香港城市大學
City University of Hong Kong

396EM Airline Operations and Scheduling/ 6075MAA Airline Scheduling and Operations

Lecture 2b
Fleet Assignment Part I

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Learning outcomes

Understand	the principles of Fleet Planning and Assignment
Know	the difference between the fleet planning and fleet assignment
Illustrate	the relationship between the Flight Scheduling and Fleet Assignment
Identify	the various factors that affect the Fleet Assignment
Understand and apply	the analytical methods of fleet assignment

The aim of Fleet Assignment

- The aim of Fleet Assignment is to assign as many flight segments as possible in a schedule to one or more fleet types, while optimizing some objective function and meeting various operational constraints (Abara, 1989)

- Match each aircraft type in the fleet with a particular route in the schedule

- It is not choose a particular aircraft, but only the fleet type

- Assign the right fleet type to each flight in the schedule

Fleet Assignment vs Fleet Planning

Fleet Assignment

- Assume the airline is operational with the existing aircraft in its fleet
- Assign a fleet type to each flight leg
- Each fleet type has different characteristics and costs
  - Seating capacity
  - Landing weights
  - Crew
  - Maintenance
  - fuel

Fleet Planning

- A strategic decision of the number and type of aircraft needed for operations
- Entail the process of acquiring the appropriate aircraft types in order to serve the anticipated markets based on airline's strategic plan
- Address the fleet size and fleet mix
- Fleet diversity requires the airlines to have skilled crew and personnel for each fleet type, plan for different maintenance checks, and have less flexibility in replacing an aircraft when a failure occurs

Fleet Diversity for selected airlines

Airline	B737	A318/ 319/ 320/ 321	A300	A330/ A340	A380	B757	B767	B777	B787	B747	A350	DC9	F-100	CRJ	EMB	C Series	Total
Air France	-	168	-	35	12	-	-	73	-	23	-	-	-	-	-	-	311
American Airlines	164	-	30	-	-	124	73	54	-	-	-	294	4	-	-	-	743
British Airways	26	90	-	-	12	11	21	52	24	57	-	-	-	-	-	-	293
Delta Air Lines	114	-	-	-	-	132	102	18	-	-	-	133	-	9	-	-	508
Lufthansa	64	144	13	67	15		-	-	-	51	-	-	-	-	28	30	412
Northwest	-	133	-	32	-	61	-	-	18	30	-	96	-	-	-	-	370
Southwest	641	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	641
United	78	194	-	-	-	97	35	52	-	30	-	-	-	-	-	-	486
US Airways	72	292	-	34	-	39	10	-	-	-	22	-	-	-	42	-	511
Continental Airlines	320	-	-	-	-	57	26	28	25	-	-	-	-	-	-	-	456

Source: 2009 Fleet-iNet – OAG Aviation Solutions.

Bazargan (2010)

JAL Group – Fleet Summary (2021)

Airbus A350-900

Boeing 787-900

Boeing 777-300ER

Boeing 767-300

Model	Owned	Leased	Total
Airbus A350-900	4	4	8
Boeing 787-9	17	3	20
Boeing 787-8	29	0	29
Boeing 777-300ER	13	0	13
Boeing 777-300	0	0	0
Boeing 777-200ER	6	0	6
Boeing 777-200	0	0	0
Boeing 767-300ER	29	0	29
Boeing 767-300	2	0	2
Boeing 737-800	43	18	61
Embraer 170	18	0	18
Embraer 190	14	0	14
Bombardier DHC8-Q400CC	5	0	5
Saab 340B	2	0	2
ATR42-600	8	1	9
ATR72-600	2	0	2
Total	192	26	218

Source: https://www.jal.com/en/outline/aircraft.html

CX Group – Fleet Summary (2021)

The Group had 234 aircraft as at 31 December 2021.

Airbus A320

The newest aircraft to join our fleet, the A321neo features uncompromising comfort, 4K Ultra HD TV screens in every seat and extra-large overhead bins.

Airbus A330

At the heart of the cockpit of this wide-body aircraft is the fly-by-wire system pioneered by Airbus – a major improvement on stability.

Airbus A350

Feel the difference with complimentary satellite TV, redesigned seats and headrests, and panoramic window views. Enjoy state-of-the-art technology onboard, with reduced noise levels and a reduced carbon footprint.

Boeing 777

With its super-wide cabins and high ceilings, you'll travel on your long-haul trip in optimal comfort. Inflight Wi-Fi is available across all four classes.

Sources: https://www.cathaypacific.com/cx/en_US/flying-with-us/aircraft-and-fleet.html
https://news.cathaypacific.com/fact-sheet#

Hong Kong Airline – Fleet Summary

Our Fleet

Our current operating fleet comprises of 32 Airbus aircraft including:

Aircraft type	Number of aircraft
A320	12
A330-200	10
A330-300	8
A350-900	2
Total	**32**

A350-900 Aircraft Specifications

Sources: *https://www.hkairlines.com/en_HK/footer/about-hk-airlines/ourfleet*

Question for Discussion …

- Single fleet or Multi fleet? …..
- What will you choose if you are the Airline CEO?
- Which model will be better?

Identify and obtain to design the fleet assignment

- 1. Demand and revenues of every OD pair (Origin-Destination)
  - time-of-the-day
  - day-of-the-week

- 2. Route information
  - Distances
  - Times
  - Operating restrictions

Identify and obtain to design the fleet assignment (Con't)

- 3. Aircraft characteristics and operating costs

- 4. Operational and managerial constraints
  - Air service agreement
  - Departure Slot / Route & Airport issues
  - Human resources constraints

Types of Aircrafts

- A wide-body aircraft is a jet airliner having a fuselage wide enough to accommodate two passenger aisles, also known as twin-aisle aircraft, with seven or more seats abreast

- A typical narrow-body airliner has a diameter of 3 to 4 m (10 to 13 ft), with a single aisle

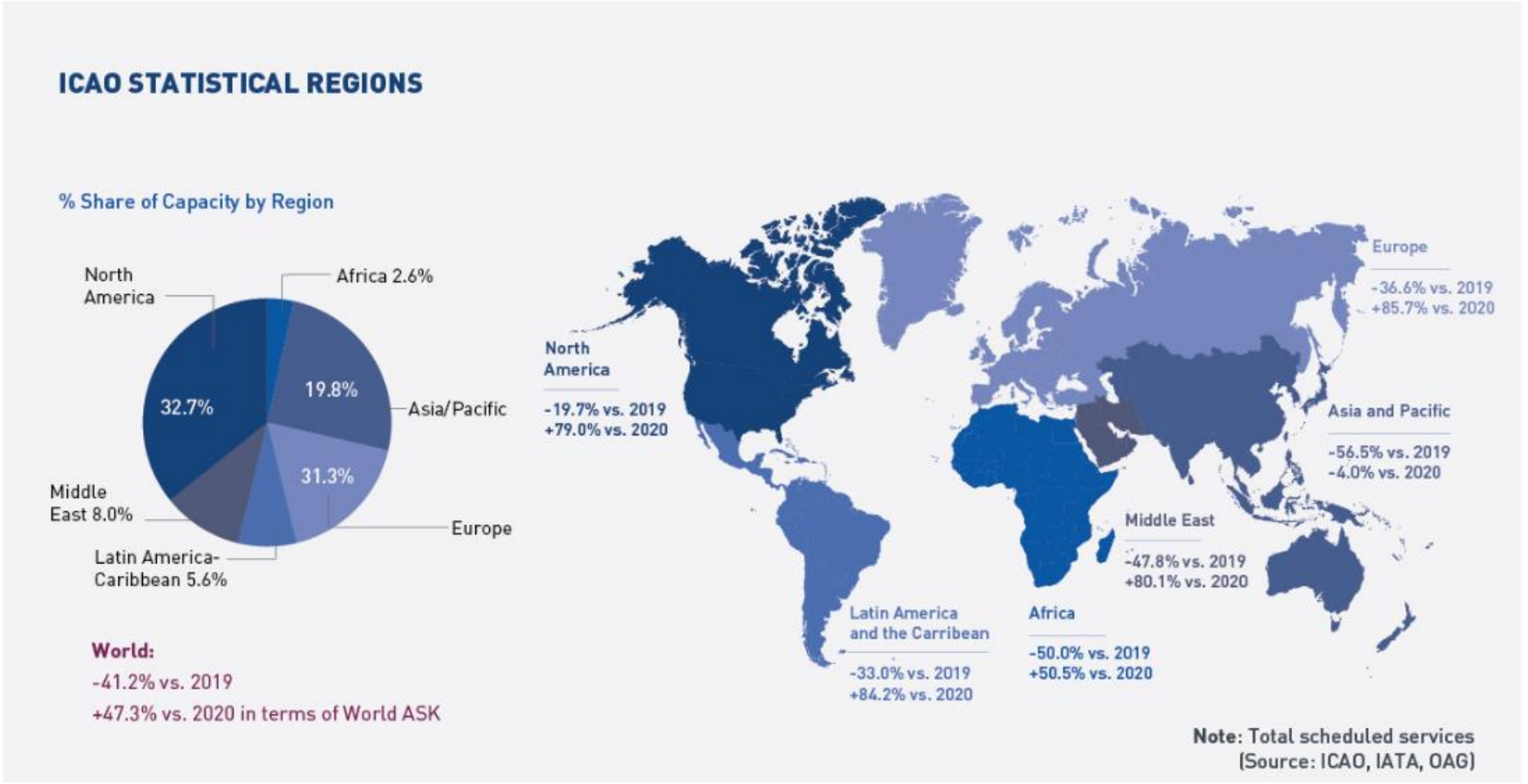
- A regional jet (RJ) is a class of short to medium-range turbofan powered regional jet airliners.

Aircraft type:
https://www.cathaypacific.com/cx/en_HK/flying-with-us/aircraft-and-fleet/airbus-a330/a330.html
https://www.airpartner.com/en-us/aircraft-guide/

World Results and Analyses for October 2021

Worldwide capacity contracted by -41.2% in October 2021, compared to 2019

Capacity by Region (ICAO Statistical Regions)



Source: https://unitingaviation.com/news/economic-development/the-air-transport-monthly-monitor-for-december-2021/

World Results and Analyses for October 2021

AIRPORTS BY NUMBER OF PASSENGERS

Airports	Passengers	vs. 2019
Atlanta GA, US (ATL)	3,818,470	↓ -19.7%
Dallas/Fort Worth TX, US (DFW)	2,975,084	↓ -6.7%
Chicago IL, US (ORD)	2,906,783	↓ -22.9%
Denver CO, US (DEN)	2,849,679	↓ -6.2%
Los Angeles CA, US (LAX)	2,423,807	↓ -32.6%
Istanbul, TR (IST)	2,180,393	↓ -29.6%
Las Vegas NV, US (LAS)	2,090,573	↓ -9.5%
Charlotte NC, US (CLT)	2,087,898	↓ -5.6%
New Delhi, IN (DEL)	2,032,665	↓ -32.4%
Guangzhou, CN (CAN)	1,978,035	↓ -37.7%
Antalya, TR (AYT)	1,932,105	↓ -7.4%
Phoenix AZ, US (PHX)	1,906,065	↓ -2.6%
Shenzhen, CN (SZX)	1,903,577	↓ -17.4%
Chengdu, CN (CTU)	1,864,987	↓ -23.3%
Orlando FL, US (MCO)	1,841,354	↓ -11.0%

AIRPORTS RANKING BY NUMBER OF FREIGHT

Airports	Freights	vs. 2019
Hong Kong SAR, CN (HKG)	459,000	↑ 9.5%
Memphis TN, US (MEM)	382,041	↑ 1.3%
Shanghai, CN (PVG)	305,458	↓ -5.0%
Anchorage AK, US (ANC)	304,494	↑ 27.3%
Incheon, KR (ICN)	284,858	↑ 18.8%
Taipei, CN (TPE)	242,019	↑ 24.1%
Louisville KY, US (SDF)	238,239	↑ 0.1%
Tokyo, JP (NRT)	231,410	↑ 32.0%
Doha, QA (DOH)	226,422	↑ 15.0%
Los Angeles CA, US (LAX)	225,718	↑ 30.3%
Miami FL, US (MIA)	222,924	↑ 29.0%
Chicago IL, US (ORD)	212,402	↑ 34.5%
Dubai, AE (DXB)	206,963	↓ -6.0%
Frankfurt, DE (FRA)	192,240	↑ 14.1%
Paris, FR (CDG)	187,000	↑ 11.3%

IATA Regional Highlights in 2021

Regional Highlights

Significant differentiation is emerging between regions with large domestic markets and those relying primarily on international traffic. Losses are highest in Europe (-$22.2 billion) with only 11% of its passenger traffic (RPK) being domestic. Proportionately, losses are much smaller in North America (-$5.0 billion) and Asia-Pacific (-$10.5 billion) where domestic markets are larger (66% and 45% respectively, pre-crisis).

REGION	2021 DEMAND VS 2019	2021 CAPACITY VS 2019	2021 PROFIT (% OF REVENUES)	2020 PROFIT (% OF REVENUES)
World	-57.0%	-47.2%	-$47.7 billion (-10.4%)	-$126.4 billion (-33.9%)
North America	-41.5%	-29.2%	-$5.0 billion (-2.7%)	-$35.1 billion (-26.8%)
Europe	-66.3%	-57.1%	-$22.2 billion (-23.9%)	-$34.5 billion (-43.0%)
Asia Pacific	-57.8%	-47.6%	-$10.5 billion (-8.8%)	-$35.0 billion (-31.1%)
Middle East	-67.6%	-58.9%	-$4.2 billion (-13.8%)	-$7.9 billion (-28.9%)
Latin America	-48.9%	-45.2%	-$4.0 billion (-20.4%)	-$11.9 billion (-80.1%)
Africa	-64.5%	-53.6%	-$1.7 billion (-24.0%)	-$2.0 billion (-32.0%)

IATA Passenger Forecast

PASSENGER NUMBERS, SHARE OF 2019	2021	2022	2023	2024	2025
Industry-wide	47%	83%	94%	103%	111%
International	27%	69%	82%	92%	101%
Domestic	61%	93%	103%	111%	118%
Asia Pacific	40%	68%	84%	97%	109%
Europe	40%	86%	96%	105%	111%
North America	56%	94%	102%	107%	112%
Africa	46%	76%	85%	93%	101%
Middle East	42%	81%	90%	98%	105%
South America	51%	88%	97%	103%	108%
Central America	72%	96%	102%	109%	115%
Caribbean	44%	72%	82%	92%	101%

Source:IATA/Tourism Economics Air Passenger Forecast, March 2022

Fleet Assignment

- Fleet: group of flights confined to a specific aircraft type
- Assign an aircraft type to each flight in the schedule
- Objective: Maximize revenue by
  - Matching seat capacity to passenger demand
  - Reducing costs such as fuel, maintenance and airport gating

Fleet Assignment (Con't)

Constraints:

- Restrictions on the operating ranges of aircraft
- Curfews and runway limitations at airports
- Aircraft must stay overnight at stations where maintenance work can be performed
- There must also be enough time for passengers to deplane and enplane and for servicing the aircraft

Terminology

- ASK (ASM): Available Seat Kilometres (Miles) represents the annual airline capacity; or supply of seats, and refers to the number of seats available for passengers during the year multiplied by the number of kilometres (miles) that those seats are flown.

- RPK (RPM): Revenue Passenger Kilometres represents the total number of paying passengers flown on all flight segments multiplied by the number of kilometres (miles) that those passengers are flown. RPK (RPM) is considered to be demand and should be less than ASK(ASM).

ICAO eg

Terminology (Con't)

- Yield: how much an airline makes per revenue passenger kilometer (mile) or how much an airline makes per kilometer (mile) on each seat sold. It is obtained by dividing total operating revenue divided by RPK (RPM)

- RASM (RASK): Revenue Per Available Seat Mile (kilometer) or 'unit revenue' represents how much an airline made across all the available seats that were supplied. It is calculated by dividing the total operating revenue divided by ASK (ASM). Thus, Yield >RASM.

- CASM (CASK): Cost per Available Seat Mile (kilometer) or 'unit cost' is the average cost of flying one seat for a mile (km). CASM is calculated by dividing the total operating cost by ASK (ASM)

Bazargan (2010)

Example - US major carriers' domestic operation key performance indicators (2008)

Carrier	ASM (million)	RPM (million)	RASM (cents)	CASM (cents)	Yield (cents)
Airtran	23,814.456	18,784.437	10.13	8.00	12.85
Alaska	21,815.762	16,742.678	10.80	7.76	14.07
American	101,855.071	83,313.426	10.89	8.22	13.32
Continental	52,987.792	44,215.689	10.95	7.79	13.12
Delta	128,976.090	105,697.565	10.73	7.17	13.10
JetBlue	32,435.674	26,069.180	9.45	6.69	11.76
Southwest	103,486.264	73,639.652	9.93	6.48	13.96
United	135,859.306	110,061.748	10.90	8.62	13.45
US Airways	74,148.295	60,567.144	10.77	8.51	13.18

Source: Form41 iNET.

Source: Bazargan (2010)

Fleet Assignment Principle - Maximize profits

- Given this example the aim is to find a profit-maximizing assignment of fleet types to flight legs in a way such that:
  - Not more than available number of aircrafts are used
  - Balance of aircrafts at each location is maintained

- The objective function tries to maximize the profit therefore the profit of assigning a fleet type to a flight leg should be calculated:

$$c_{l,f} = fare_l \times \min(D_l, Cap_f) - OpCost_{l,f}$$

with:

$c_{l,f}$: profitability of assigning fleet type f to flight leg l;
$fare_l$: fare of flight leg l;
D_l: demand of flight leg l;
Cap_f: capacity of fleet type f;
$OpCost_{l,f}$: operating cost of assigning fleet type f to flight leg l.

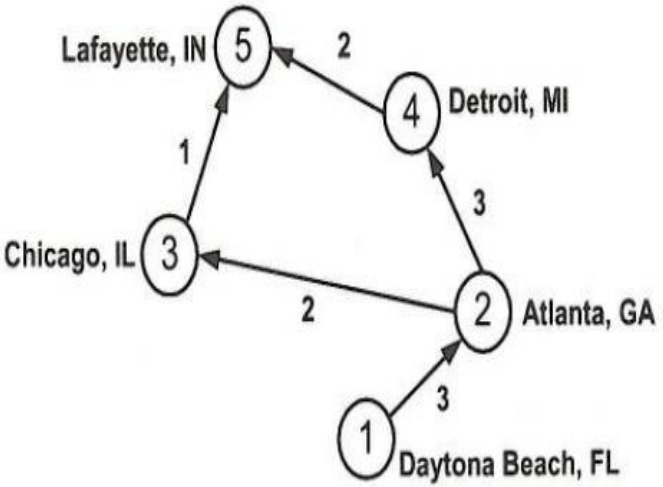
Source: Neyshabouri (2013)

Profit calculation

- Airlines need to do the calculation for each possible assignment.

- An example of the resulting profit for each assignment of fleet type to flight leg is listed in the following table

Flight No.	DC9 (1)	B737 (2)	A300 (2)
101	8 (cents)	10.5	22.5
102	8	10.5	22.5
103	5	3	0
221	8	10.5	7.5
222	8	10.5	22.5
223	8	10.5	7.5
351	31	43	60
352	31	43	60



Will you work out how to choose the fleet for certain flight legs for the above provided airline fleet and network?

Fleet Assignment

- The specific aircraft fleets have been allocated to the certain flight legs according to the profit maximisation rule

Flight No.	DC9 (1)	B737 (2)	A300 (2)
101	8	10.5	22.5
102	8	10.5	22.5
103	5	3	0
221	8	10.5	7.5
222	8	10.5	22.5
223	8	10.5	7.5
351	31	43	60
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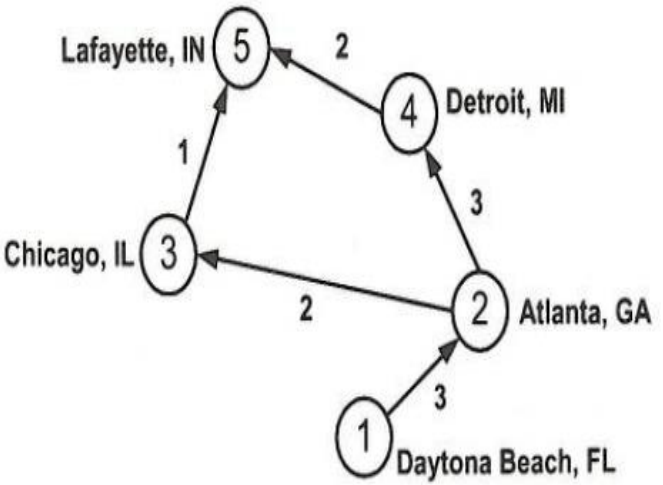


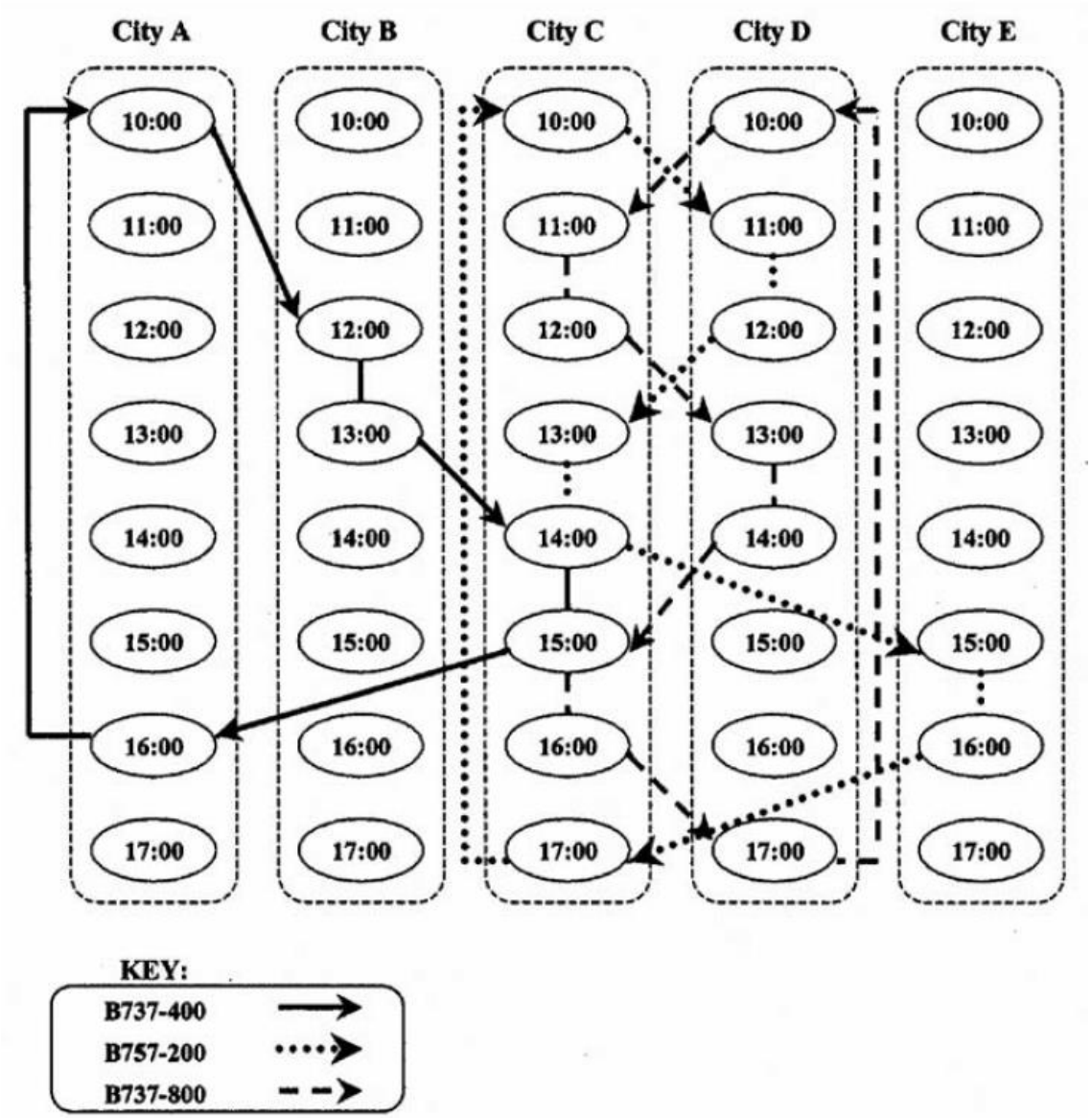
Fleet Assignment Tool – Time Space diagram

- Fleet assignment is keeping track of the fleet at different stations (airports) at any given pint in time.
- A time-space network is developed to solve the fleet assignment
- In the time-space diagram, columns represent the different airports, and the times of the day are shown as rows.

Time-Space Diagram (Networks)

- Decisions that are needed to be made at different times require adding variables that keeps track of time.
- Time is a continuous variable!
- Adding a continuous variable to this problem makes the problem even more complicated to solve.

Sample of time-space diagram



Source: Bazargan (2010)

Key Reference

- M. Bazargan (2010) Airline Operations and Scheduling. 2nd edition, Ashgate
  - Chapter 4 Fleet Assignment

References

- Abara, J. (1989) 'Applying Integer Linear Programming to the Fleet Assignment Problem'. Interfaces 19(4), 20-28
- Belobaba, P., Odoni, A. and Barnhart, C. (2009) The Global Airline Industry. Wiley
- Burghouwt, G. (2007) Airline Network Development in Europe and Its Impliations for Airport Planning. Ashgate
- CAPA database
- Altonaviation.com database
- Neyshabouri, S. (2013) Airline Schedule Optimisation. Lecture notes. George Manson University