香港城市大學
City University of Hong Kong

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

Lecture 2a
AIRLINE SCHEDULING

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專業 創新 胸懷全球
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Coventry University

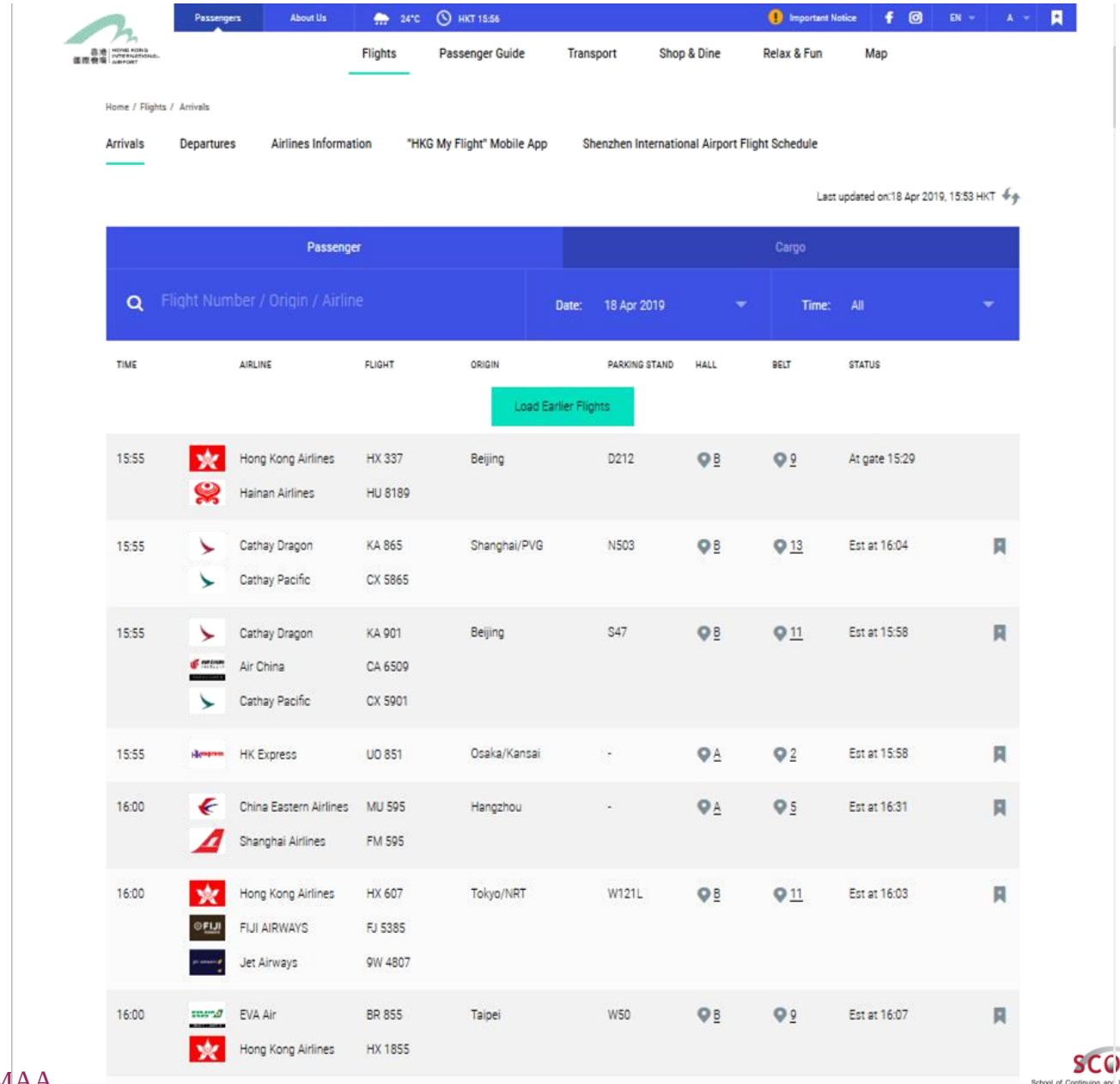
Learning outcomes

- Understand the definition of flight scheduling and the process of airline schedule planning
- Understand airline route development and network structures

- Identify the two key elements of flight schedule
- Illustrate the various factors affect the airline flight schedule and operations

Understand and apply the analytical methods to model and solve a range of situations of flight scheduling

Flight Schedule – Passenger Arrivals (AAHK)

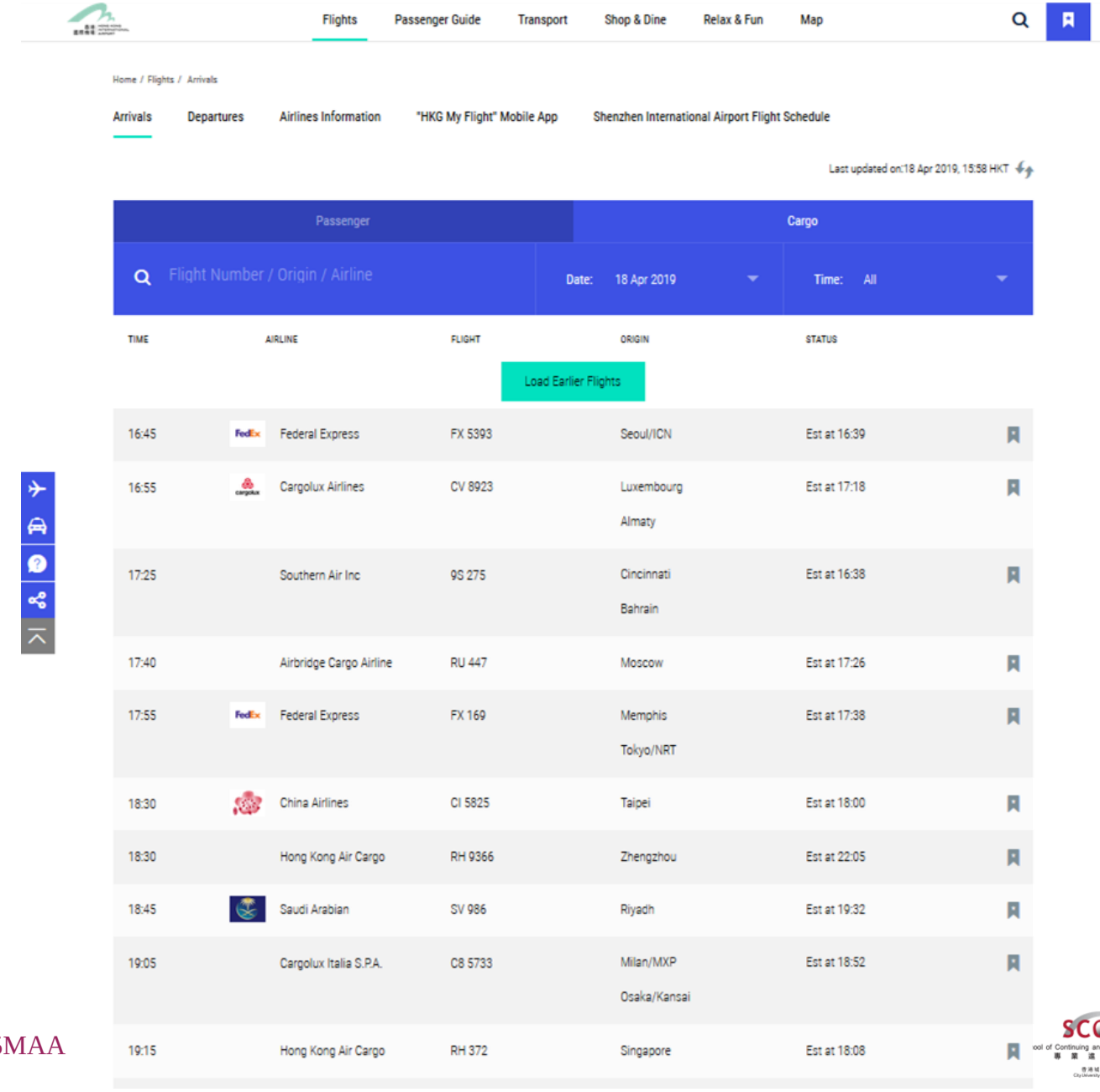


AAHK

Google

Flight Schedule – Cargo (AAHK)

AAHK



Flights | Passenger Guide | Transport | Shop & Dine | Relax & Fun | Map

Home / Flights / Arrivals

Arrivals | Departures | Airlines Information | "HKG My Flight" Mobile App | Shenzhen International Airport Flight Schedule

Last updated on:18 Apr 2019, 15:58 HKT

Passenger | Cargo

Flight Number / Origin / Airline | Date: 18 Apr 2019 | Time: All

Load Earlier Flights

TIME	AIRLINE	FLIGHT	ORIGIN	STATUS
16:45	Federal Express	FX 5393	Seoul/ICN	Est at 16:39
16:55	Cargolux Airlines	CV 8923	Luxembourg Almaty	Est at 17:18
17:25	Southern Air Inc	9S 275	Cincinnati Bahrain	Est at 16:38
17:40	Airbridge Cargo Airline	RU 447	Moscow	Est at 17:26
17:55	Federal Express	FX 169	Memphis Tokyo/NRT	Est at 17:38
18:30	China Airlines	CI 5825	Taipei	Est at 18:00
18:30	Hong Kong Air Cargo	RH 9366	Zhengzhou	Est at 22:05
18:45	Saudi Arabian	SV 986	Riyadh	Est at 19:32
19:05	Cargolux Italia S.P.A.	C8 5733	Milan/MXP Osaka/Kansai	Est at 18:52
19:15	Hong Kong Air Cargo	RH 372	Singapore	Est at 18:08

Flight Scheduling

- Flight Scheduling is the starting point for all other airline planning and operations (Barnhart, 2008; Yu and Thengvall, 2002)
- The Flight schedule is a timetable consisting of what cities to fly to and at what times (Bazargan, 2010)
- For large air carriers, the flight-scheduling group and route development may contain more than 30 employees (Note: In some US based carriers only)
- Scheduling is built to maximize airline long-term profitability (Note: at least on a seasonal basis)

Flight Scheduling (CON'T)

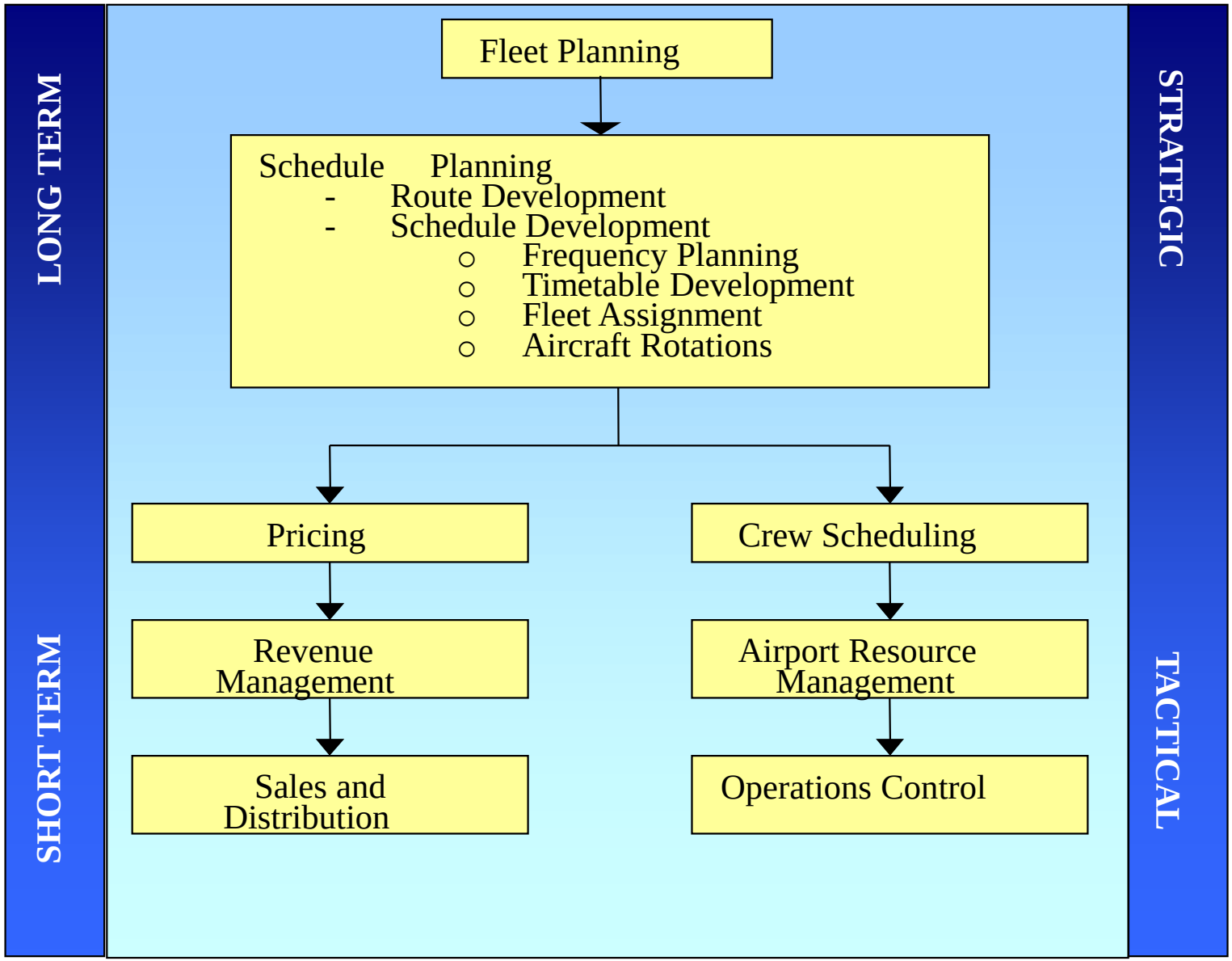
- An airline decides to offer certain flights mainly depending on the following factors:

  - Market demand forecasts
  - Available aircraft operating characteristics
  - Available manpower
  - Regulations
  - The behaviour of competitors (airlines)

- The flight schedule construction phase begins from a rough first schedule, which requires extensive modification to be both operationally feasible and economically viable (Etschamaier and Mathaisel, 1985)

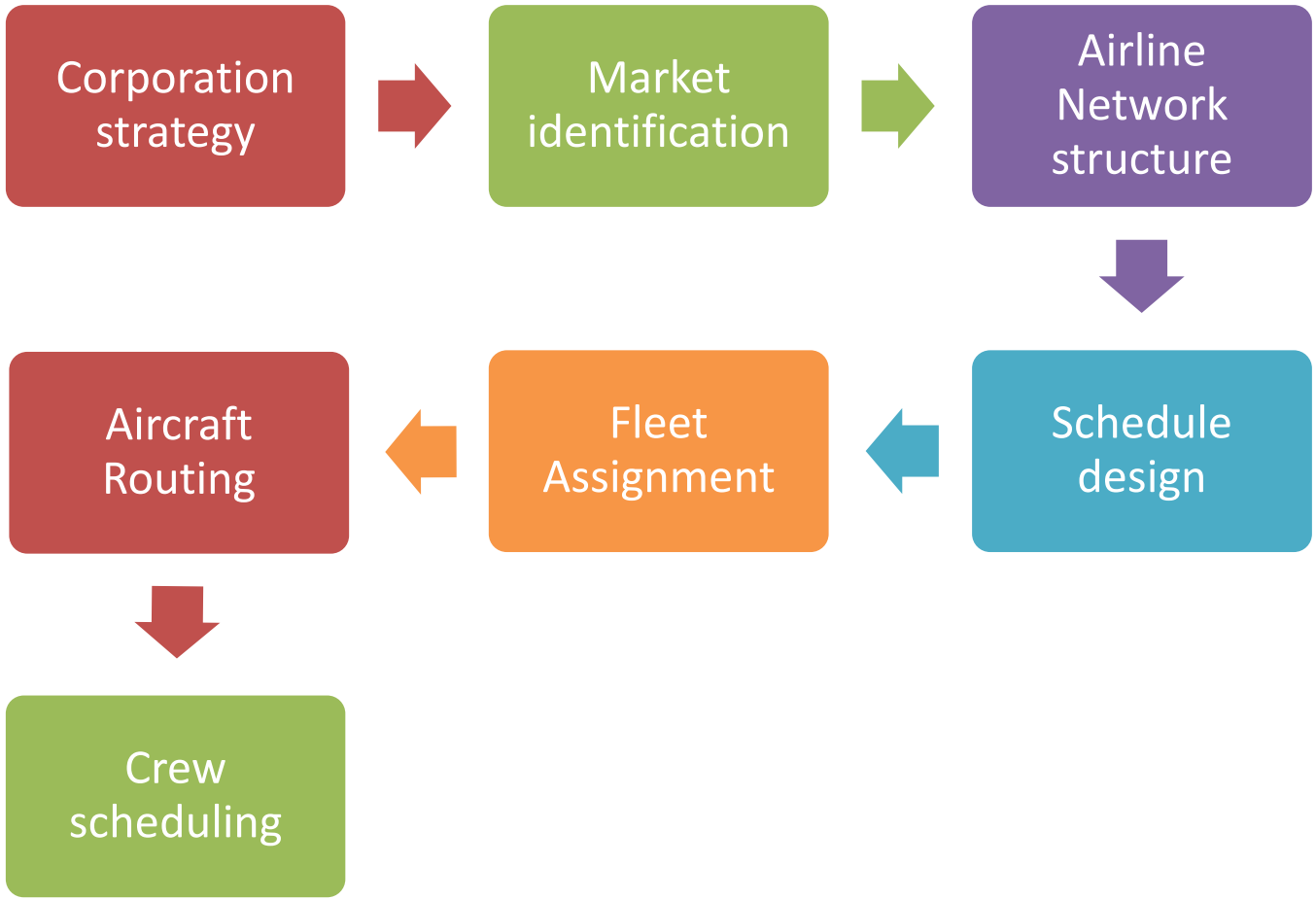
Flight Scheduling (CON'T)

- The flight schedule, containing the flight legs to be flown and the departure time of each flight leg, is the single most important product of an airline.
- It largely defines the market share an airline will capture, and hence is a key determinant of airline profitability.
- Designing a flight schedule to maximize profitability is extraordinarily complex, with essentially all elements of the airline (and competing airlines as well) linked to the flight schedule design decisions.
- One leading industry executive remarked, "The network planners are usually the smartest people in an airline."

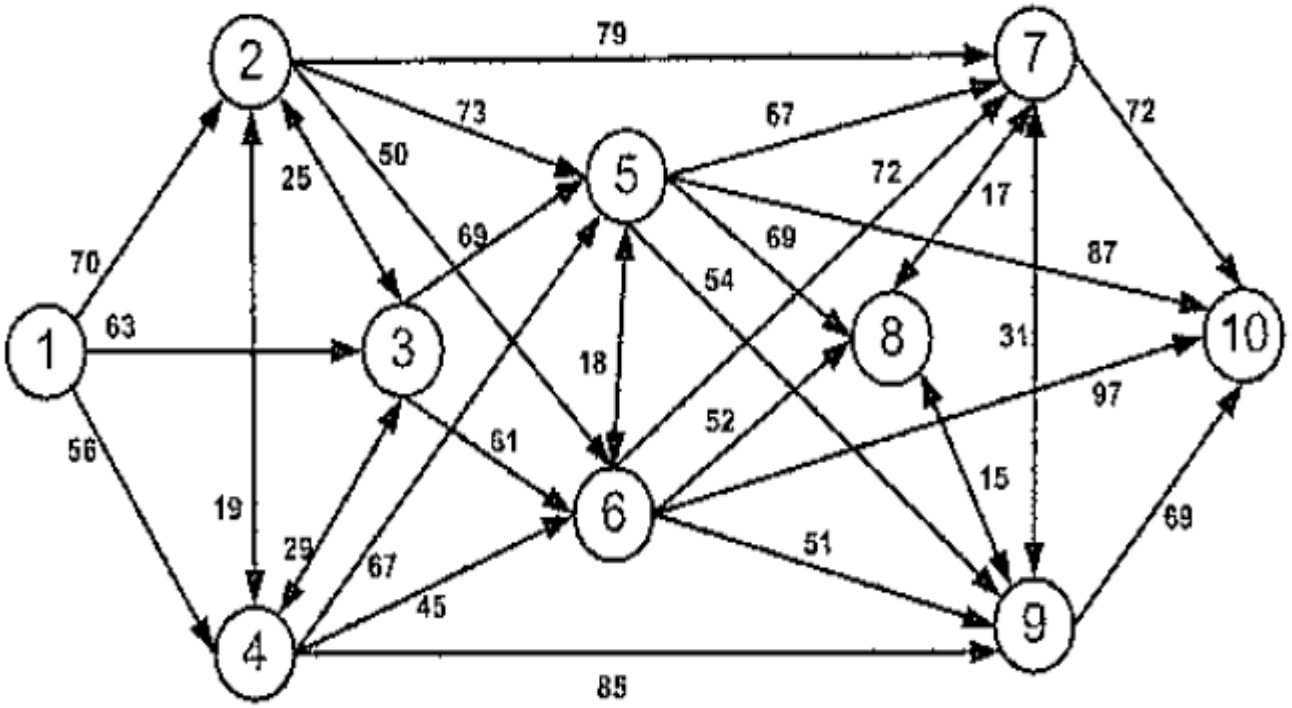


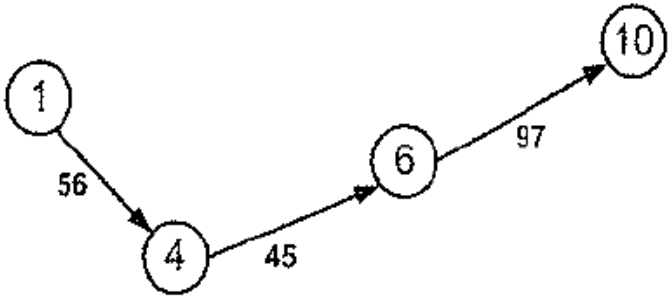
Barnhart 1.206J/16.77J/ESD.215J

Airline Schedule Planning Process



Airline Network: Route development - network with flight times between city pairs





The minimum cost is 198
The shortest path is 1-4-6-10

Airline network

- "A set of nodes and as the connections (flows, linkages) between the nodes."

  – Burghouwt (2007)

- "A network can be defined as the sum of elements/objectives (nodes) and their connections (edge/leg)."

  - Wittmer, et al, (2011)

Airline types - examples

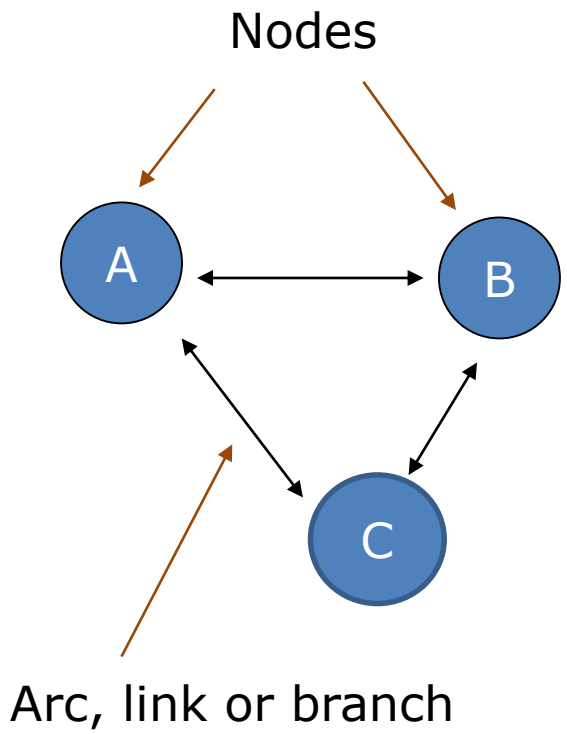
- International full-service network carriers
- Regional carriers
- Low-cost carriers
- Charter carriers
- Air cargo carriers
- Network niche carriers (e.g. flying taxis)

Airline network: Hub-and-Spoke

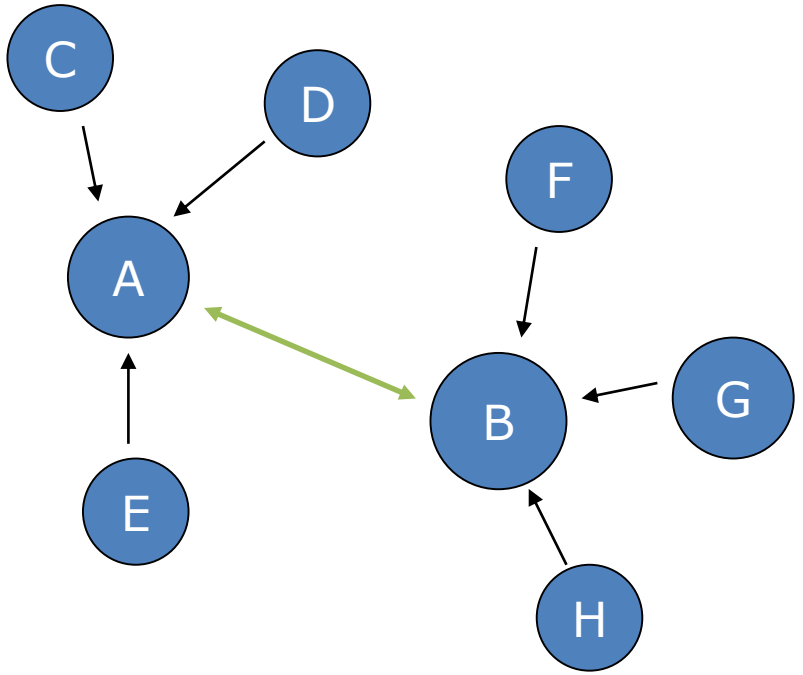
- Most airlines adopt some variation of a hub-and-spoke system.
- Air carriers normally assign large capacity non-stop flights between their hubs.
- Smaller airplanes are assigned to hub-and-spoke flights.
- Major advantages for the airlines adopting hub-and-spoke operations include higher revenues, higher efficiency, and lower number of aircraft needed as compared with point-to-point operations.

Airline Network Structure

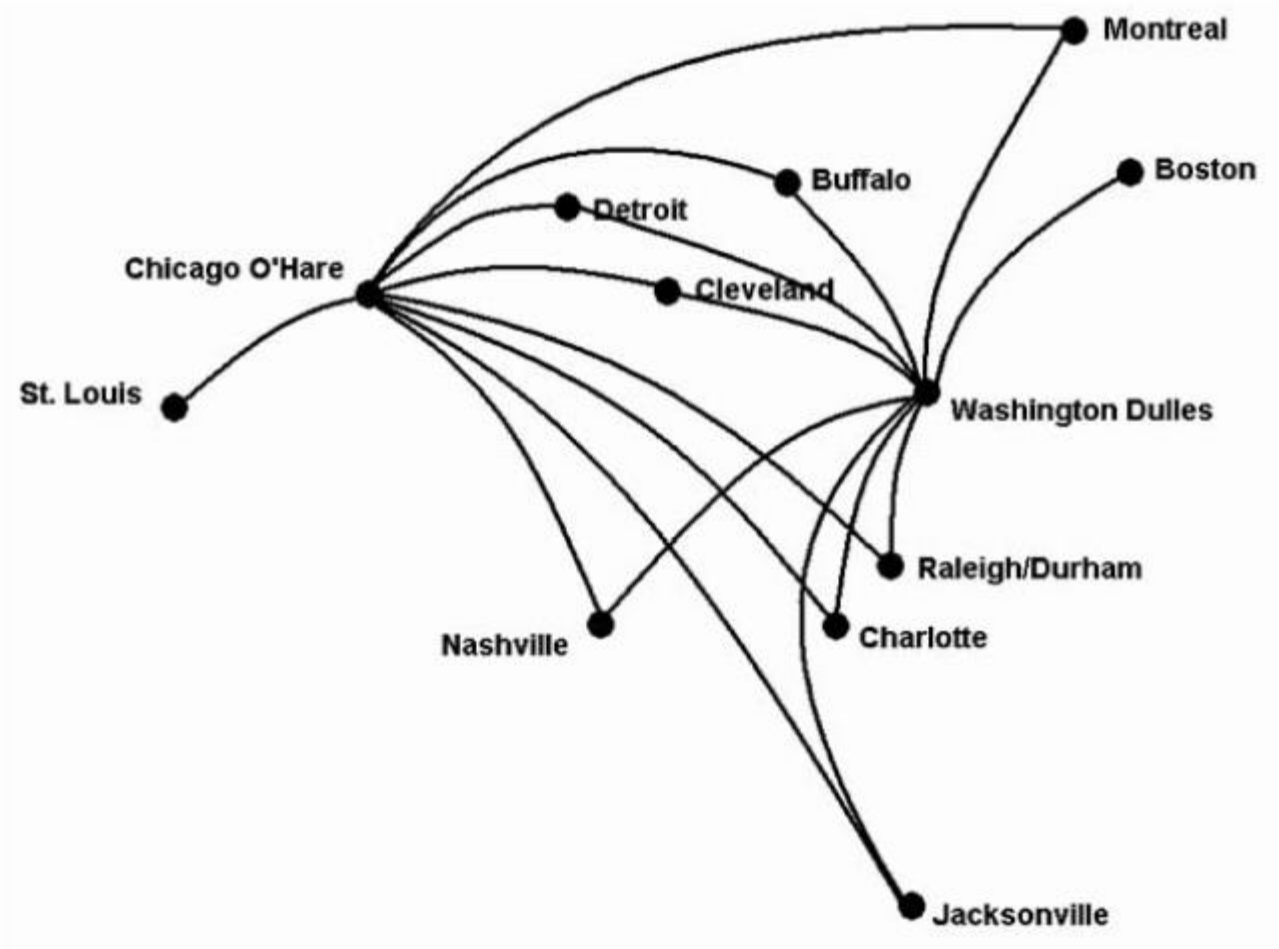
- Point-to-Point system



- Hub-and-Spoke system



HUBS And SPOKES



What are the advantages and disadvantages of Hub & Spoke network?

- Airline hubs are airports that an airline uses as a transfer point to get passengers to their intended destination.

- It is part of a hub and spoke model, as opposed to the Point to Point model, where travellers moving between airports not served by direct flights but changing planes and route to their destinations

What are the advantages and disadvantages of Hub & Spoke network? (Con't)

Advantages:

- Higher revenue
- Higher frequency
- lower number of aircraft needed compared with Point-to-Point network

Disadvantage:

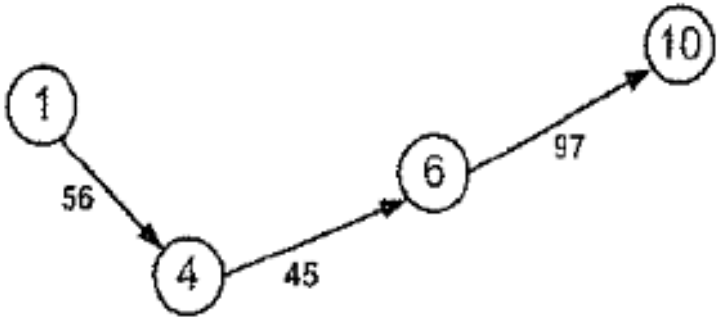
- Discomfort to Passengers (PAX) as multiple connecting flights at different hubs are required
- Congestions and delays at Hub airports
- Higher personnel and operational costs for airlines (Radnoti 2002)

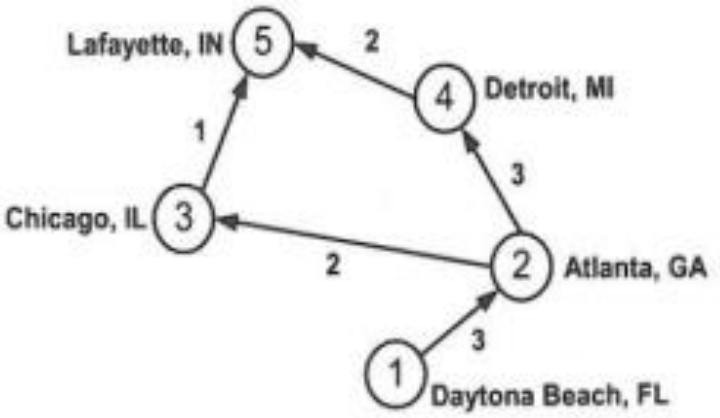
Network types

Point-to-Point (P2P)

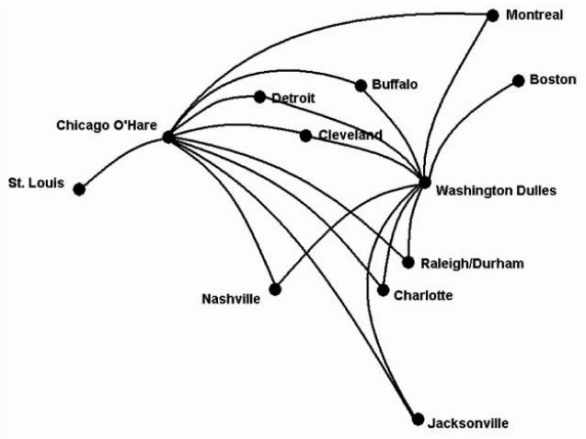
- Linear
- Grid

(Holloway, 2008)

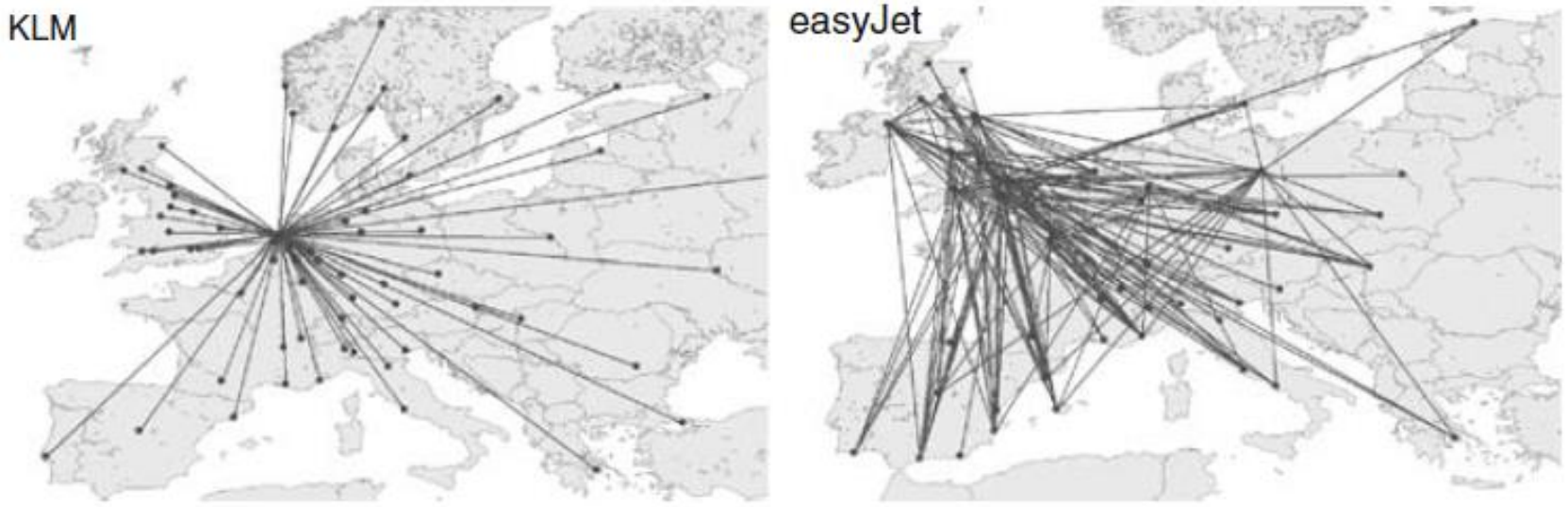




Hub-and-Spoke (H&S)



Hub-and-Spoke (H&S) - Example



Example: Airline network design – Hub selection

- An American airline wants to design its 'Hub' system. Each Hub will be used for connecting flights to and from cities within 1,000 miles of the hub.

- This airline wants to serve the following cities: Atlanta (AT), Boston (BO), Chicago (CH), Denver (DE), Houston (HO), Los Angeles (LA), New Orleans (NO), New York (NY), Pittsburgh (PI), Salt Lake City (SL), San Francisco (SF), and Seattle (SE).

- The airline wants to determine the smallest number of 'Hubs' it will need in order to cover all of these cities. By cover, which means each city should be within 1,000 miles of at least one hub.

- The distance between the above cities is listed in the table A of next slide.

Table A: Distance – matrix between cities

		1	2	3	4	5	6	7	8	9	10	11	12
		AT	BO	CH	DE	HO	LA	NO	NY	PI	SL	SF	SE
1	AT	0	1037	674	1398	789	2182	479	841	687	1878	2496	2618
2	BO	1037	0	1005	1949	1804	2979	1507	222	574	2343	3095	2976
3	CH	674	1005	0	1008	1067	2054	912	802	452	1390	2142	2013
4	DE	1398	1949	1008	0	1019	1059	1273	1771	1411	504	1235	1307
5	HO	789	1804	1067	1019	0	1538	356	1608	1313	1438	1912	2274
6	LA	2182	2979	2054	1059	1538	0	1883	2786	2426	715	379	1131
7	NO	479	1507	912	1273	356	1883	0	1311	1070	1738	2249	2574
8	NY	841	222	802	1771	1608	2786	1311	0	368	2182	2934	2815
9	PI	687	574	452	1411	1313	2426	1070	368	0	1826	2578	2465
10	SL	1878	2343	1390	504	1438	715	1738	2182	1826	0	752	836
11	SF	2496	3095	2142	1235	1912	379	2249	2934	2578	752	0	808
12	SE	2618	2976	2013	1307	2274	1131	2574	2815	2465	836	808	0

Table B:Binary-matrix showing cities covered by each hub

Value = 1, if the distance is less than 1,000 miles (covered)
Value = 0, if the distance is equal to or more than 1,000 miles

		1	2	3	4	5	6	7	8	9	10	11	12
		AT	BO	CH	DE	HO	LA	NO	NY	PI	SL	SF	SE
1	AT	1	0	1	0	1	0	1	1	1	0	0	0
2	BO	0	1	0	0	0	0	0	1	1	0	0	0
3	CH	1	0	1	0	0	0	1	1	1	0	0	0
4	DE	0	0	0	1	0	0	0	0	0	1	0	0
5	HO	1	0	0	0	1	0	1	0	0	0	0	0
6	LA	0	0	0	0	0	1	0	0	0	1	1	0
7	NO	1	0	1	0	1	0	1	0	0	0	0	0
8	NY	1	1	1	0	0	0	0	1	1	0	0	0
9	PI	1	1	1	0	0	0	0	1	1	0	0	0
10	SL	0	0	0	1	0	1	0	0	0	1	1	1
11	SF	0	0	0	0	0	1	0	0	0	1	1	1
12	SE	0	0	0	0	0	0	0	0	0	1	1	1

Formulate the problem

- Define X_j = { 1, if city j (1, 2, … 12) is selected as a hub; 0, otherwise

- Objective function:
  - *Minimize:* $X_1+X_2+X_3+X_4+X_5+X_6+X_7+X_8+X_9+X_{10}+X_{11}+X_{12}$

- Constraint function: each city must be covered by at least one hub.
  - e.g. Atlanta (Index 1) covered cities 1, 3, 5, 7, 8 and 9
  - $X_1+X_3+X_5+X_7+X_8+X_9 \geq 1$ (Atlanta)
  - $X_2+X_8+X_9 \geq 1$ (Boston)

- Note: use the greater than or equal to sign because a city can be covered by more than one hub.

Set covering problem – Hub selection

- 3 Hubs are selected: Atlanta, Pittsburgh & Salt Lake city by the shortest path method
  - Atlanta (AT) covers Chicago, Houston, New Orleans, New York, and Pittsburgh
  - Pittsburgh (PI) covers Atlanta, Chicago, Boston, and New York
  - Salt Lake City (SL) covers Denver, Los Angeles, San Francisco, and Seattle

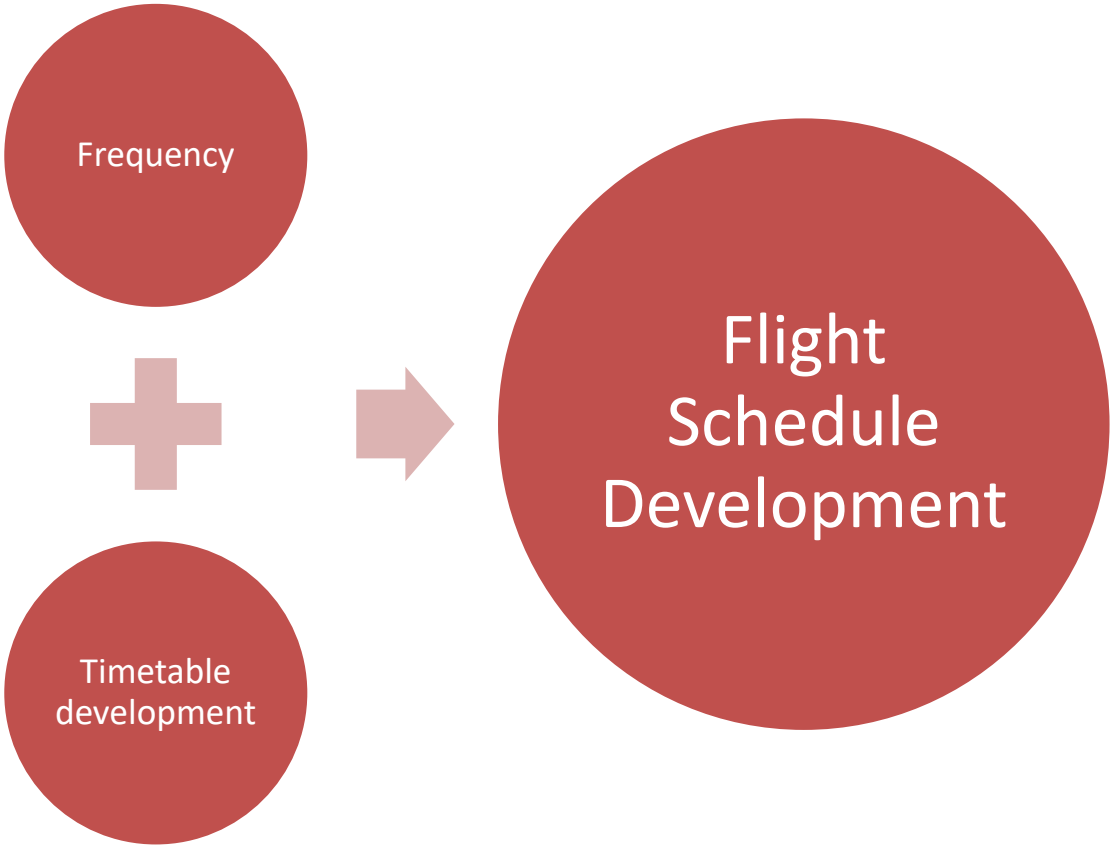
- Remarks: If we want to cover each city by exactly one hub (use set-partitioning) The hubs selected should be: Boston, New Orleans and Salt Lake City

- Boston covers New York and Pittsburgh

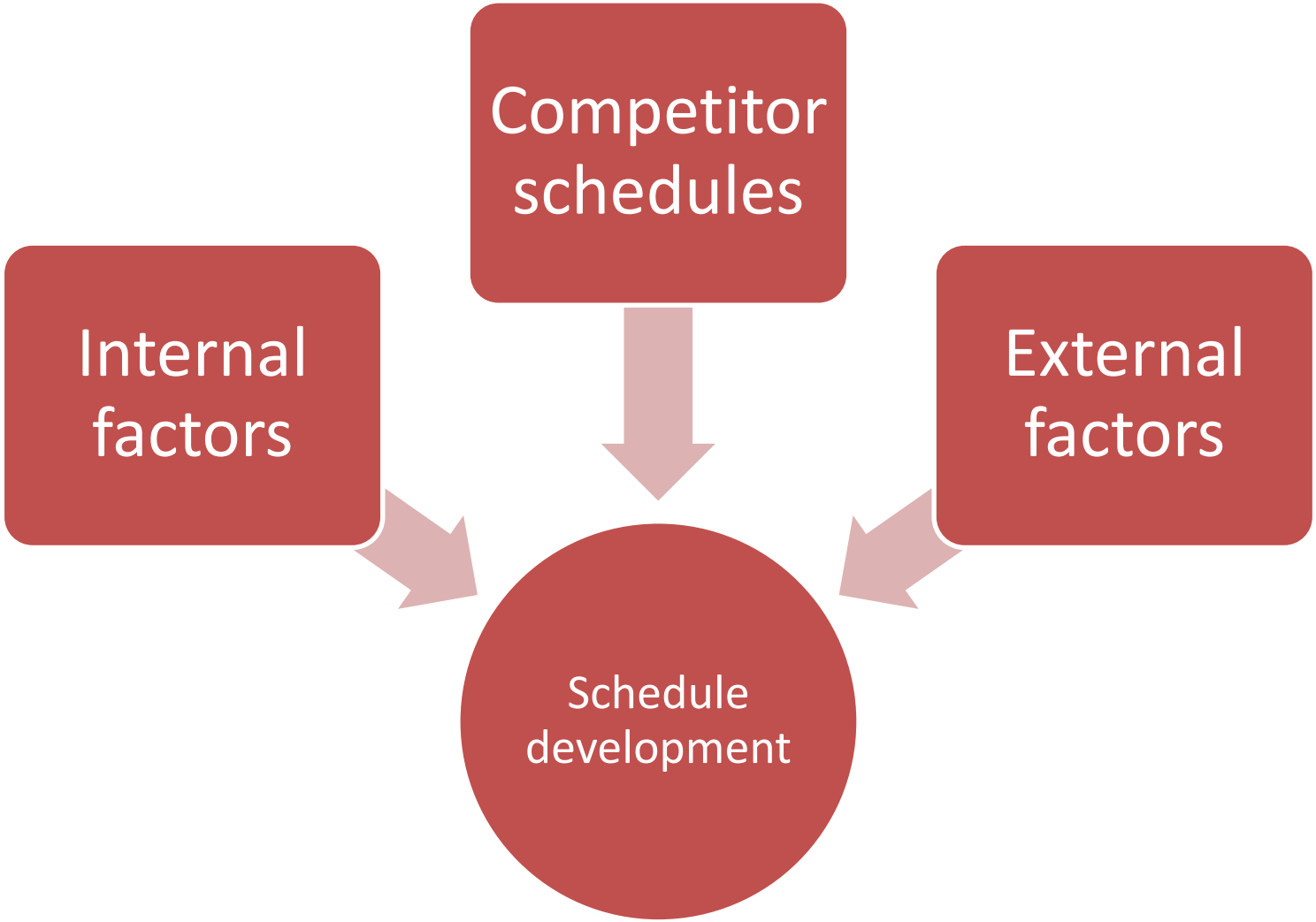
- New Orleans covers Atlanta, Chicago and Houston

- Salt Lake City covers Denver, Los Angeles, San Francisco and Seattle

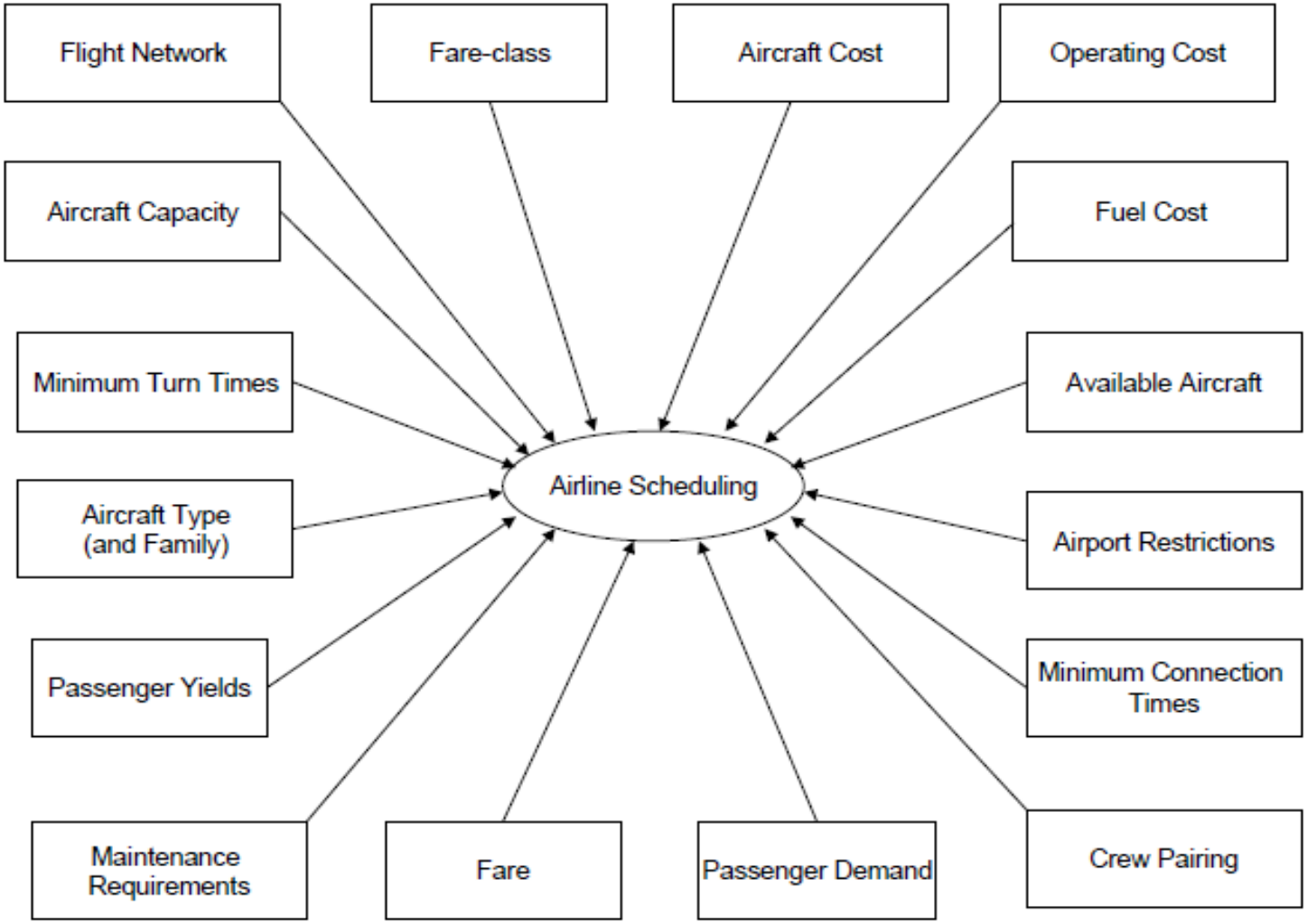
Flight Schedule



Conceptual Framework of the Flight Schedule Development Process



Impact factors of Airline Scheduling



Ki-Hwan Bae, 2010

How do airline planners calculate the flight frequency?

How to Calculate the Flight Frequency according to the passenger demand?

$$\text{Frequency} = \frac{PAX_{ij}}{CAP * LF}$$

PAX_{ij} : Daily number of Passengers between city pair i and j.

CAP: Aircraft capacity

LF: load factor

Calculate the Flight Frequency Route: LONDON - PARIS

Forecasting daily passenger number: 1000

Use aircraft B737-800 (162 seats)

LF = 0.90

FREQ = 1000/ (162*0.90)

= 1000/145.8

= 6.86 (7)

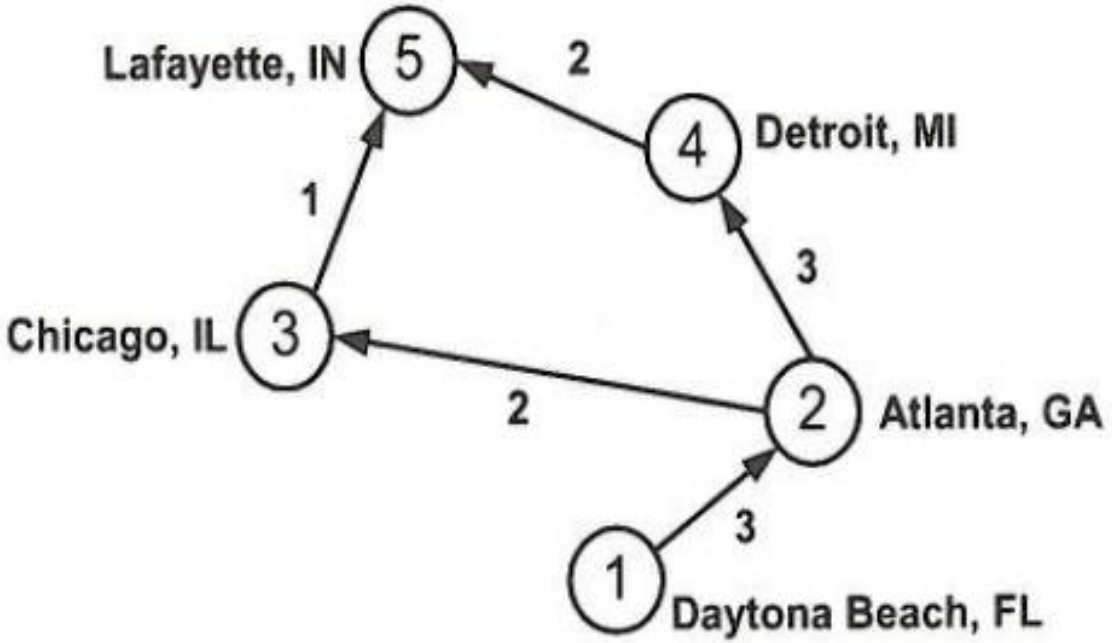
They need provide 7 flights daily.

Flight Frequency Decision - Maximum flow problem (Lecture 1c)

- After the airline network is built up, an airline needs to decide its flight frequency.
- It attempts to find the maximum amount of flow that can be sent from one node (origin, source node) to another (destination node) when the network is capacitated
- In another words, the arcs in the network have a capacity restriction.
- For airlines, they can apply this model to sort out how to maximize the daily number of connecting flights along the city pairs in their network

Maximum flow

- The airline wants to determine how to maximize the number of connecting flights daily from Daytona Beach, FL to Lafayette, IN under the current slot restrictions



Route: London - Paris

RYANAIR

Search details: London (Gatwick) → Dublin T1, One Way, 1 Adult

EDIT

London (Gatwick) → Dublin T1

Sun, Oct 26	Mon, Oct 27	Tue, Oct 28	Wed, Oct 29	Thu, Oct 30	Fri, Oct 31	Sat, Nov 01
No Flight	154.99 GBP	129.99 GBP	129.99 GBP	109.99 GBP	109.99 GBP	64.99 GBP

Tue, Oct 28 2014

Flight	Depart	Arrive	Lowest Fare	Business Plus
FR113	09:40	11:05	129.99 3 left @ this fare	182.99 3 left @ this fare
FR115	13:25	14:50	129.99 2 left @ this fare	182.99 2 left @ this fare
FR123	14:45	16:15	129.99 3 left @ this fare	182.99 3 left @ this fare
FR117	17:45	19:10	129.99 1 left @ this fare	182.99 1 left @ this fare
FR119	21:30	22:55	129.99 2 left @ this fare	182.99 2 left @ this fare

Sold out No Flight Optional charges excluded

BOOKING SUMMARY

▶ Passenger(s)

London (Gatwick) › Dublin T1

Tue, 28 Oct 2014 09:40 - 11:05

▼ 1 Adult, 129.99 GBP

1 x Adult Fare 129.99 GBP

Discount Pay by debit card: 129.99 GBP

Pay by credit card / PayPal: 132.59 GBP

TOTAL 129.99 GBP

Flight Schedule Development
- timetable development

Flight No.	Departure -Location -Time	Arrival -Location -Time	Aircraft Type
FR113	London (Gatwick) 09:40, 28th Oct. 2014	Dublin 11:05, 28th Oct. 2014	737-800 ?

Flight Scheduling: AN OVERVIEW

Flight Schedule Development

Fleet Assignment

Aircraft routing

Crew Scheduling

Summary & Self Test - Flight scheduling (Take-away for Lecture 02a)

- What is airline flight scheduling?
- What are the two key elements of flight scheduling?
- How many stages involve in the flight schedule process?
- What are the key impact factors of flight schedule?

Key Reference

- Bazargan, M. (2010) Airline Operations and Scheduling. 2nd edition, Ashgate
  - Chapter 3 Flight Scheduling

References

- Bae, Ki-Hwan (2010) Integrated Airline Operations: Schedule Design, Fleet Assignment, Aircraft Routing, and Crew Scheduling. Unpublished PhD thesis. Virginia Polytechnic Institute and State University
- Barnhart, C. (2008) 'Airline scheduling: Accomplishments, opportunities and challenges'. Proceedings of the International Conference on Integrationof AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems
- Burghouwt, G. (2007) Airline Network Development in Europe and Its Impliations for Airport Planning. Ashgate
- Etschamaier, M. and Mathaisel, D. (1985). 'Airline scheduling: An overview'. Transportation Science 9 (2), 127–38
- Holloway, S. (2008) Sraight and Level: Practical Airline Economics. 3rd edn. Ashgate
- Wittmer, A., Bieger, T. and Muller, R (2011) Aviation Systems. Springer
- Yu, G. and Thengvall, B. (2002) 'Optimization in the Airline Industry'. Handbook of Applied Optimization, ed. by P.M. Pardalos and M.G.C. Resende, New York: Oxford University Press