Optimization Techniques And Applications

(Mini - Project)

Fleet Routing and Assignment

Determine which aircraft to fly on each route, and the sequence of segments flown by each aircraft.

Abstract

Flight planning is the process that produces a flight plan to describe a proposed aircraft flight which involves various aspects to be considered including flight disruptions and irregular operations that can have a significant impact on airlines and passengers.

Flight planners normally wish to minimise flight cost through the appropriate choice of the factors that affect an aircraft's fly. For enhanced operations, airlines need optimization techniques that seek optimal balance between operational reliability and cost efficiency.

There are two ways that we are going to consider for cost minimization which include the total distance covered by all the planes and the total number of airports. Also we are going to consider the segment flown by each aircraft.

Problem Description

Airline fleet planning process is one of the most problematic issues for airline industry. Considering the profit margin of the airline industry and the high competition in the industry around the world, if the aircraft planning is not optimized properly it can be very detrimental to the company. Therefore, airlines must develop a more practical fleet planning approach to meet market demand with lower costs and more controllable risks at a strategic level. From the plethora of problems faced by the airline companies, some are:

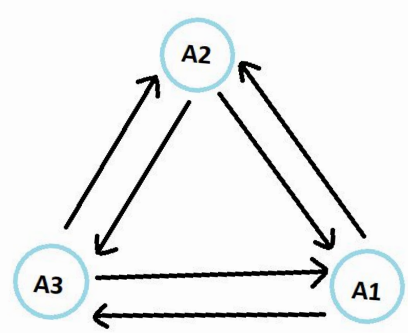
- **Network Design problem** which consists in mainly deciding which airports should be served by the airline.
- **Fleet Design problem** which consists in deciding the size and the composition of the fleet of the airline.
- **Aircraft Routing problem** which consists in designing the sequence of flight legs that each aircraft will have to operate on.
- **Flight Scheduling problem** which consists in finding when and how often should each leg flight be operated in a planning period.
- **Cost Design problem** which consists of deciding the minimum cost that the company must bear for total distance covered by an aircraft.

Here in this problem we consider 2 planes moving between 3 airports so that maximum number of aircraft are flown between the airports. Based on this approach we are going to design the mixed integer programming problem and solve it using **MATLAB**.

Formulation

For the formulation of **Fleet Routing and Management Problem**, the assumptions and variables that we have taken will be explained in this section. Let us assume an aircraft would like to use mathematical programming to schedule its flights to minimize cost. Here, we are tackling the problem keeping 2 planes in mind, namely Apovarde J-047 and Lockheed L-188. From here on we will consider assigning flight frequency for each path and minimizing its overall operating cost.

	Apovarde J-047	Lockheed L-188
Seating Capacity	250	100
Cost Per Flight Hour	5300 USD	2845 USD



Graph - 1.1 Segment flown by aircraft

Nomenclature

There are 2 aircraft used in the profit maximization :

The decision variable we will be using is X_{ijk}, which corresponds to the k^{th} plane flying from airport i to airport j.

Airport 1 = Netaji S. C. Bose International Airport(Kolkata (KOL))

Airport 2 = Chhatrapati Shivaji International Airport(Mumbai(MUB))

Airport 3 = Kuala Lumpur International Airport(Singapore(SGP))

Aircraft 1 = Apovarde J-047

Aircraft 2 = Lockheed L-188

X_{ij1} = Number of Apovarde J-047 used from airport i to airport j

X_{ij2} = Number of Lockheed L-188 used from airport i to airport j

$A_{12} = A_{21}$ = distance KOL to MUB in hours flight time = 2h15m

$A_{13} = A_{31}$ = distance of KOL to SGP in hours flight time = 5h15m

$A_{23} = A_{32}$ = distance of MUB to SGP in hours flight time = 6h00m

S_1 = Seats in Apovarde J-047

S_2 = Seats in Lockheed L-188

F_{ij} = Number of flights running between i and j

C_k = Operating cost of k^{th} aircraft in USD/flight hour

Constraints

Cost Function:

Cost = $\Sigma\Sigma(X_{ijk})(C_k)(A_{ij})$

Cost = $(X_{121})(5300)(2.25) + (X_{122})(2845)(2.25) + (X_{211})(5300)(2.25) + (X_{212})(2845)(2.25) +$
$(X_{131})(5300)(5.25) + (X_{132})(2845)(5.25) + (X_{311})(5300)(5.25) + (X_{312})(2845)(5.25) +$
$(X_{231})(5300)(6.00) + (X_{232})(2845)(6.00) + (X_{321})(5300)(6.00) + (X_{322})(2845)(6.00)$

Supply of Seats:

We need to meet the **demand of passengers** moving from airport to airport.

$(X_{ij1})(S_1) + (X_{ij2})(S_2) \geq$ (demand from i to j)

$250X_{121} + 100X_{122} \geq 1350$

$250X_{211} + 100X_{212} \geq 850$

$250X_{131} + 100X_{132} \geq 1700$

$250X_{311} + 100X_{312} \geq 1100$

$250X_{231} + 100X_{232} \geq 950$

$250X_{321} + 100X_{322} \geq 1000$

Aircraft Availability:

The next constraint we have is **aircraft availability**, given by:

$(A_{ij})(F_{ij}) \leq (X_{ij1} + X_{ij2})*(20)$

Here we are assuming we can run our aircraft for up to 20 hours a day. That allows time for refueling and regular maintenance.

This constraint ensures that there is a sufficient number of aircraft to cover the amount of time for all the flights needed to cover the route with the frequency each route is flown.

The constraints are given explicitly below:

$(2.25)*(7) \leq (X_{121} + X_{122})*(20)$

$(2.25)*(6) \le (X_{211} + X_{212})*(20)$

$(5.25)*(10) \le (X_{131} + X_{132})*(20)$

$(5.25)*(11) \le (X_{311} + X_{312})*(20)$

$(6)*(8) \le (X_{231} + X_{232})*(20)$

$(6)*(7) \le (X_{321} + X_{322})*(20)$

Flight Frequency:

Constraint for the **number of flights for each route**:

We want each route to be covered a certain number of times. This will insure a reliable airline, which runs regular flights.

$(X_{121} + X_{122}) \ge 7$

$(X_{211} + X_{212}) \ge 6$

$(X_{131} + X_{132}) \ge 10$

$(X_{311} + X_{312}) \ge 11$

$(X_{231} + X_{232}) \ge 8$

$X_{321} + X_{322}) \ge 7$

Path Constraints:

Incoming number of particular aircraft at a particular airport should be equal to outgoing number of same aircraft at the same airport.

$X_{121} + X_{131} - X_{211} - X_{311} = 0$

$X_{211} + X_{231} - X_{321} - X_{121} = 0$

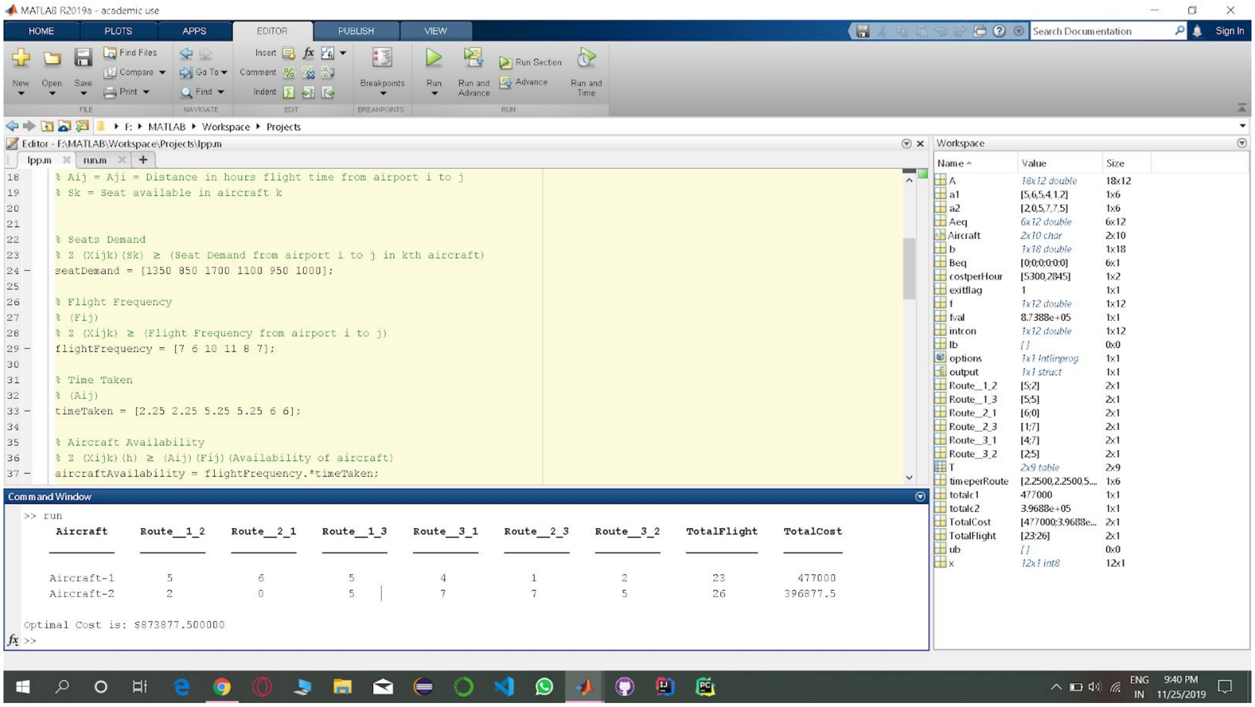
$X_{321} + X_{311} - X_{131} - X_{231} = 0$

$X_{122} + X_{132} - X_{212} - X_{312} = 0$

$X_{212} + X_{232} - X_{322} - X_{122} = 0$

$X_{322} + X_{312} - X_{132} - X_{232} = 0$

Source Code


MATLAB R2019a - academic use
HOME PLOTS APPS EDITOR PUBLISH VIEW
Editor - F:\MATLAB\Workspace\Projects\lpp.m
lpp.m run.m
% Aij = Aji = Distance in hours flight time from airport i to j
% Sk = Seat available in aircraft k
% Seats Demand
% Σ (Xijk)(Sk) ≥ (Seat Demand from airport i to j in kth aircraft)
seatDemand = [1350 850 1700 1100 950 1000];
% Flight Frequency
% (Fij)
% Σ (Xijk) ≥ (Flight Frequency from airport i to j)
flightFrequency = [7 6 10 11 8 7];
% Time Taken
% (Aij)
timeTaken = [2.25 2.25 5.25 5.25 6 6];
% Aircraft Availability
% Σ (Xijk)(h) ≥ (Aij)(Fij)(Availability of aircraft)
aircraftAvailability = flightFrequency.*timeTaken;
Command Window
>> run
Aircraft Route__1_2 Route__2_1 Route__1_3 Route__3_1 Route__2_3 Route__3_2 TotalFlight TotalCost
Aircraft-1 5 6 5 4 1 2 23 477000
Aircraft-2 2 0 5 7 7 5 26 396877.5
Optimal Cost is: $873877.500000
Workspace

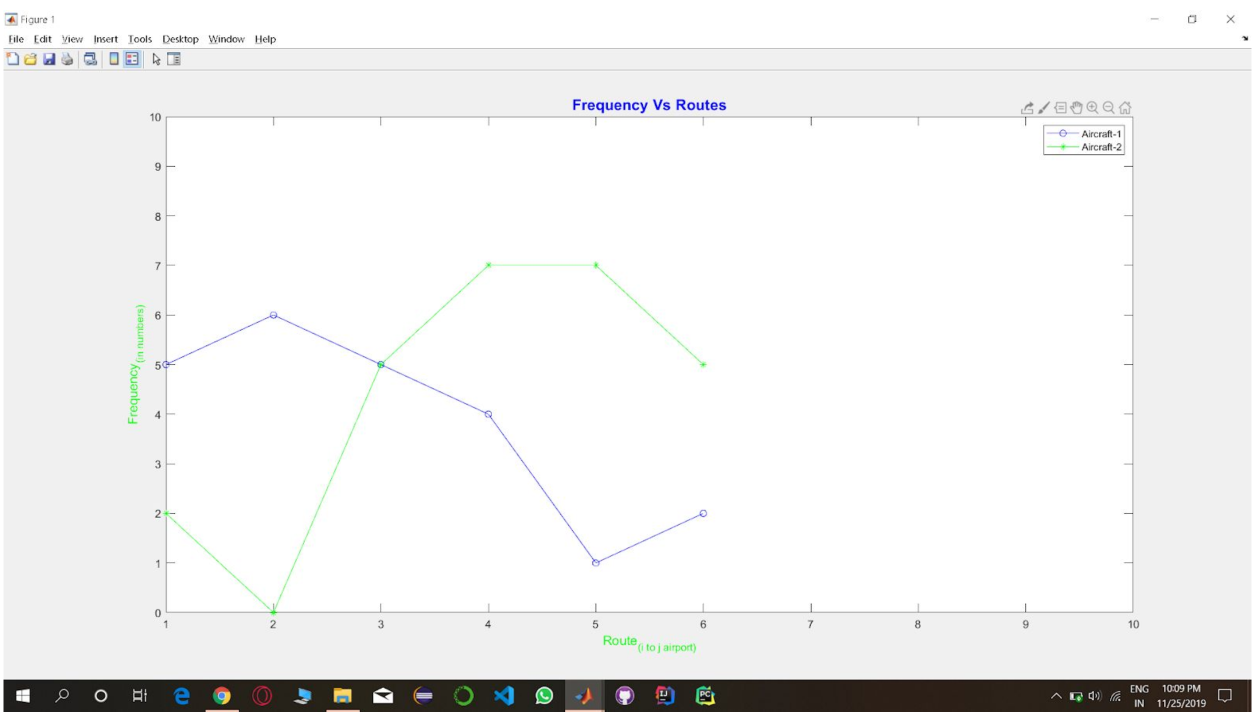


Figure 1
Frequency Vs Routes
Aircraft-1
Aircraft-2
Frequency(in numbers)
Route(i to j airport)

Conclusion

The optimized cost comes out to be: **USD 873,877.5** .

X_{121} = 5
That is Aircraft 1 travelled from Airport 1 to Airport 2 five times.
X_{122} = 2
That is Aircraft 2 travelled from Airport 1 to Airport 2 two times.
X_{211} = 6
That is Aircraft 1 travelled from Airport 2 to Airport 1 six times.
X_{212} = 0
That is Aircraft 2 did not travel from Airport 2 to Airport 1.
X_{131} = 5
That is Aircraft 1 travelled from Airport 1 to Airport 3 five times.
X_{132} = 5
That is Aircraft 2 travelled from Airport 1 to Airport 3 five times.
X_{311} = 4
That is Aircraft 1 travelled from Airport 3 to Airport 1 four times.
X_{312} = 7
That is Aircraft 2 travelled from Airport 3 to Airport 1 seven times.
X_{231} = 1
That is Aircraft 1 travelled from Airport 2 to Airport 3 one time.
X_{232} = 7
That is Aircraft 2 travelled from Airport 2 to Airport 3 seven times.
X_{321} = 2
That is Aircraft 1 travelled from Airport 3 to Airport 2 two times.
X_{322} = 5
That is Aircraft 2 travelled from Airport 3 to Airport 2 five times.

Aircraft Scheduling

Aircraft 1 can follow sequence:

A1→A2→A1→A3→A1→A2→A3→A2→A1→A2→A1→A2→A1→A2→A1→ A3→ A1→ A3→ A1→ A3→ A1→ A3→ A2.

Aircraft 2 can follow sequence:

A2→ A3→ A1→ A3→ A2→ A3→ A1→ A3→ A2→ A3→ A1→ A2→ A3→ A1→ A3→ A2→ A3→ A1→ A3→ A2→ A3→ A1→ A3→ A2→ A3→ A1→ A2.