Airline System Optimization

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Problem

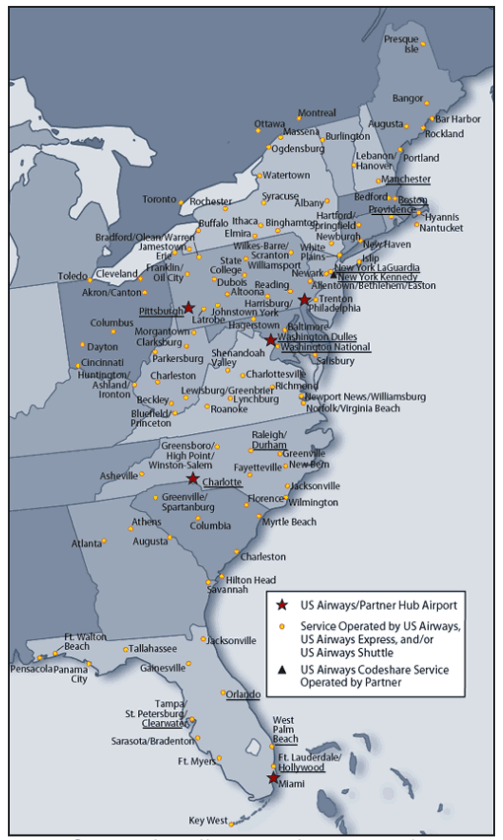
- Hub-and-Spoke versus Point-to-Point Service
- Hub-and-Spoke Service: Passengers are routed through a central location and combined with passengers from other flights
- Point-to-Point Service: Passengers take direct flights from origins to destinations

Problem cont.

- From the airline’s perspective, maximum profit is desired.
- From the customer’s perspective, maximum satisfaction is desired.
- Solution?

Project Overview

- System modeled after current East Coast operations of US Airways.



Source: http://www.usairways.com/

Project Overview cont.

- 30 origin cities
- 1 destination (Orlando – chosen for its constant level of flight demand)
- 2 hubs (Philadelphia and Charlotte)
- Total of 88 possible routes (direct flight, flight through CLT hub, flight through PHL hub

Project Overview cont.

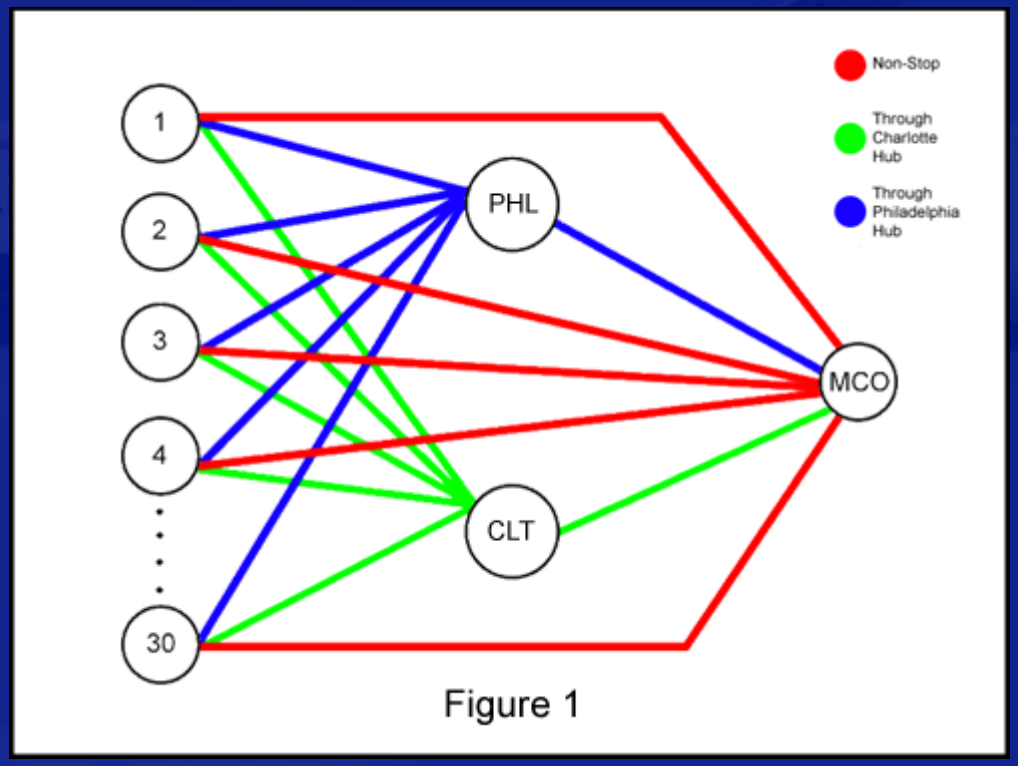


Figure 1

Project Overview cont.

- Aircraft used: Airbus 319
- Capacity = 120 passengers
- Range = 3,700 nautical miles (well within the required range of this system)

Project Overview cont.

Goal:

Formulate best possible system routing based strictly on the airline's perspective (profit) and another incorporating both customer satisfaction and profit.

Formulation

Linear Program (Objective Function):

```
MAX
-11924.75r1 - 7223.98r2 - 1717.24r3 + 5590.86r4 + 8197.28r5 +
11923.13r6 - 14092.57r7 - 8694.53r8 - 3240.74r9 + 4715.37r10 +
7930.73r11 + 12129.61r12 + 83407.12r13 + 81375.48r14 + 86044.31r15 +
24215.15r16 + 26038.33r17 + 30801.33r18 + 37169.91r19 + 36412.35r20 +
37257.30r21 + 19637.90r22 + 20874.20r23 + 22997.21r24 + 21671.39r25 +
24169.32r26 + 26306.63r27 + 23818.49r28 + 24504.10r29 + 24240.03r30 +
29927.62r31 + 30095.47r32 + 28586.79r33 + 125016.64r34 + 126305.18r35 +
119261.56r36 + 15160.46r37 + 18003.10r38 + 20881.80r39 + 637510.36r40 +
627068.01r41 + 641266.79r42 + 52428.46r43 + 49868.34r44 + 41862.43r45 +
67931.49r46 + 73910.03r47 + 67890.57r48 + 12971.44r49 + 16056.90r50 +
18059.32r51 + 127379.21r52 + 124841.27r53 + 62939.84r54 + 66257.44r55 +
65947.29r56 + 122560.28r57 + 124529.50r58 + 116463.48r59 + 4087.65r60 +
8564.21r61 + 5414.25r62 + 13884.15r63 + 18420.36r64 + 15027.56r65 +
37413.25r66 + 37015.94r67 + 32648.82r68 + 16739.84r69 + 17403.26r70 +
10824.25r71 + 93539.77r72 + 80435.44r73 + 91514.24r74 + 92272.63r75 +
79178.58r76 + 233732.72r77 + 220529.11r78 + 177746.99r79 + 18918.57r80 +
19421.76r81 + 10783.63r82 + 18032.60r83 + 21627.64r84 + 25184.99r85 +
46727.90r86 + 48348.56r87 + 50640.41r88
```

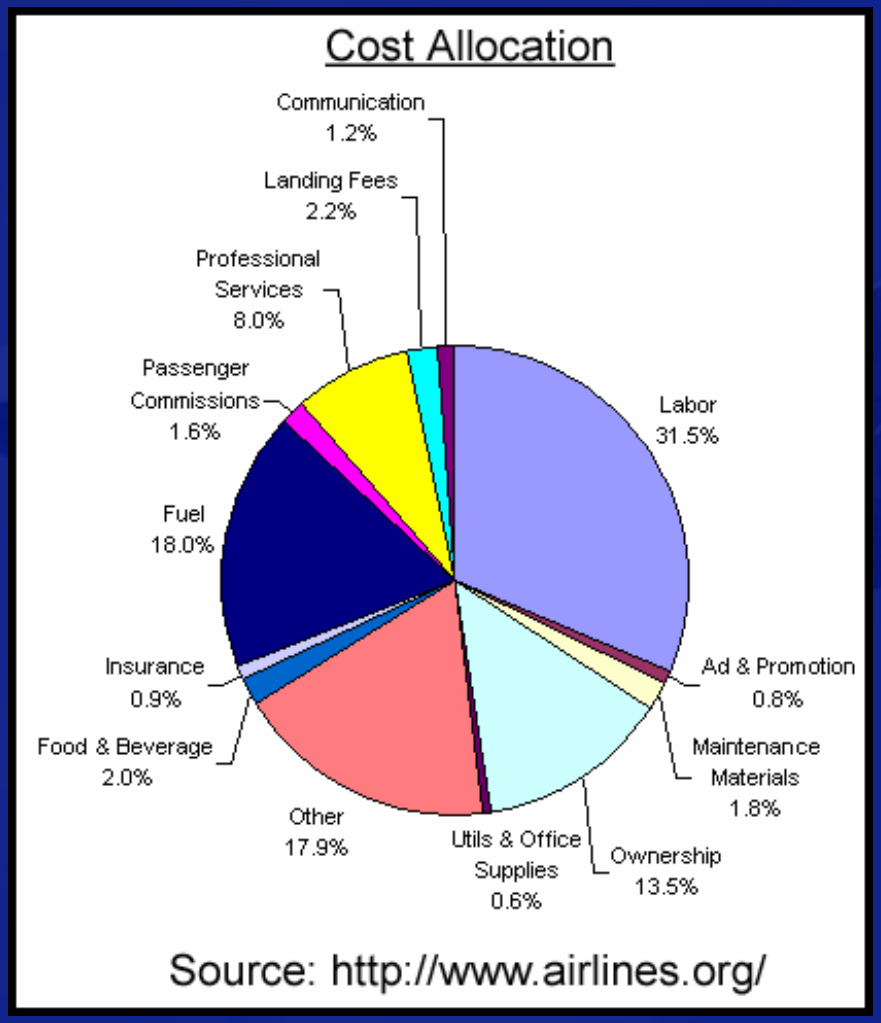
Formulation cont.

How to determine coefficients for each route:

Profit = Revenue – Cost

Revenue = (Ticket Price * # of Passengers)
Cost = (Cost of Flight * # of Flights)
Cost of Flight = (120 * 0.1097 * Distance)
# of Flights = Passengers / 120

Formulation cont.



- $0.1097
- Cost per seat per mile
- Air Transport Association statistic
- Industry cost standard
- Includes everything from fuel to landing fees

Formulation cont.

Example: Possible Route # 28 (Direct flight from Rochester, NY to Orlando, FL)

Profit = (358.80*104.1) – (13532.59*1) = 23818.49

Ticket Price = 358.80

Passengers = (1041000*0.0001) = 104.1

Cost = (120*0.1097*1028) = 13532.59

# of Flights = 104.1/120 = 0.868 ~ 1

Formulation cont.

Example: Possible Route # 29 (Hub flight from Rochester, NY through Charlotte, NC to Orlando, FL)

Profit = Revenue – Cost

Profit = (358.80*104.1) – [(7582.46*1)+(5264.51)] = 24504.10

Ticket Price = 358.80
Passengers = (1041000*0.0001) = 104.1
Cost = Cost to CLT + Cost from CLT to MCO
Cost to CLT= (120*0.1097*576) = 7582.46
# of Flights = 104.1/120 = 0.868 ~ 1
Cost from CLT to MCO = (0.1097*104.1*461) = 5264.51

*Cost from CLT to MCO is based on number of passengers, not number of seats

Formulation cont.

Incorporating Customer Satisfaction:

- Based on (travel time / distance)
- Value between 0 and 1
- Higher values mean more satisfied customers
- Direct flights have highest levels of customer satisfaction

Formulation cont.

Customer Satisfaction:

Direct flight

CS = [1 – (total flight time / total distance)]

Hub flight

CS = [1 – ((time to hub + time from hub to MCO + wait time at hub) / total distance))]

Wait time at hub = 90 minutes

Formulation cont.

Example:

Pittsburgh, PA to MCO (direct and through CLT hub)

Direct:

CS = 1 – (time / distance) = 1 – (180 / 824) = 0.78

Through CLT Hub:

CS = 1 – (time to CLT + time from CLT to MCO + wait time) / distance)

CS = 1 – (100 + 105 + 90) / 825 = 0.64

Formulation cont.

<u>Finding Customer Satisfaction Coefficients:</u>

Profit Model:

Coefficient = Route Profit

Profit/CS Model:

Coefficient = (Route Profit*Wp)*(CS*Wcs)

Wp = weight of profit in model

Wcs = weight of customer satisfaction in model

Formulation cont.

For example:

Possible Route 35 (Cleveland through Charlotte Hub to Orlando)

Coefficient = (Route Profit*Wp)*(CS*Wcs)

Wp = 0.20

Wcs = 0.80

Route Profit = 126305.18

CS = 0.68

Coefficient = (126305*0.20)*(0.68*0.80) = 13773.61

Formulation cont.

Constraints (condensed):

Must choose only one of the possible routes

r1 + r2 + r3 = 1

r4 + r5 + r6 = 1

…

r86 + r87 + r88 = 1

Hub capacity

10r2 + 51r5 + 4r8 + … + 77r87 <= 3500

10r3 + 51r6 + 4r9 + … + 77r88 <= 3500

Solution

- Using LINDO software, the linear program is evaluated and a 0 or 1 value is returned for each of the 88 possible routes.
- 1 means that the route has been chosen in order to maximize the objective function on that route
- 0 means that the route was not chosen.

Solution cont.

Origin City	Chosen Route	Profit ($)	
BANGOR	Through PHL	-1717.24	
PORTLAND	Through PHL	11923.13	
BURLINGTON	Through PHL	-3240.74	
MANCHESTER	Through PHL	12129.61	
BOSTON	Through PHL	86044.31	
PROVIDENCE	Through PHL	30801.33	
HARTFORD	Through PHL	37257.30	
ALBANY	Through PHL	22997.21	
SYRACUSE	Through PHL	26306.63	
ROCHESTER	Through PHL	24240.03	
BUFFALO	Through CLT	30095.47	
CLEVELAND	Through CLT	126305.18	
WILKES-BARRE	Through PHL	20881.80	
NEW YORK	Through PHL	641266.79	
COLUMBUS	Direct Flight	52428.46	
PITTSBURGH	Through CLT	73910.03	
HARRISBURG	Through PHL	18059.32	
PHILADELPHIA	Direct Flight	127379.21	
BALTIMORE	Through CLT	66257.44	
WASHINGTON, DC	Through CLT	124529.50	
CHARLESTON, WV	Through CLT	8564.21	
ROANOKE	Through CLT	18420.36	
RICHMOND	Direct Flight	37413.25	
RALEIGH	Through CLT	17403.26	
CHARLOTTE	Direct Flight	93539.77	
CINCINNATI	Through CLT	92272.63	
ATLANTA	Direct Flight	233732.72	
COLUMBIA	Through CLT	19421.76	
READING	Through PHL	25184.99	
ALLENTOWN	Through PHL	50640.41	
		2124448.11	**TOTAL**

- Profit Model
- 100% Profit
- 0% Customer Satisfaction

Solution cont.

Origin City	Chosen Route	Profit ($)	
BANGOR	Through PHL	-1717.24	
PORTLAND	Through PHL	11923.13	
BURLINGTON	Through PHL	-3240.74	
MANCHESTER	Through PHL	12129.61	
BOSTON	Direct Flight	83407.12	
PROVIDENCE	Through PHL	30801.33	
HARTFORD	Direct Flight	37169.91	
ALBANY	Through PHL	22997.21	
SYRACUSE	Through PHL	26306.63	
ROCHESTER	Direct Flight	23818.49	
BUFFALO	Direct Flight	29927.62	
CLEVELAND	Direct Flight	125016.64	
WILKES-BARRE	Through PHL	20001.00	
NEW YORK	Direct Flight	637510.36	
COLUMBUS	Direct Flight	52428.46	
PITTSBURGH	Direct Flight	67931.49	
HARRISBURG	Through PHL	18059.32	
PHILADELPHIA	Direct Flight	127379.21	
BALTIMORE	Direct Flight	62939.84	
WASHINGTON, DC	Direct Flight	122560.28	
CHARLESTON, WV	Through CLT	8564.21	
ROANOKE	Direct Flight	13884.15	
RICHMOND	Direct Flight	37413.25	
RALEIGH	Direct Flight	16739.84	
CHARLOTTE	Direct Flight	93539.77	
CINCINNATI	Direct Flight	91514.24	
ATLANTA	Direct Flight	233732.72	
COLUMBIA	Direct Flight	18918.57	
READING	Through PHL	25184.99	
ALLENTOWN	Direct Flight	46727.90	
		2094450.11	**TOTAL**

- Profit/CS Model
- 20% Profit
- 80% Customer Satisfaction

- Cost increased by $29,998.00

Conclusion

- In this system, there is no single service that is optimal.
- A combination of direct flights and hub flights should be utilized in order to maximize the profit over the system.
- Assumption before analysis: an entire hub-based system would be most profitable and an entire point-to-point system would satisfy the most customers

Conclusion cont.

- A hub flight was not always chosen in the profit-driven model. This was a result of the origin's proximity to the destination as opposed to either hub.
- Where a route obtains a negative profit, there are not enough passengers to justify using the Airbus 319. A smaller plane that is less expensive to operate should be considered for use in these cities.

Conclusion cont.

Future Extensions

- Variable Equipment (smaller aircraft for smaller cities)
- System Expansion (more than 30 origins; multiple destinations)
- More fluid route scheduling would allow for further optimization (changing demand for different seasons, etc.)
- Elimination of smaller, less-profitable cities


QUESTIONS?