TGAI - Chapter 3.2

## How to define a market?

- Typical Air Passenger Trip:

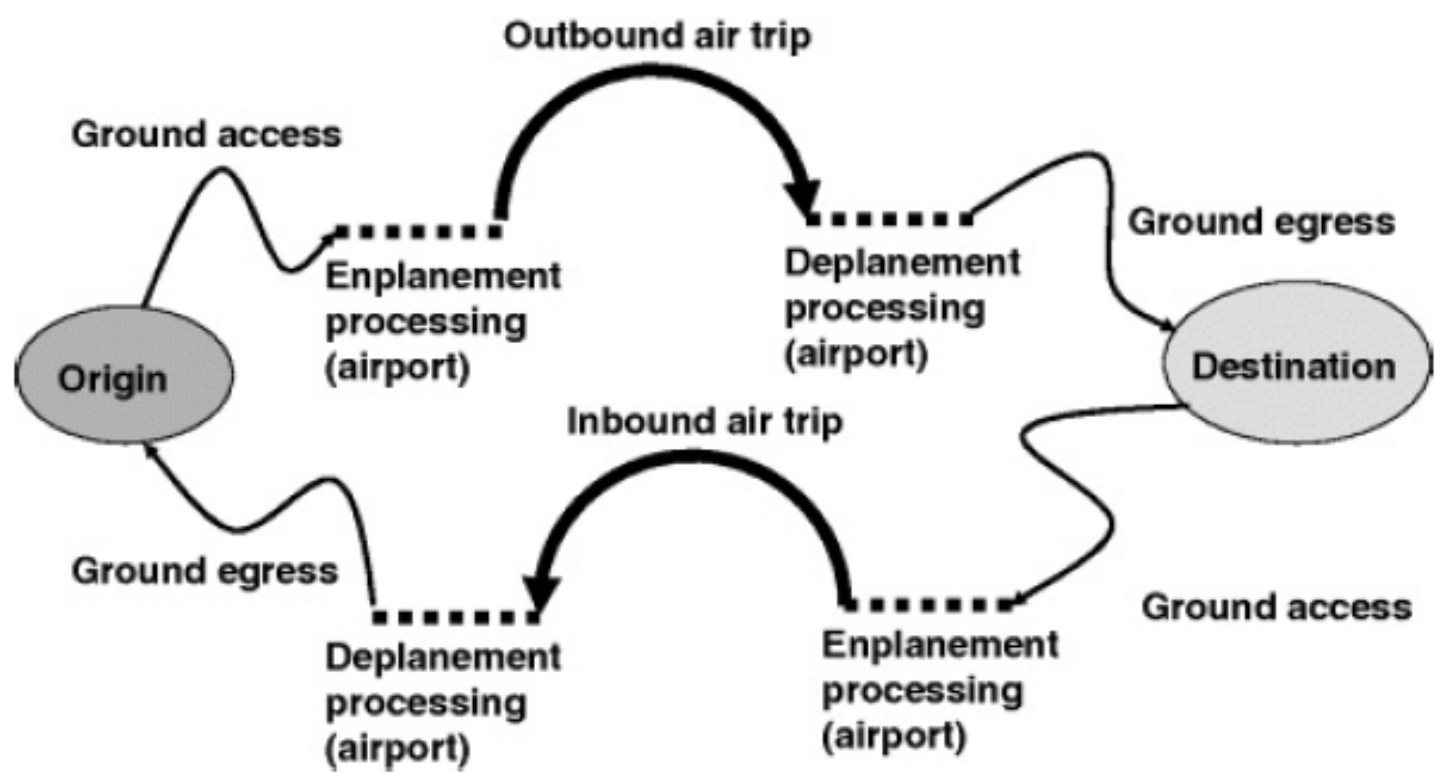



Figure 3.1 Representation of a typical air passenger trip

TGAI - Chapter 3.2

- Spatial definition of airline markets:

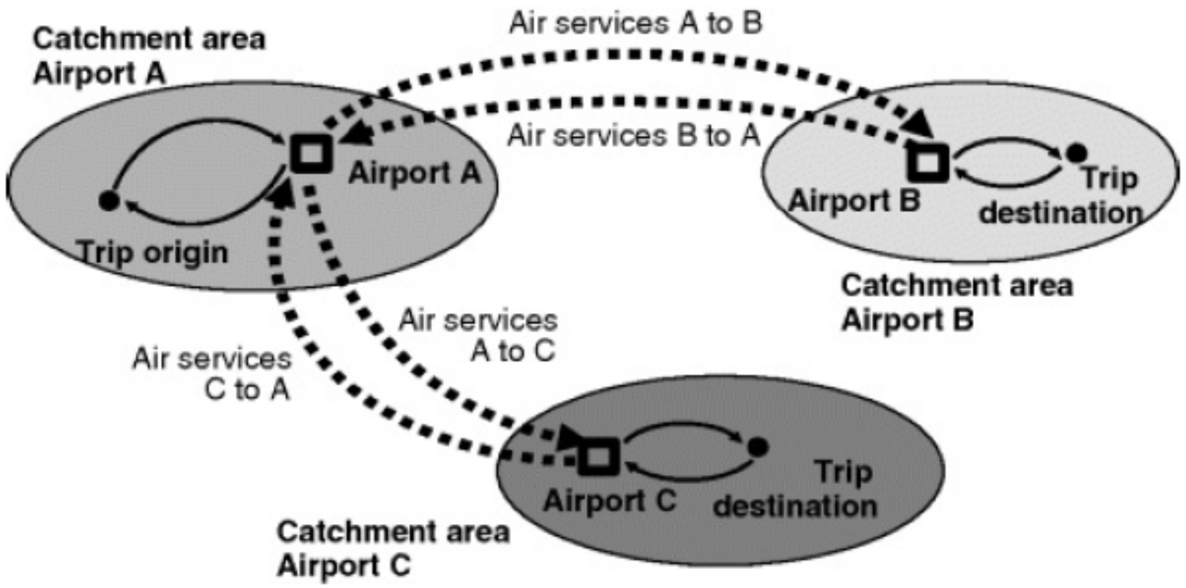
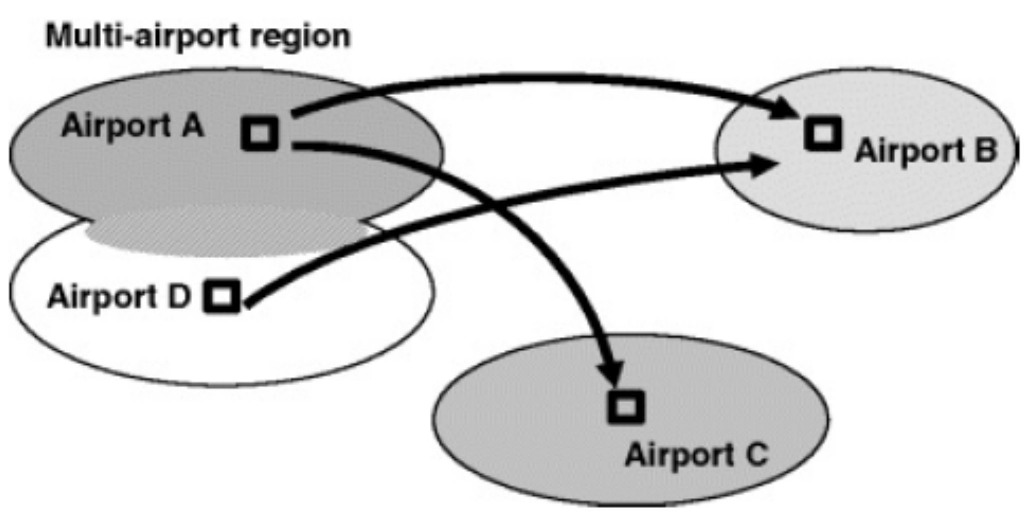
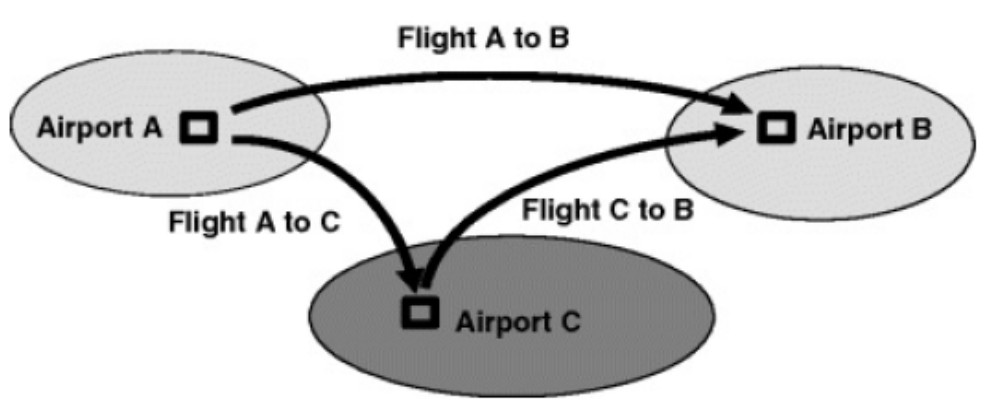



Figure 3.2 Distinct and separate O-D markets




e 3.4 Nonstop versus connecting service from A to B

Figure 3.3 Parallel markets and overlapping airport regions

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## Origin-Destination Market Demand

TGAI - Chapter 3.3

- Air travel demand is defined for origin-destination (O-D) *markets*, not for a flight leg in an airline network.
- Measured in terms of (potential) passenger flow per time period in one or both directions of an O-D market.
- Number of person traveling from A to B includes both travellers from the A-B-A round-trip market and travellers from the B-A-B round-trip market. Typically aggregated.
- Common measure: *passenger trips per day each way* (PDEW)
- Many markets simultaneously served by a single flight in an airline network.


Figure 3.5 Joint supply of service to multiple O-D markets

## Origin-Destination Market Demand

TGAI - Chapter 3.3

- Dichotomy of demand and supply: inherent inability to directly compare demand and supply in an individual O-D market.
- Demand generated at level of passenger’s O-D trip
- Supply in form of flight leg departures on a network of scheduled flight operations. One flight leg provides *joint supply* of seats to many O-D markets simultaneously.
  - ➡ Total #seats on flight leg does not represent the “supply” of air transportation to a single O-D market.
  - ➡ And: not practical to determine accurately the actual #seats supplied to each O-D market
- Single O-D market typically served by many competing airline paths (nonstop, one-stop, and connecting).
  - ➡ Volume of an O-D market demand cannot be determined simply by counting the number of passengers on nonstop flights operating between the origin and destination under consideration. Need detailed ticket samples to include all passengers.

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## Factors affecting volume of O-D demand

TGAI - Chapter 3.3

- Affected by many variables, models include usually only those variables with greater impact on demand and those that can be measured.
- ❖ Socioeconomic and demographic variables
  - ❖ Larger populations, greater potential demand for air travel
  - ❖ Amount and type of economic interaction between cities: two cities with common industries will generate more demand for air travel
  - ❖ Disposable income
  - ❖ Levels of education
  - ❖ Age of the populations
- ❖ Prices of travel options
  - ❖ Monetary price
  - ❖ Disutility cost of fare restrictions
  - ❖ Prices of competing modes (train, bus, car)
- ❖ "Quality of service"
  - ❖ Frequency of flight departures
  - ❖ Time spent flying
  - ❖Together: total trip time ("true" origin to "true" destination)
  - ❖ Comfort
  - ❖ Safety
  - ❖ Ease of travel

# Demand

- Strategical, technical, operational level
- How to measure?
  - Market analysis
  - Check other companies
  - Prognosis

# Prognosis models

| qualitative models | quantitative models |
|---|---|
| based on opinions and assessment (from experts) | mathematical |
| long-term prognosis | use of historical data |
| no historical data | extrapolation of  historical values |
| | time series models |

Different types of prognosis need different methods

- Estimate demand for a completely new flight
  - How many pax can we obtain Norrköping – Brussels
- Estimate demand for a proven route
  - How many pax during the winter half year on the route Norrköping – Munich

# Prognosis models

- Based on historical data
  - Time series analysis
    - Trends, cyclical variations, seasonal variations, irregular events
    - Moving average, exponential smoothing
- Based on knowledge of influencing factors
  - Regression analysis
  - Example for factors?

# Prognosis models

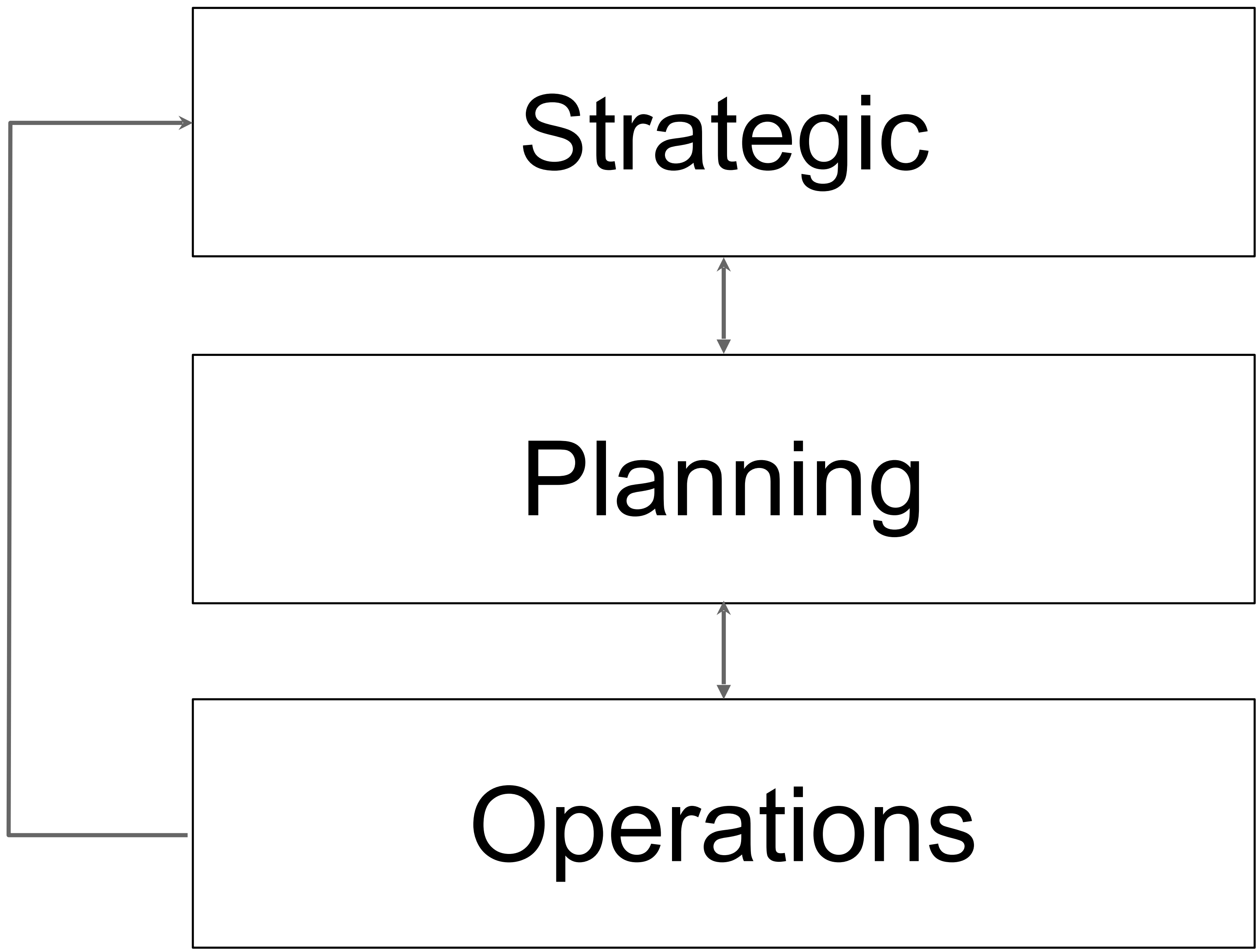
- Based on historical data
  - Time series analysis
    - Trends, cyclical variations, seasonal variations, irregular events
    - Moving average, exponential smoothing
- Based on knowledge of influencing factors
  - Regression analysis
  - Example for factors?
- Based on knowledge of future events
  - Delphi method
    - Panel of experts
    - Experts answer questionnaires in two or more rounds
    - After each round anonymous summary of the experts forecasts from the previous round
    - Experts answer same questions
    - It is believed that during this process the group will converge towards the “correct” answer

# Paradigm shift

- Personal judgement or experience
  - Important
  - But difficult and even infeasible for a large airline
- OR and math
  - Modeling
- CS

# Planning process

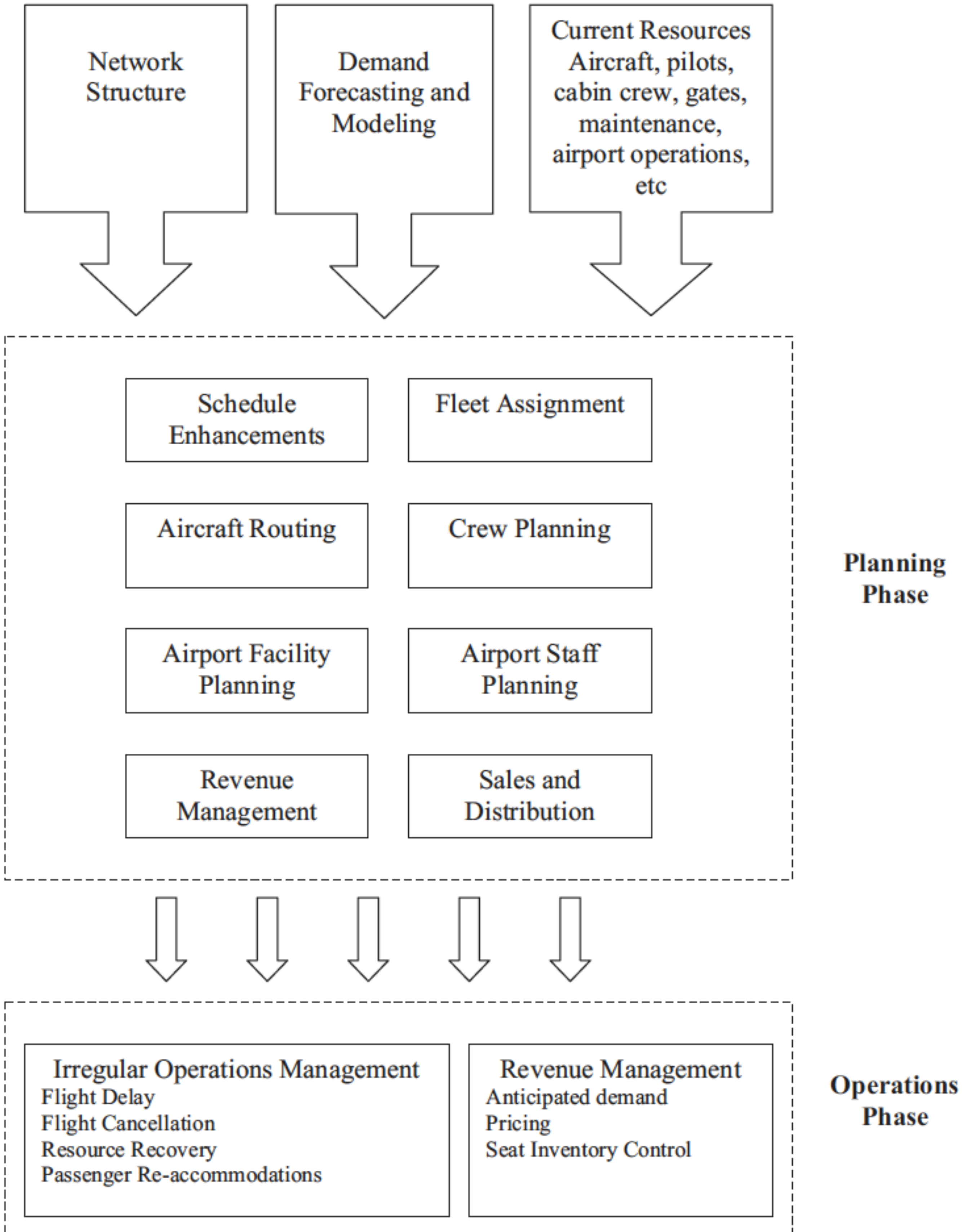
# Layers or Phases of decision



# Management/planning – example

| | general | aircraft | staff |
|---|---|---|---|
| **strategical** | orientation, alliances | fleet planning | hire, train |
| **tactical** | price setting, time table | fleet assignment and routing | crew scheduling |
| **operational** | class reservation, customer management | fleet operations | crew operations |

# Processes in planning&operations phases of airlines




Abdelghany&Abdelghany, 2010

Planning:

- Starts by recording anticipated demand and supply
- Set of interrelated planning processes is considered:
  - Schedule planning
  - Time banking
  - Fleet assignment
  - Aircraft routing
  - Crew scheduling
  - Airport facility planning
  - Airport staff scheduling
  - Pricing
  - Seat inventory control
  - Sales
  - Marketing initiatives
- Planning processes typically completed by a month/few months before implementation of the schedule
- Repeated on a frequent basis

TGAI Chapter 7

Operations phase:

- Implementing the planned airline schedule, while
- Taking into consideration recovery for any unanticipated incidents such as:
  - Adverse weather conditions
  - Aircraft breakdown
  - Crew absence
- Decisions are made to:
  - Recover the airline schedule from flight delay and cancellations
  - Compensate for missing or delayed aircraft and crew
  - Reaccommodate stranded passengers
- Monitors seat bookings in different markets
- Updates seat inventory control and pricing decisions

# Airlines #2
# Management of Resources

TGAI Chapter 7

# Airline Planning

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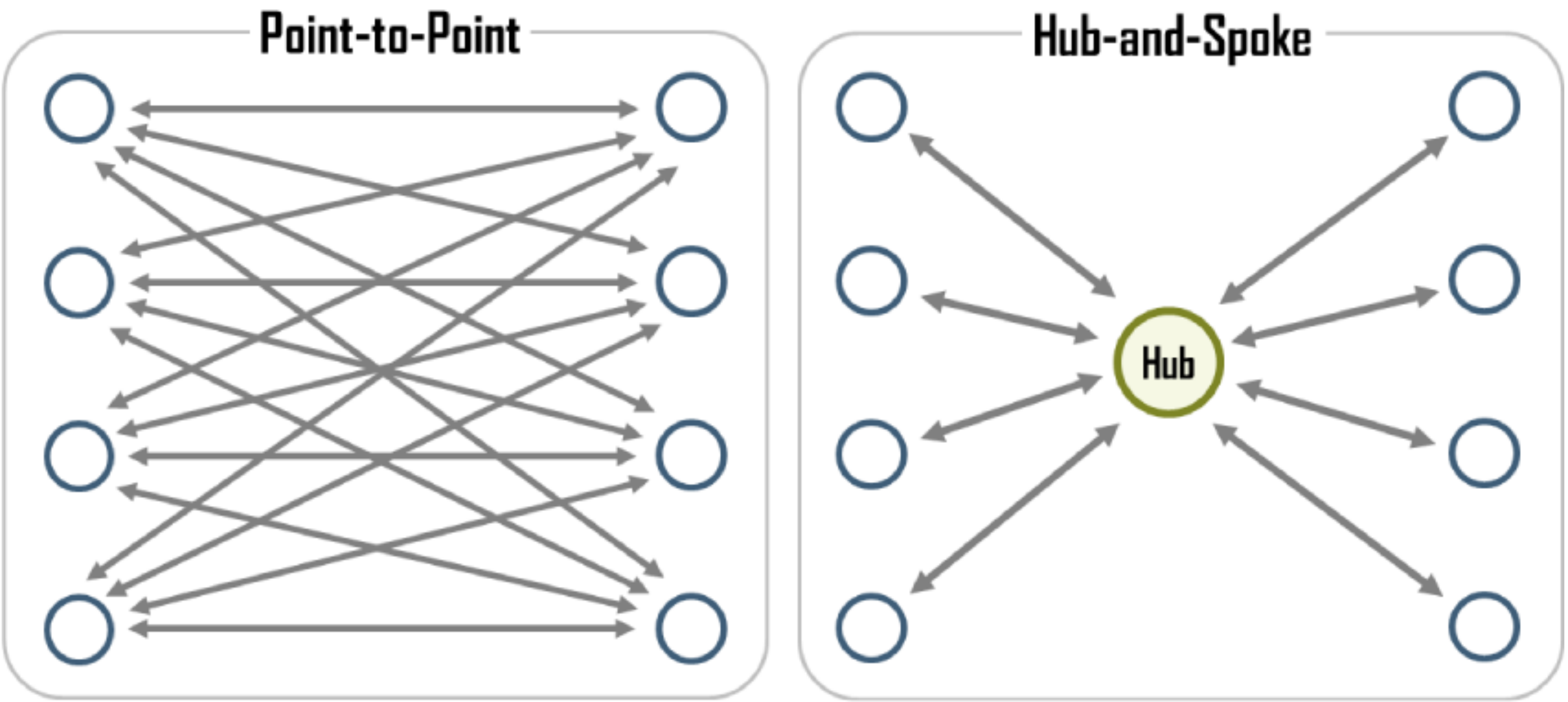
TGAI Chapter 7.2.1




often mixed systems, or hub-systems with multiple hubs

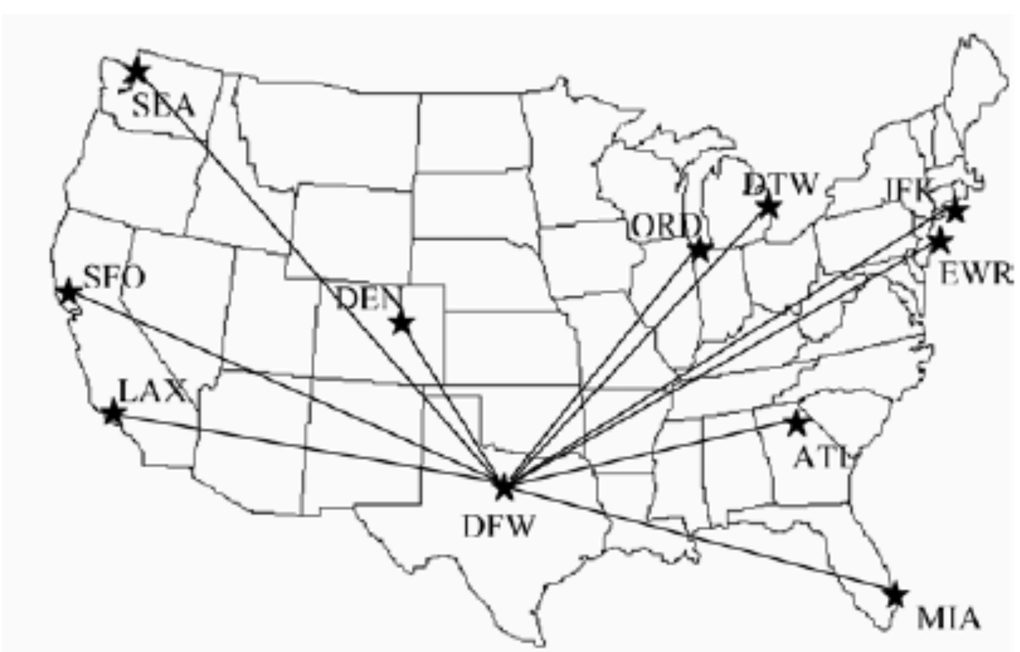
source: https://people.hofstra.edu/geotrans/eng/ch1en/conc1en/hubnetwork.html source: SAS årsredovisning 2014/2015

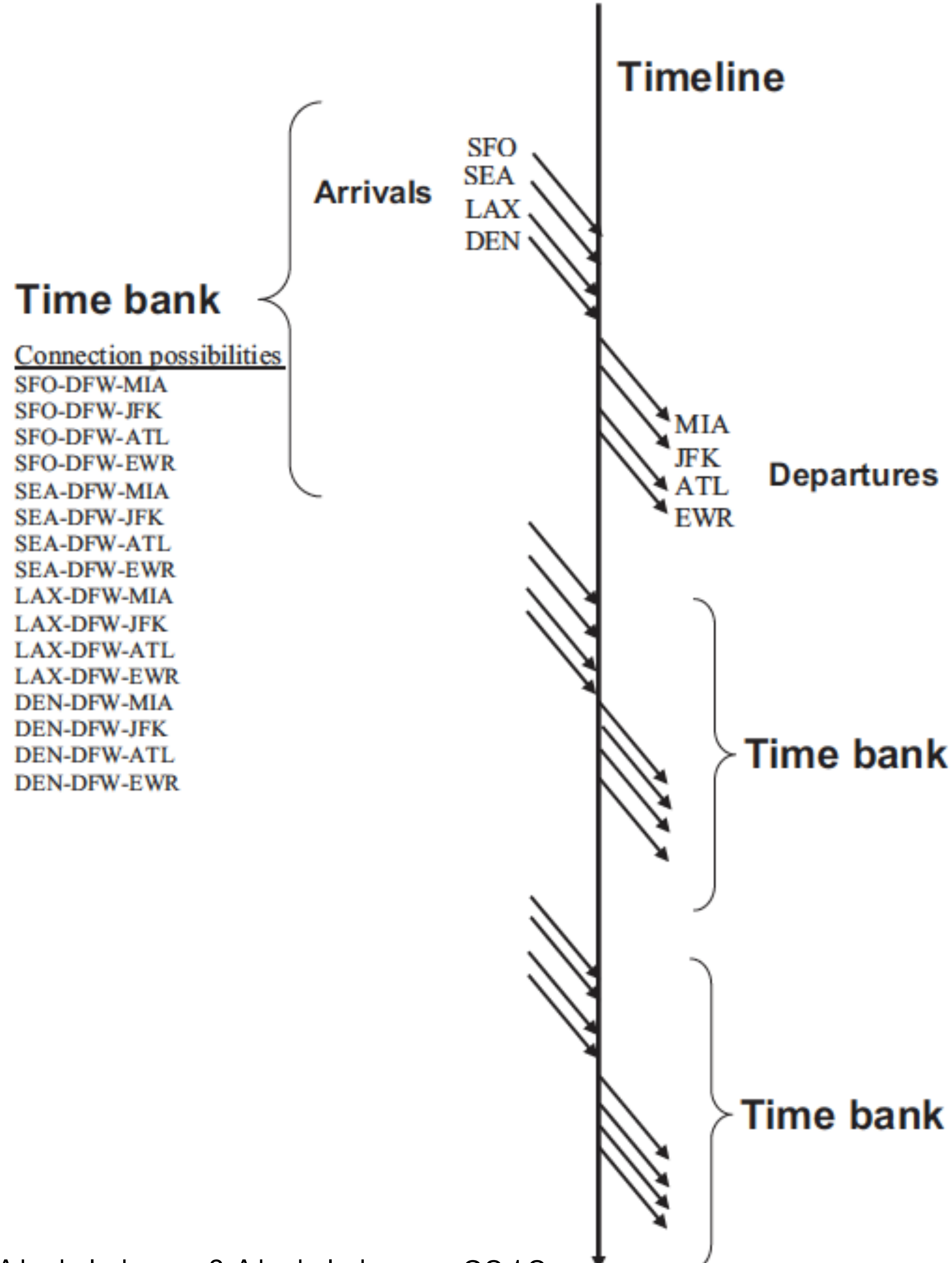

Befintliga linjer.
Nya linjer 2015 och 2016.

# Example of time bank for hub-and-spoke airline

Time bank:

- Arrivals and departures at the hub are adjusted in time banks
- Consists of a set of flight arrivals followed by a set of departures
- Allows for several connection possibilities during a short period of time

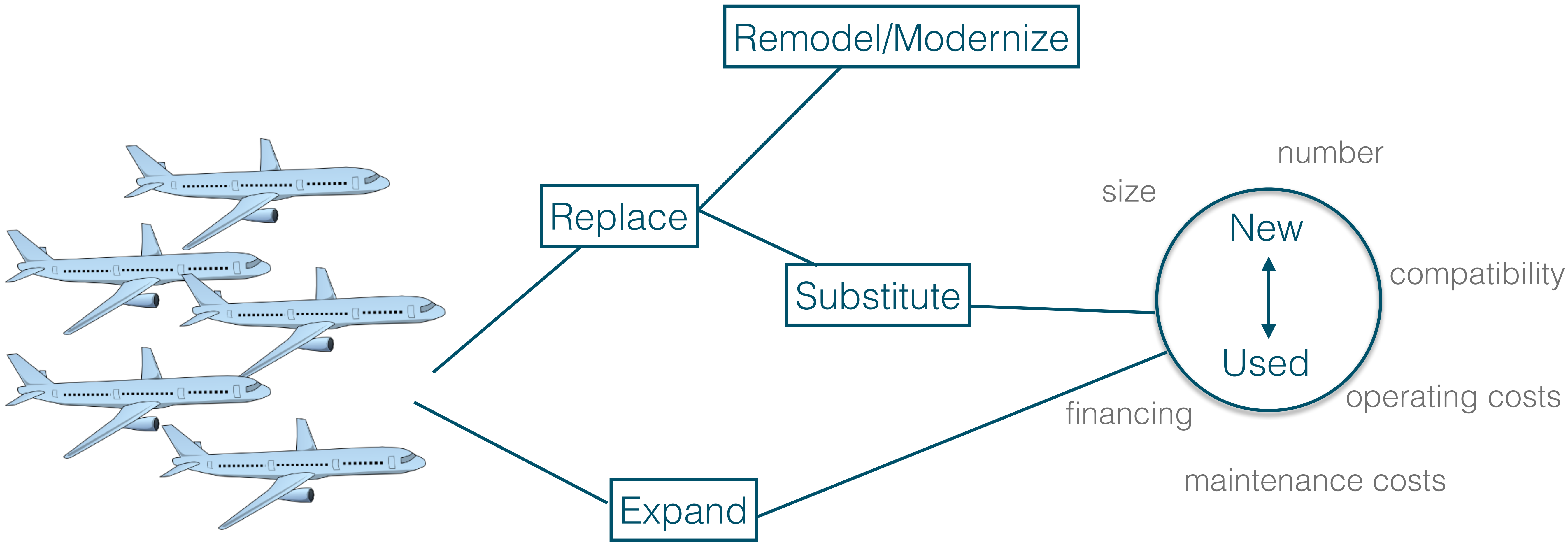



Abdelghany&Abdelghany, 2010

## How to determine which aircraft to use?

TGAI Chapter 7.1



## What is available?

- Boeing
  - American company
  - 737-787
  - http://www.boeing.com/company/about-bca/index.page%23/prices
  - Older: DC and MD
- Airbus
  - European company
  - A300-A380
  - http://www.airbus.com/presscentre/pressreleases/press-release-detail/detail/new-airbus-aircraft-list-prices-for-2016/

- Fokker
- Bombardier
- Canadair
- Embraer
- SAAB

## The SAS Group's fleet of aircraft at October 31, 2012[1]

| | Age | Owned | Leased | Total | In service | Leased out | On order |
|---|---|---|---|---|---|---|---|
| Airbus A330/A340 | 10.4 | 5 | 6 | 11 | 11 | 0 | |
| Airbus A319/A320/A321 | 8.8 | 4 | 10 | 14 | 12 | 0 | 30 |
| Boeing 737 Classic | 19.4 | 0 | 10 | 10 | 10 | 0 | |
| Boeing 737NG | 11.4 | 23 | 49 | 72 | 72 | 0 | |
| Boeing 717 | 12.2 | 0 | 9 | 9 | 9 | 0 | |
| McDonnell Douglas MD-80-serien | 23.1 | 13 | 8 | 21 | 19 | 0 | |
| McDonnell Douglas MD-90-serien | 0.0 | 8 | 0 | 8 | 0 | 8 | |
| Avro RJ-85 | 0.0 | 0 | 5 | 5 | 0 | 1 | |
| deHavilland Q-serien | 14.7 | 32 | 10 | 42 | 39 | 0 | |
| Bombardier CRJ900NG | 3.4 | 12 | 0 | 12 | 12 | 0 | |
| **Total** | **13.1** | **97** | **107** | **204** | **184** | **9** | **30** |

1) In addition, the following aircraft are wet leased: four CRJ200s and one ATR for SAS in Denmark and two ATRs and four SAAB 2000s for Blue1 in Finland.

## The aircraft fleet divided by airline and leased-out aircraft

| | Age | Owned | Leased | Total | In service | Leased out | On order |
|---|---|---|---|---|---|---|---|
| SAS Scandinavian Airlines | 12.6 | | | 143 | 136 | 8 | 30 |
| Widerøe | 14.9 | | | 39 | 39 | 0 | |
| Blue1 | 12.2 | | | 13 | 9 | 1 | |
| Leased-out aircraft | | | | 9 | | | |
| **Total** | **13.1** | | | **204** | **184** | **9** | **30** |

## SAS FLYGPLANSFLOTTA 31 OKTOBER 2015

| SAS flygplan i trafik | Ålder | Ägda | Leasade | Totalt | Order köp | Order lease |
|---|---|---|---|---|---|---|
| Airbus A330/A340/A350 | 11,9 | 7 | 7 | 14 | 10 | - |
| Airbus A319/A320/A321 | 10,7 | 6 | 19 | 25 | 30 | - |
| Boeing 737NG | 12,8 | 15 | 69 | 84 | - | - |
| **Totalt** | **12,3** | **28** | **95** | **123** | **40** | **0** |

| Flygplan i trafik under annan trafiklicens än SAS (SK) | Ålder | Ägda | Wet leasade | Totalt | Order på wet lease |
|---|---|---|---|---|---|
| Boeing 737 | 10,2 | - | 1 | 1 | - |
| Bombardier CRJ900 | 6,4 | 12 | - | 12 | 8 |
| ATR-72 | 3,7 | - | 13 | 13 | 3 |
| SAAB 2000 | 18,6 | - | 3 | 3 | - |
| **Totalt** | **6,6** | **12** | **17** | **29** | **11** |

# Turkish airlines

**Fleet as of year-end 2010**

| Aircraft Type | Number | Fleet Age | Total Capacity (Seat) |
|---|---|---|---|
| **Commercial Aircraft** | | | |
| A340-300 | 9 | 14.2 | 2,446 |
| A330-200 | 7 | 4.6 | 1,812 |
| A330-300 | 4 | 0.1 | 1,156 |
| B777-300ER | 9 | 1.6 | 2,933 |
| A319-100 | 4 | 4.9 | 528 |
| A320-200 | 25 | 3.7 | 3,962 |
| A321-200 | 21 | 4.8 | 4017 |
| B737-400 | 3 | 18.9 | 450 |
| B737-800 | 52 | 7.5 | 8,596 |
| B737-700 | 14 | 5.0 | 1,986 |
| **Cargo Aircraft** | | | |
| A310-300F | 4 | 22.5 | - |
| A330-200F | 1 | 0.3 | - |
| | | | |
| **TOTAL** | **153** | **6.5** | **27,886** |

2016

**NARROW BODY (234 Ea)**

| | |
|---|---|
| 15 Ea | B737-900ER |
| 110 Ea | B737-800 |
| 29 Ea | A320-200 |
| 66 Ea | A321-200 |
| 13 Ea | A319-100 |
| 1 Ea | B737-700 |

**WIDE BODY (87 Ea)**

| | |
|---|---|
| 20 Ea | A330-200 |
| 31 Ea | A330-300 |
| 4 Ea | A340-300 |
| 32 Ea | B777-300ER |

**CARGO (13 Ea)**

| | |
|---|---|
| 3 Ea | A310-300F |
| 8 Ea | A330-200F |
| 1 Ea | A300-600F |
| 1 Ea | B747-400F |

| | |
|---|---|
| Total Aircraft: | 334 |
| Average Fleet Age: | 7,1 |

TGAI Chapter 7.3

When fleet and routes (networks) are planned: **airline schedule development**

- **Frequency planning** (How often on the selected routes?)
- **Time table development** (Schedule departures at what times?)
- **Fleet assignment** (What type of aircraft used for each departure time?)
- **Aircraft routing** (Create routes for fleets) also called aircraft rotation planning

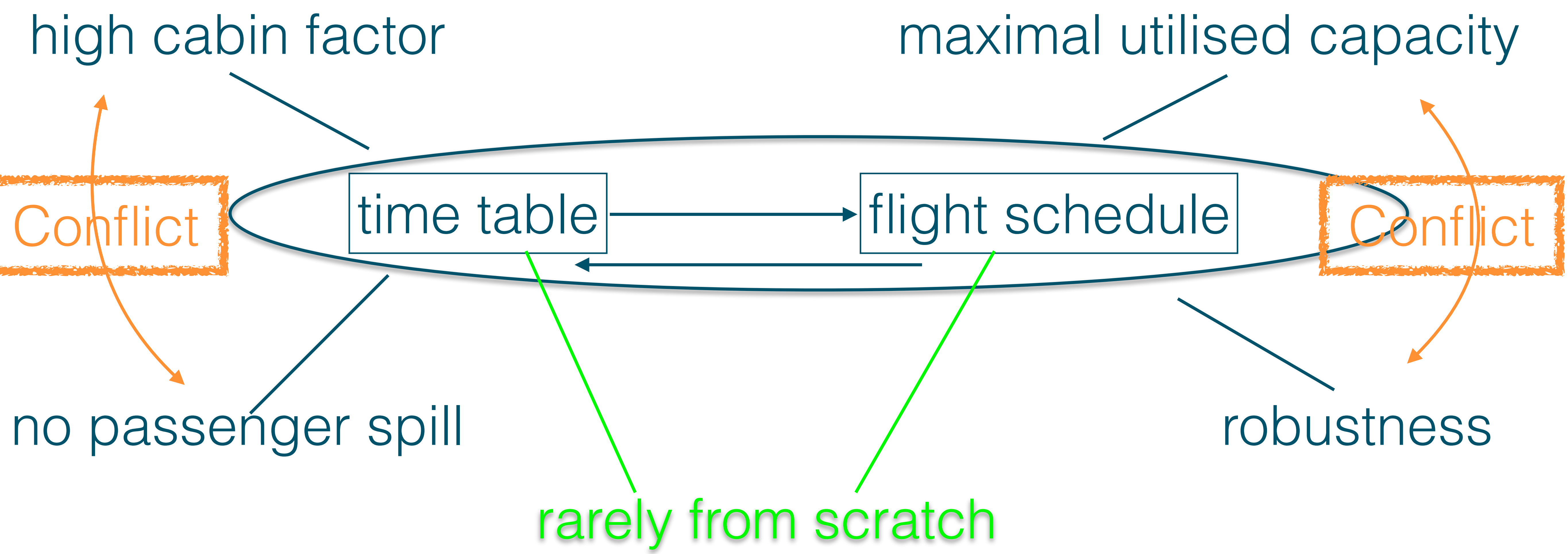
# Timetable

TGAI Chapter 7.3.2

- Two seasons: winter and summer
- Product range
  - Large selection of times
  - High cabin factor

Conflictive

- Limitations
  - Physical
  - Contract
  - Slots
    - IATA (International Air Transport Association): airport, strategical
    - CFMU (Central Flow Management Unit): ground holding, operational
  - Flight schedule
  - Staff schedule
  - Turnaround times


high cabin factor
maximal utilised capacity
Conflict
time table
flight schedule
Conflict
no passenger spill
robustness
rarely from scratch

- Usually, during the timetable development some flights are deleted, and others are added
- One problem is to estimate the demand on the final flights
    - The total demand between two airports is reduced, when the supply is reduced
    - Certain pax choose different companies if the number of flights is reduced
    - The demand from connecting flights is reduced

# Flight schedule planning

- Assume that fleet and timetable (and routes) are available and fixed: come up with a good feasible flight schedule.
- Discuss:
  - Talk to your neighbours
  - Make a list of goals and requirements for a flight schedule

# Flight schedule planning

- Goals
  - High cabin factor
  - No pax spill
  - Robustness
- Requirements
  - Balance
  - Airport Limitations
  - Maintenance requirements
  - Aircraft limitations
  - Weather
  - Crew

# Maintenance

- Regular check and service
- Requirement from civil aviation authorities (CAA): FAA, EASA,…
- Usually: each airline develops own CAA-approved maintenance program
- Executed at:
  - Maintenance base (largest, most versatile, best-equipped facility)
  - Major station (incl. large hub cities, substantial inventory of spare parts, extensive facilities)
  - Service station (large stations, not at major hub cities, well equipped and staffed, less than major stations)

# Maintenance

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Maintenance types:

- Visual inspection
  - Prior to flight (sometimes called " walk-around")
  - Ensure no obvious problems: leaks, missing rivets, cracks
- Overnight maintenance
  - End of working day
  - Ad hoc repairs
  - 1 – 1.5 hours
- A-check
  - Appx. every 125 flight hours (2 – 3 weeks)
  - Amplified visual inspection, easily reachable parts
- B-check
  - Appx. every 750 flight hours
  - Exterior wash, engine oil spectro-analysis, oil filters re me carefully examined
  - Incorporates A-check
- C-check
  - appx. every 3000 flight hours or 15 months
  - Incorporates both A- and B-check
  - Plus: components repaired, flight controls hanisms tested, …
- D-check
  - Most intensive form
  - Every 6-8 years/appx. every 20000 flight hours
  - Cabin interiors removed —> careful structural inspections
  - 15-30 days

"line" maintenance:
at airport
usually overnight

"heavy" maintenance:
special facilities
extensive downtime

Maintenance types:
- Non routine Maintenance
  - Unforeseen event (accident, random occurrence)
  - Response to AD (Airworthiness Directive)

# Maintenance

Planning:

- Timers used, e.g., A-timer
- If the check is not performed in time the aircraft can be grounded
- Maintenance must be carefully included in flight schedule

- SAS 2014
  - 807 flights/day
  - 125 destinations
  - 138 a/c (aircraft)
  - 5 a/c types
- Large = hard problem
- Exercise:
  - Determine which aircraft should fly which flight every day during a season
- How?
  - Split up the problem

Discuss: How can the problem be decomposed and solved?

# Flight schedule

Flight schedule - problem decomposition

- Geographical
  - Domestic – international
    - Advantage at airport because of different terminals and gates
    - Schengen or not
    - Simplifies crew planning
  - Must take maintenance and crew into account
- Different companies
- Cargo or passengers
- Aircraft types
  - Partition fleet in subgroups of interchangeable aircraft
  - Assign flights to subfleets without determining how and when which aircraft should fly **fleet assignment**
  - Create routes for fleets **aircraft routing**

Four successive aircraft and crew schedule problems

1 Timetable planning

2 Fleet assignment

3 Aircraft routing

4 Crew pairing

# Fleet assignment and aircraft routing

TGAI Chapter 7.33

FA=Fleet assignment=Assign aircraft types to flight legs

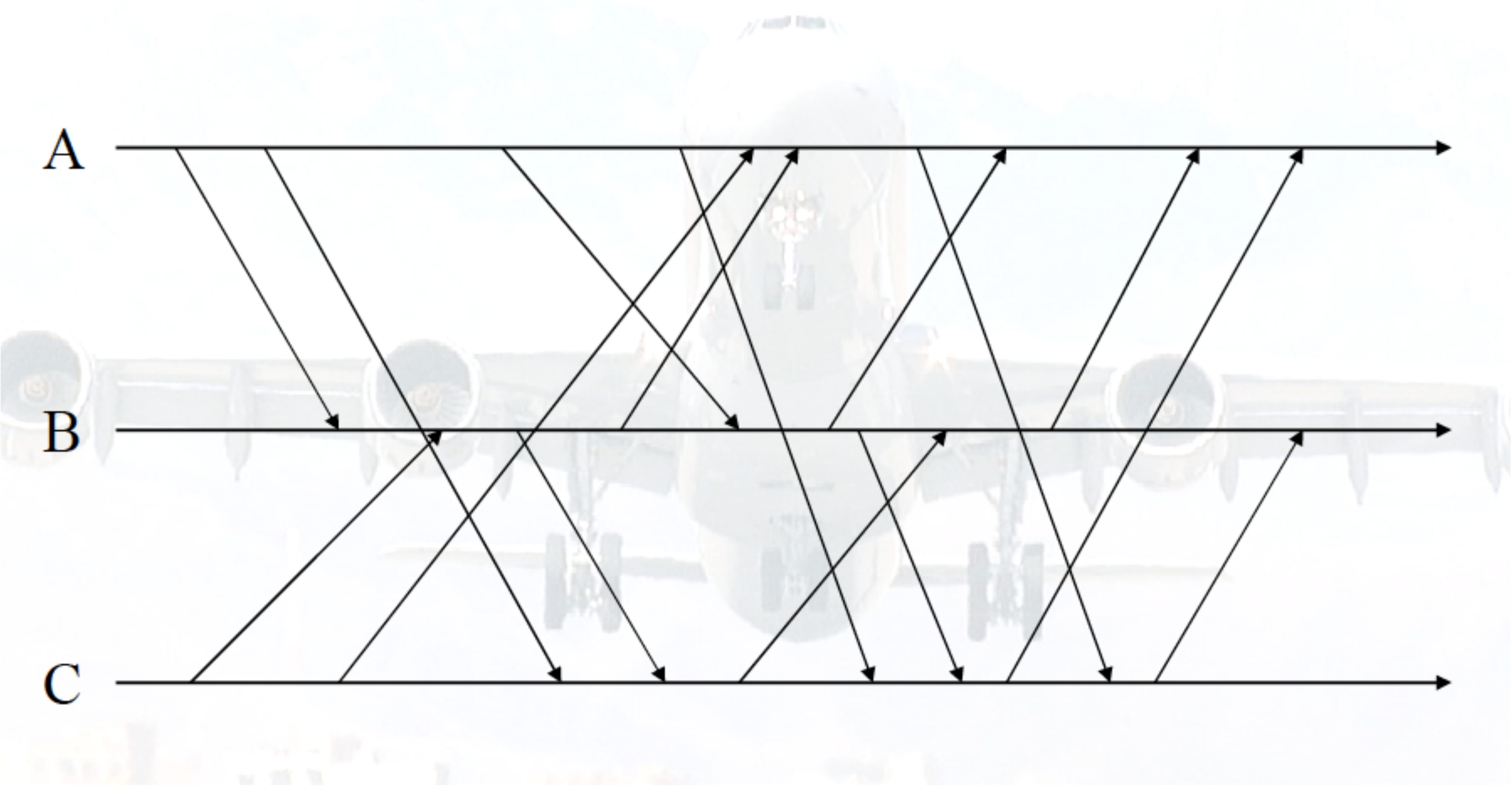
- Input: A schedule, flights cost (depending on demand and airplane type), fleet sizes
- Output: A fleeting
  - Goals of FA:
    - Max pax
    - Min costs
    - Robustness
  - Requirements:
    - Balance
    - Airport Limitations
    - Maintenance
    - Crew
  - Routing problem for each subfleet

TGAI Chapter 8.2

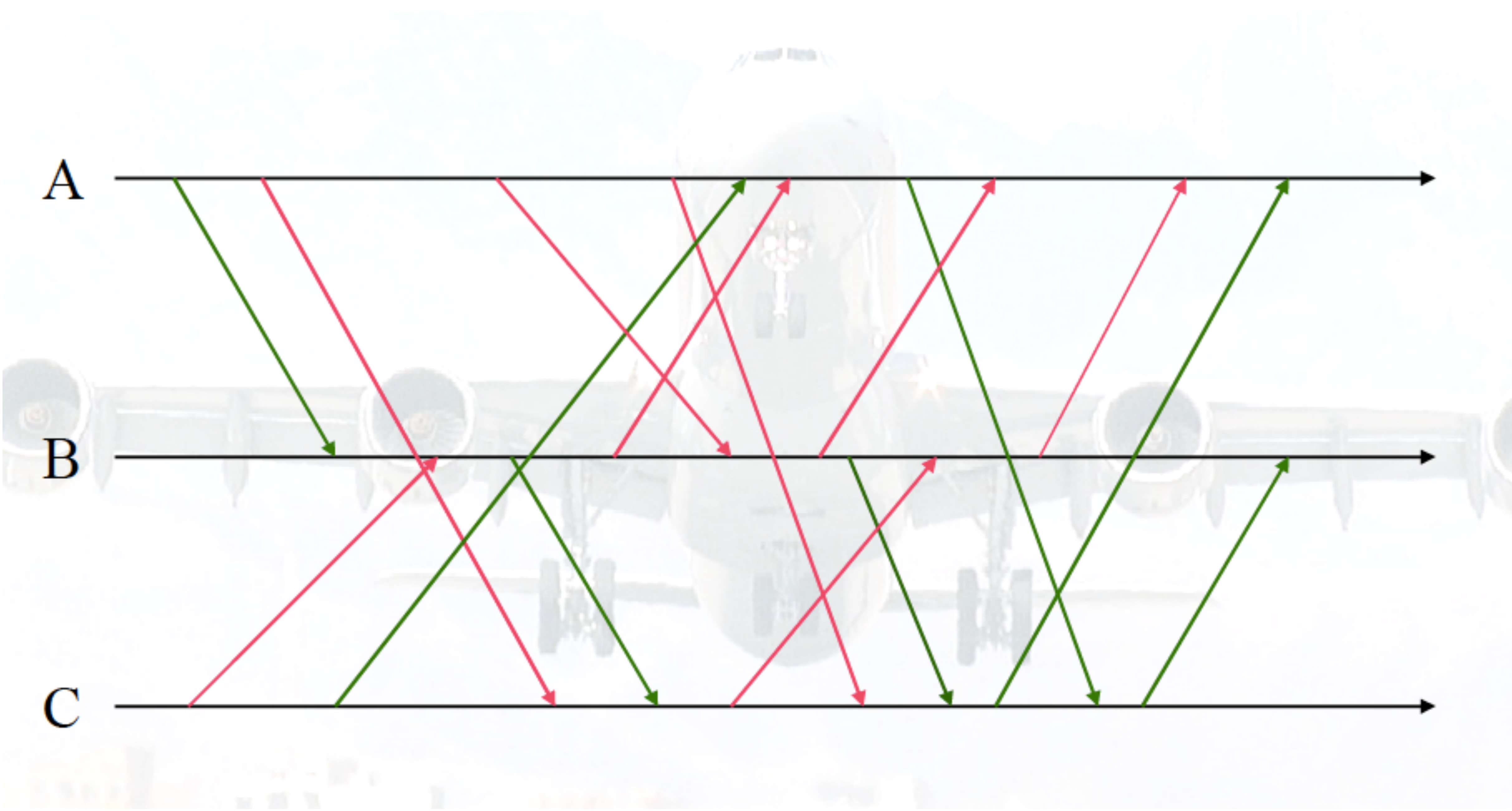
Aircraft routing: determining a route for each aircraft

- Input: A one-fleet schedule, maintenance constraints, border conditions
- Output: A feasible routing
  - Goals of FR:
    - Feasibility
    - Robustness
  - Requirements:
    - Maintenance
      - Timer
  - Routes for each subfleet

# Fleet assignment: example



# Fleet assignment: example



# Aircraft routing

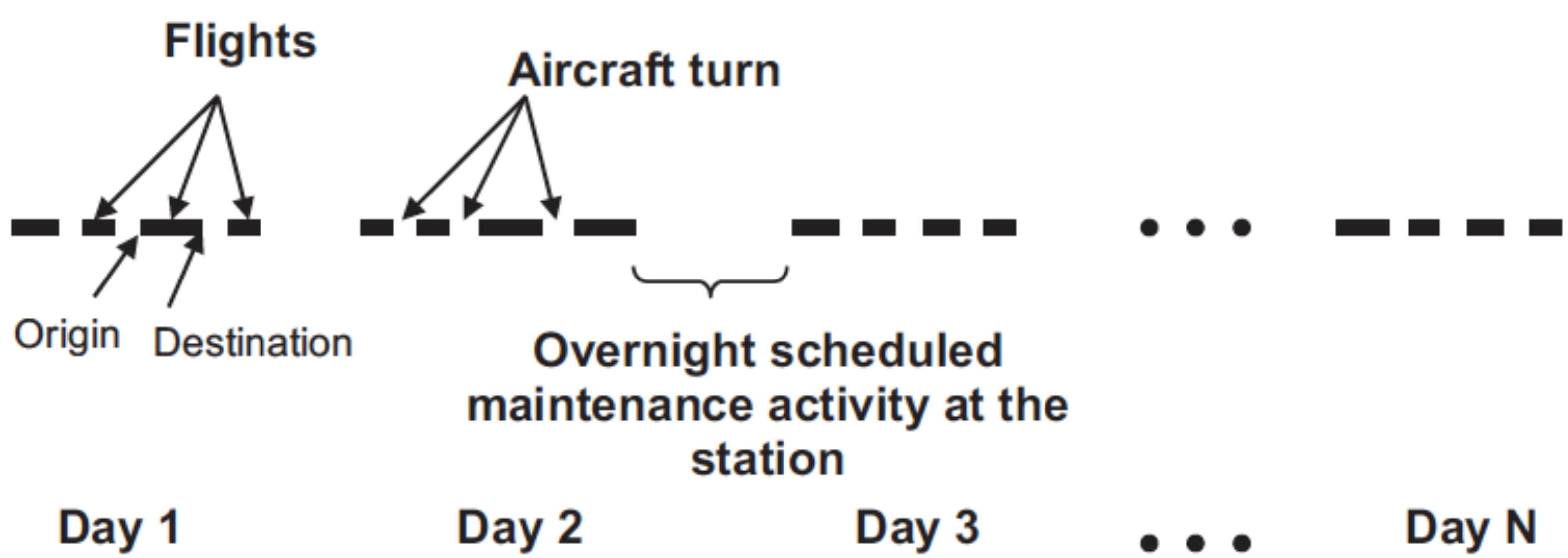


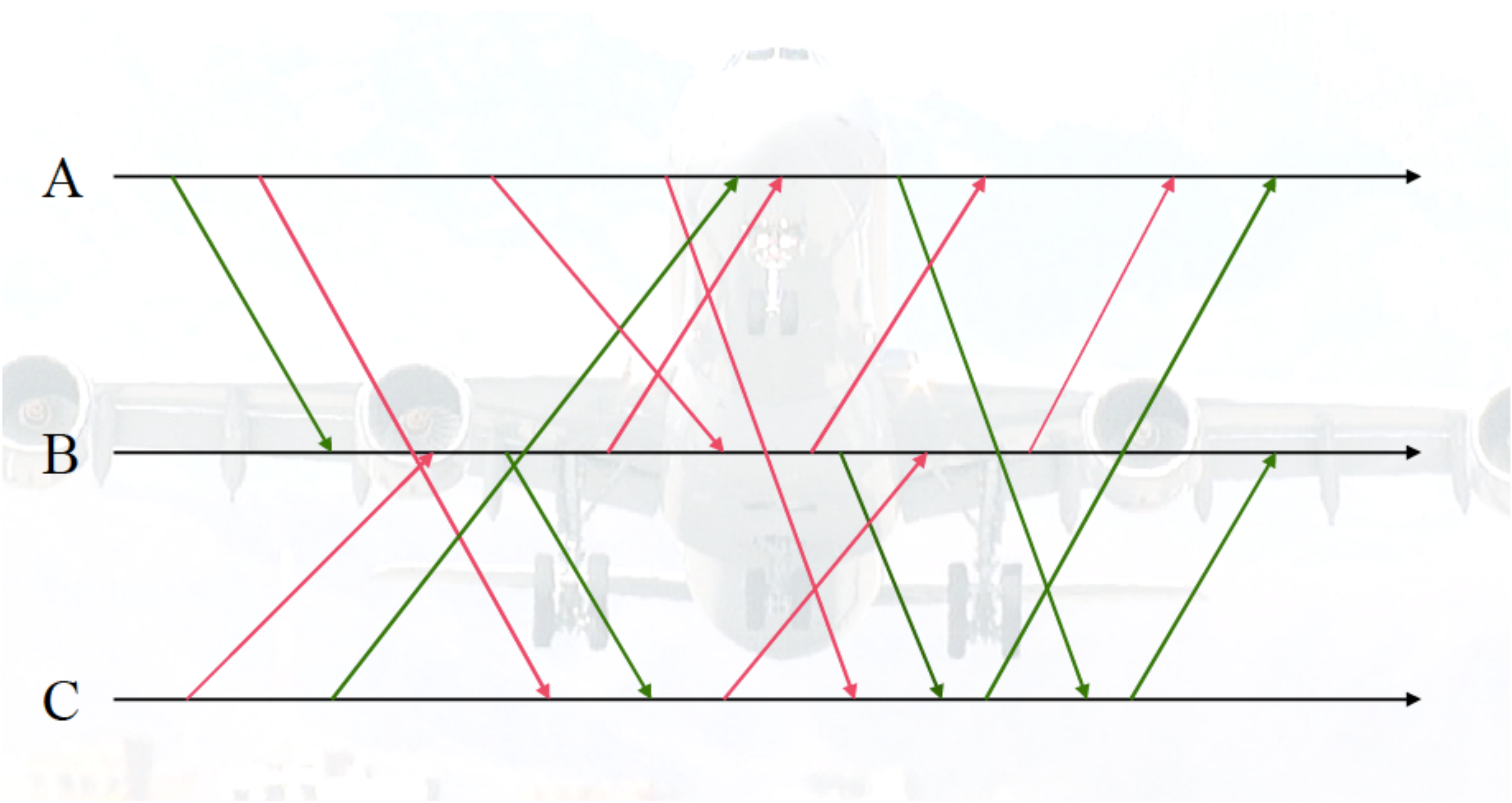

**Figure 1.8 Example of an aircraft route**

Abdelghany&Abdelghany, 2010

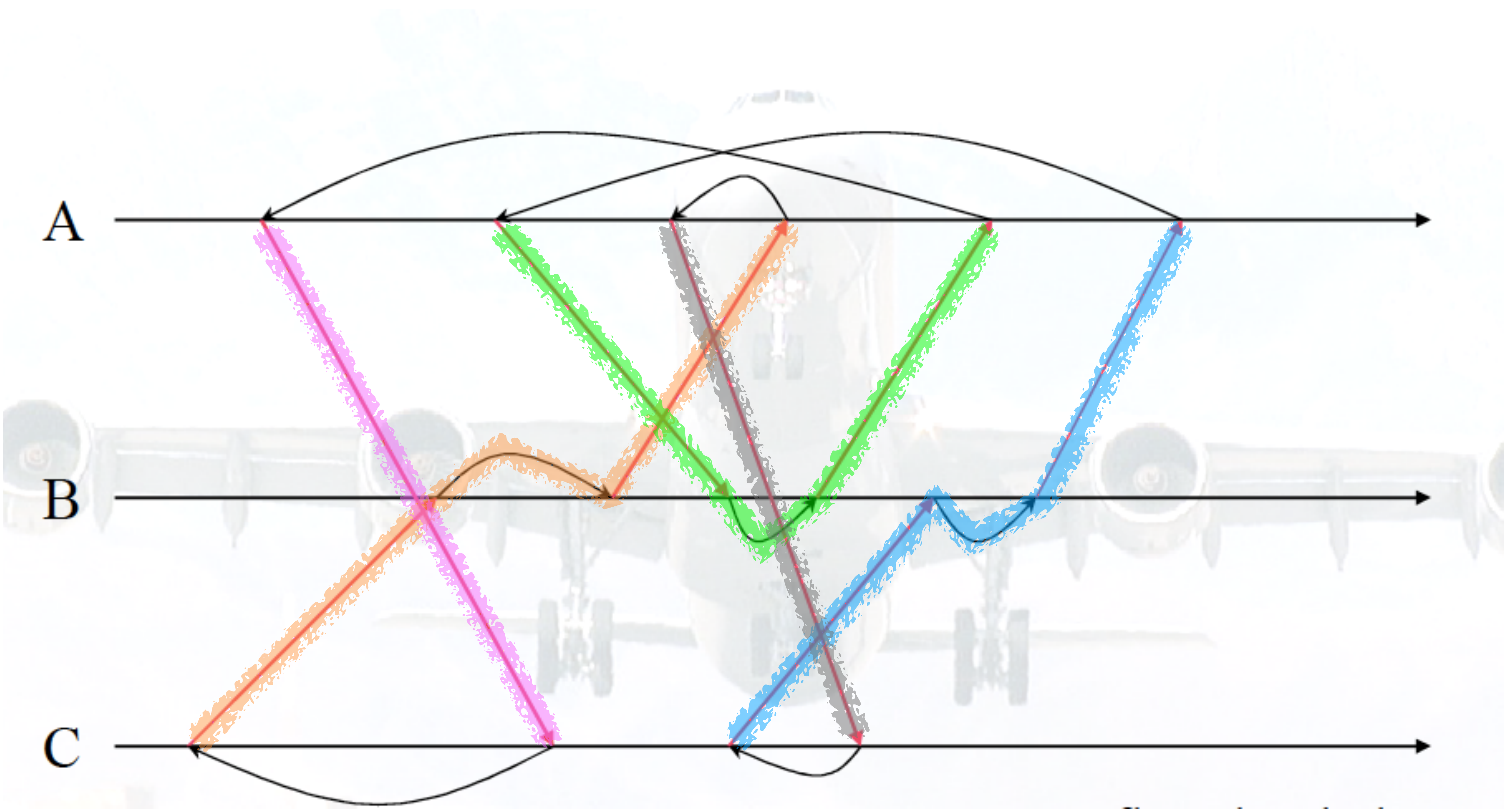
- Route of aircraft consists of:
  - Sequence of flights
  - Maintenance activities
- Extend over a few days
- Flights are selected to ensure enough time between them to complete aircraft turn or maintenance activity

Aircraft turn: time difference between arrival time of a flight and departure time of the next flight.

# Fleet assignment: example

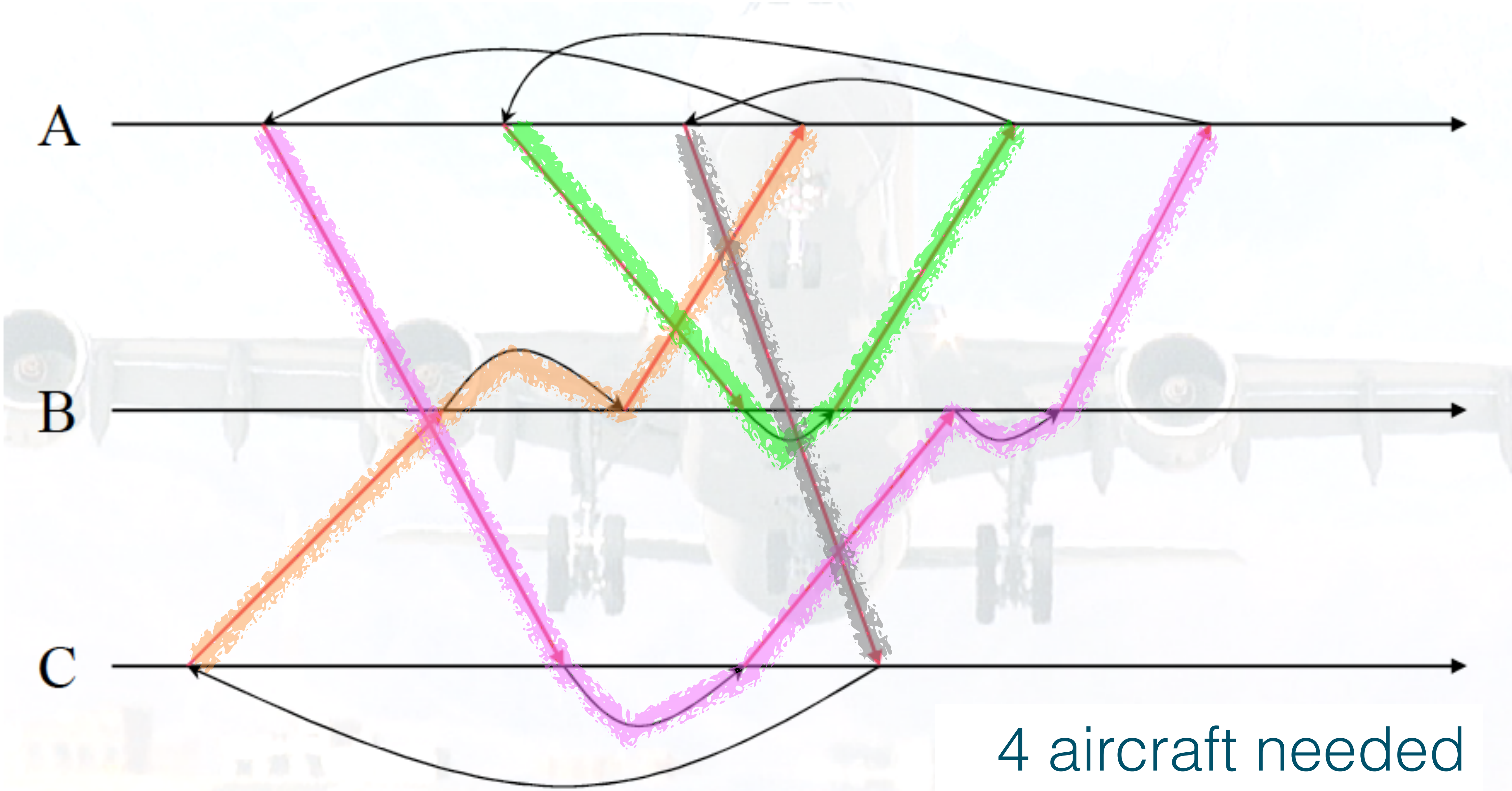


# Aircraft routing: an example




5 aircraft needed

# Aircraft routing: an example




4 aircraft needed
better routing?

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**Dichotomy of Demand and Supply**

You are working for a large, international airline. In conversation with a representative of a large dairy company at a conference, said representative asks you to quantify demand and supply on the route Arlanda-Newark. He is surprised to hear that you cannot easily quantify the demand and supply, as he easily can for, for example, milk with 3,25% fat in Stockholm in January. Give the dairy representative a detailed explanation on dichotomy of demand and supply in the airline industry.

The assignment should be done individually.

# Homework #1, question 2

## Planning of aircraft routes

A small Swedish airline focusing on domestic traffic has the following timetable:

| Flightnr | Dep time | Arr time | Dep AP | Arr AP | E[Pax] | R |
|---|---|---|---|---|---|---|
| 1 | 450 | 900 | A | L | 16 | 500 |
| 2 | 1000 | 1230 | A | G | 18 | 300 |
| 3 | 1020 | 1410 | A | L | 25 | 500 |
| 4 | 1810 | 2200 | A | L | 49 | 500 |
| 5 | 510 | 840 | L | G | 12 | 400 |
| 6 | 1030 | 1225 | L | U | 21 | 350 |
| 7 | 1510 | 1810 | L | G | 55 | 400 |
| 8 | 2020 | 2350 | L | A | 24 | 400 |
| 9 | 615 | 800 | U | A | 21 | 200 |
| 10 | 1545 | 1740 | U | A | 23 | 200 |
| 11 | 1745 | 1930 | U | L | 19 | 250 |
| 12 | 2000 | 2310 | U | G | 17 | 500 |
| 13 | 430 | 710 | G | A | 12 | 400 |
| 14 | 920 | 1250 | G | U | 24 | 500 |
| 15 | 1330 | 1640 | G | U | 53 | 500 |
| 16 | 1920 | 2250 | G | U | 11 | 500 |

The timetable is cyclic, with a cycle time of one day. This means that each flight in the table should be own once each day (including weekends).

**Fleet.** The aircraft fleet consists of two types of aircraft, two Jetstream 31 (J31) and four Fokker 50 (F50). The F50 has a capacity for 50 passengers and requires 50 minutes from landing until it can start again (i.e. turn-around time). The J31 can take 18 passengers and needs 30 minutes of turn around time. The airline approximates the operating cost as 1000 per hour in  for the J31 and 1500 for the F50 aircraft.
**Maintenance.** The same rules for maintenance applies to both aircraft types. After a maximum of 30 hours in flight, a maintenance check has to be performed. This takes five hours. The maintenance base for the J31 is located at airport A, while the base for the F50 fleet is located at airport L.
**Assignment.** Your assignment is to create a feasible aircraft schedule for the next summer season (5 months, May-Sept). The objective is to maximise profit.

Write a simple report describing how you solved the problem, presenting your solution, and discussing advantages and disadvantages with the schedule.

The assignment should be done in groups of 2-3 students.