Abstract

Hub and spoke routes are compared with point to point routes considering costs to the airline and value provided to customers. Customer value focuses on passenger time and reliability of making connecting flights. Point-to-point routes are found to be superior because they provide more non-stop flights, more direct flights even if stops are required, and more reliable connections when connections are necessary. Furthermore, point-to-point routes provide better aircraft utilization, reducing costs. The result for the point-to-point airline is higher yields and lower costs for better profits.

Introduction

The five largest airlines in North America use hub and spoke routing for aircraft. This means that a typical trip for a passenger consists of a flight from the embarkation airport to one of the airline’s hub airports; a layover of forty to ninety minutes; and a flight from the hub to the destination airport. Each aircraft need only fly round trips between a hub airport and a non-hub airport. These aircraft routes constitute the “spokes” of the system. Airline operations at the hub are a sequence of banks. Each bank is characterized by a large number of aircraft arrivals; a period of less than an hour in which aircraft are emptied, fueled, and reloaded; the en masse departure of the recently arrived aircraft. While the aircraft refuel, passengers who have just arrived in the concourse walk to the departure gate of the second leg of their trip. A quiescent period of an hour or two elapses before the next bank begins.

Figure 1 illustrates a hub and spoke route network among twenty cities, one of which is the hub. Among n cities there are n(n-1) city pairs that might be connected by air routes. A hub and spoke system with one hub can only realistically connect about 70% of these city pairs because, for example, travelers from New York to Boston will generally not accept a routing through a Chicago hub. Even still, in our example, aircraft flying only nineteen routes (between the hub and the remaining cities) can connect over 250 city pairs. Major North American airline hubs, particularly those that combine traditional majors with regional affiliates or subsidiaries, directly connect to many dozens of cities providing routes between thousands of city pairs.

In contrast, point to point routing does not use a hub airport (Figure 2). Many travelers find a point to point flight directly from their embarkation airport to their destination. Others combine two or even three flight
legs to reach their destination. Point to point routing requires a greater number of different aircraft routes to connect a set of cities, and yet provides fewer city pairs that are reasonably connected. Aircraft arrivals and departures are not synchronized as they are at a hub, and passengers who make connections have longer layovers. On the other hand, connecting flights tend to be more collinear, which may compensate somewhat for the longer layover, because more passengers stay on the same aircraft as it arrives and then departs an airport. These passengers have a shorter layover than hub and spoke passengers because the aircraft will not wait for passengers from simultaneously arriving flights (there are no banks) and often will not refuel.

Key questions addressed by this research are:

- Under what conditions is the hub and spoke system superior?
- How does the variability in time over distance affect the relative value of hub and spoke versus point to point?
- Does the relative value of point to point decline as the network becomes more comprehensive (includes a larger fraction of all possible city pairs)?
- What is the optimum profit maximizing balance between utilization (short aircraft layovers) trip time (short passenger layovers) and trip reliability (long passenger layovers)? How is this influenced by cost and customer value assumptions?

**Method**

Customer value analysis uses airline profitability as an ultimate measure. Profit is essentially price minus cost.

In customer value analysis, price is a function of customer value. The more satisfied customers are, the more they are willing to pay. Two properties are used in this analysis to measure customer value: time and reliability. Four cost issues are addressed: aircraft capital cost, crew, fuel and maintenance. These are all a function of stage length distribution and utilization. The model is summarized in Figure 3.

The model has four inputs, which are all random variables:

- Leg Distance — The distance between cities connected by direct flights. The distribution is determined by geography and the route map
- Time / Distance — Flight time divided by leg distance. For simplicity, the model treats this random variable as if it were independent of leg distance.
- Passenger Layover — The time from the arrival of the first leg of a passenger’s flight to the departure of the second leg.
- Aircraft Layover — The time from the end of one leg to the beginning of the next.

These are used to calculate four intermediate variables:

- Operating Cost — This includes fuel, crew and maintenance.
- Utilization — Aircraft flying hours per day
- Trip Time — Passenger time from embarkation to arrival at destination
- Trip Reliability — Probability that the first leg of the flight will arrive before the second leg departs

![Figure 3: Overview of customer value model](image-url)
To determine the leg distance, city maps are randomly generated with 20 to 50 cities. The cities are uniformly distributed on a north-south interval and independently normally distributed on an east west interval. Population is hyperbolically distributed so that the distribution corresponds to Pareto’s law. Cities less than 50 miles apart are combined. Route maps are created for hub and spoke and point to point operation among the cities. To create a hub and spoke map, the hub is chosen and every other city is connected to the hub with a spoke. The hub is chosen as the city which scores highest with a metric which positively weights population and negatively weights location near the perimeter of the map.

Results

The following results were observed when exploring the model.

1. The point-to-point route system always earns a greater return on capital than the hub and spoke route system.

2. When the point-to-point network is small, it earns better returns by choosing only the most profitable routes (cherry picking).

3. Even when comparable in size to the hub and spoke system, point to point earns more profits because it commands higher yields (customers are willing to pay higher prices) and obtains greater utilization of aircraft (more flying hours per day).

4. Customers pay more for point-to-point service because: (a) on true point-to-point routes they benefit from non-stop service which requires less time and provides greater reliability (less chance of trip interruption); (b) on through flights (flights with an intermediate stop but no change of planes) customers spend less time in a point-to-point stop than in a bank at a hub; (c) when a connection is necessary, the point-to-point connection is longer but more reliable; (d) passengers who must stop or connect still spend less time on a point-to-point route on the average, because it tends to be more collinear.

5. Point-to-point routes provide greater aircraft utilization because intermediate stops are shorter. The stops are shorter because the aircraft does not wait for passengers—passengers are in queue before the aircraft lands.

Conclusions

Although collinear routes and a higher percentage of non-stop service are important advantages to the point-to-point routing, the key disadvantage to the hub and spoke operation is an element that is not really essential to the route structure: connections in banks. A bank is the arrangement in which a group of aircraft land, passengers debark and cross the terminal to their connecting flight, the aircraft reload the passengers and then depart.

Banks are nice because they provide the maximum number of city-pair connections at the maximum frequency. However, when organizing a schedule around banks, the airline must trade-off connection time with trip reliability. If the connection time is too short, a significant number of passengers will miss connections. Longer connection times are problematic because all the passengers must wait, and all the aircraft sit on the ground.

A typical simulation used $560 as the value to a passenger of making the connection, $20 per hour as the value to the passenger of saving time and $20 per hour per seat as the opportunity cost to the airline to let the aircraft sit at the gate. Given a normal distribution of flight times with a standard deviation of 20 minutes, the best trade is to pad connections with 40 minutes additional delay. This will still cause 3.2% of passengers to miss connections.

This frustration with missed connections and irritation at the wait for successful connections is very unattractive for passengers, and should be reflected in yields. An alternative is asynchronous arrivals and departures. Average connection times will be longer, but missed connections are fewer and aircraft utilization is improved (aircraft only embark passengers who are ready when they land).

Still, the point-to-point route better exploits asynchronous connections because more passengers stay on the plane at the intermediate stop, minimizing their equivalent of connection time.