight. In this paper the term air freight is used in a broad sense to refer to the materials carried by the integrators. It combines packages, documents, and larger freight items. A detailed comparison of operational aspects of FedEx and UPS is in Cosmas and Martini (2007). More specifically, Bowen (2012) compares the structure of UPS and FedEx networks, emphasizing the significant role of network organization for these carriers. The macro design of such networks has also been given a lot of attention (O'Kelly and Miller, 1994, Campbell and O'Kelly, 2012). At a more micro level, such networks solve a complex geographic distribution problem using feeders, spokes, and high volume inter-hub links (Kuby and Gray, 1993). Prior work has proposed models of certain aspects of these systems (Hall, 1989) but there is a need for further detailed examination of hubs in the freight sector, especially with respect to the network's usage of circuitous routes and their intensive use of fuel as an input.[1]

There is considerable interest from both applied policy and academic modeling perspectives in the efficient use of aircraft and their impact in terms of GHG and other emissions (see World Bank, 2012; Brian et al., 2009, GHG in airports).[2] From an operational point of view, air carriers devote a very large fraction of their total costs to jet fuel, and they are vulnerable to uncontrollable variations in these costs. In an effort to minimize costs, freight carriers optimize fleets and plan their flights in the most effective way (see Armacost et al., 2002, 2004). They may also pursue other options, such as: equipment changes, modification of route structure, substitution of bio-fuels, and hedging (The World Bank, 2012). This paper considers the role of hubs in air express and air freight

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[1] See also excellent coverage of hub location in Kara and Taner (2011), Liu et al. (2013), O'Kelly (1986, 1987), and a general text book introduction in Taaffe et al. (1996). A recent case study for Turkey is in Oktal and Ozger (2013).

[2] The World Bank (2012) has issued a comprehensive overview of the status of air transport efficiency from the energy/fuel burn point of view. While primarily related to passenger traffic, special circumstances in freight applications are evident.

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transportation, with particular attention to the estimated total fuel cost as well as the share attributable to individual hubs.

2. Key aspects of air freight

While there are similarities between air freight and air passenger traffic, there are some particular issues for air freight with relevance to fuel consumption.

2.1. Integrated decision making

An integrated air freight operation may exercise control over package routing to a much greater extent than is possible in the passenger airlines. Systems with a centrally planned set of location and routing decisions have been described as "delivery systems" by O'Kelly (1998). These contrast with "user attracting" systems typically seen for air passenger transportation. Centralized sorting at a hub is very concentrated and packages are generally not routed directly to their destination. In the case of domestic freight, flows are routed through mid-continent hubs, largely in one major overnight sort, with secondary peak flows related to international departures and arrivals. Since the freight hub airport is not necessarily a major traffic generator, it is reasonable to expect that air freight units are carried on a more circuitous path than a comparable passenger for the same OD pair. These extra ton miles are offset by the efficiency of the large scale central sorting hub.

2.2. Exclusive access

With a night time peak operation, the carrier has exclusive access to multiple runways. This has allowed FedEx, with four runways at Memphis (MEM), to devote considerable attention to optimization of arrival and departure patterns. Adjustment to inter-aircraft spacing has also proven to be extremely beneficial.[3] Because the single operator of a major freight hub has exclusive access, the merits and benefits of any technological improvement to the fleet accrue to that carrier. There is generally no need to compete for access, and the benefits of coordinating operations are fully captured. The FedEx fleet, for example, has been widely refitted with upgrades that improve the performance at their main hub airport (see Cosmas and Martini, 2007, p 28). By contrast, a passenger fleet gains less benefit if it operates from a hub where the majority of the other carriers have not also been upgraded, or where its improved performance confers un-priced benefits to other carriers.

2.3. International RTW paths for pilots/crew

Of course all the issues in crew scheduling that arise in passenger systems also arise in freight, and the aircraft movements are scheduled separately from the crews (Belobaba et al., 2009). Crew schedule and positioning is a separate matter from aircraft deployment – the aircraft keep moving and the crew is assigned to them, based on rest and work rules. However, there are also significant added complicating factors arising from the global freight network, such as long range, and round-the-world (RTW) flow patterns.

FedEx pilots bid on flights and schedules based on their seniority. For example, a senior pilot's preference for achieving flight hours in large blocks might have a mission connecting Memphis to Paris, Paris to Delhi, Delhi to Shanghai, and Shanghai back to Memphis. [Notes from interview with FedEx Pilot, 1/24/2013.] A pilot with seniority can devise a contiguous block of long range flights in this global network, because after rest they may continue on to the east. A tour might also include several segments and even intra-European short haul operations from the Cologne hub. Others, to be clear, may have different patterns based on domestic routes, with the daily/nightly arrival and departure pattern at Memphis. This crew and equipment flexibility can be advantageous in the case of asymmetric flows, as discussed next.

2.4. Exploiting asymmetry/long range and Backhaul

A fourth significant difference between freight and passenger flows is the presence of asymmetries. For passengers, most journeys are round trip and return home. For freight, in view of trade imbalances, and the different locations of sources and sinks, there are asymmetric flows. The addition of long range B-777 has opened the possibility of global links which were previously infeasible, and may allow the system to avoid some extra fueling stops. Also, while a route from A to B for passengers is essentially reversible (possibly routing the same way or through a different hub) air freight actually opens the possibility of round the world (RTW) freighter tours, as mentioned above. These links chain together links to form a global backbone, in a way somewhat different from the local feeder spokes in the domestic system.

3. Research goals

The study focuses on two main types of flows – domestic and international. In turn these are concentrated on two types of hubs: Memphis (MEM) a large air express operation including long range international routes; and Indianapolis (IND) primarily domestic air express and other similar US regional hubs. The basic idea is that air freighters have a set of range and payload parameters and their corresponding fuel burn depends on weight and distance. Some long range international linkages are highly dependent on particular aircraft range and performance characteristics, but shorter domestic links might be more flexible and could involve realignment of some equipment. Initial observations suggest that traffic from regional air freight hubs is likely to respond in complex ways to fuel costs. Of course there are lags in adapting to a change in fuel costs, but in a longer term planning sense, anticipating the costs of these interactions is a useful precursor to modeling alterations in aircraft use and other types of change. While the air carriers undoubtedly deal with such operational planning as part of their own proprietary cost optimization, there are opportunities to analyze sensitivity to energy costs in a generic fashion.

This paper primarily focuses on the consumption of fuel, with a view to fuel cost reduction (lower miles or better aircraft). In particular, following much work on idealized hub models (Campbell and O'Kelly, 2012), this paper presents a data-driven assessment of some aspects of the FedEx air freight system from the perspective of the main components of their use of fuel in aircraft. With these issues in mind, the author obtained one year of US-based FedEx air traffic from FlightAware for research purposes.[4] These data for 5/1/2011 through 4/30/2012 include more than 180,000 flights with at least one end in the continental US or its outlying territories. For example, while the interaction between Honolulu and Sydney is included, we are unable to observe flights from Paris to onward points such as Guangzhou. With this caveat and a few other data cleaning issues to deal with, the goal was to approximate the total fleet miles as a driver of fuel costs. In other

[3] http://www.commercialappeal.com/news/2013/jan/30/faa-changes-in-memphis-save-jet-fuel-cut-and/.

[4] FedEx has been the subject of numerous prior academic and business related case studies (Chan and Ponder, 1979; Mason et al., 1997; Bowen, 2012).