Pairing Introduction

Developed by
Jeppesen Crew Academy

for version 22 of Crew Pairing

Participants presentation

- Name, company
- Role
- Experience
- Your expectations
- Other

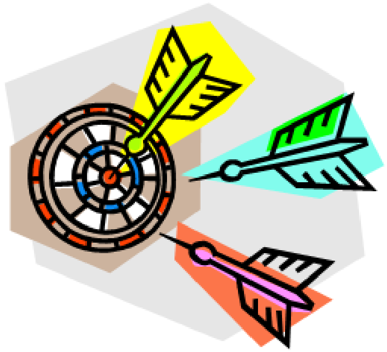
Practical Details

- **Restrooms –** in the corridor, to the right
- **Coffee breaks -** around 10.00 and 14.30 (water and fruit located in the back of the course room)
- **Phones -** are turned off (or kept on silence) and phone calls are taken outside the training room
- **Internet browsing,** typing e-mails etc. is done during breaks.
- **Lunch arrangements**
- **Evaluation**

Course goals

Give an understanding of:

- complete planning process
- planning concepts
- Crew Pairing problem objective and complexity
- complicating factors



Prerequisites

– None

Please –

Don't be afraid to ask questions if anything is unclear!

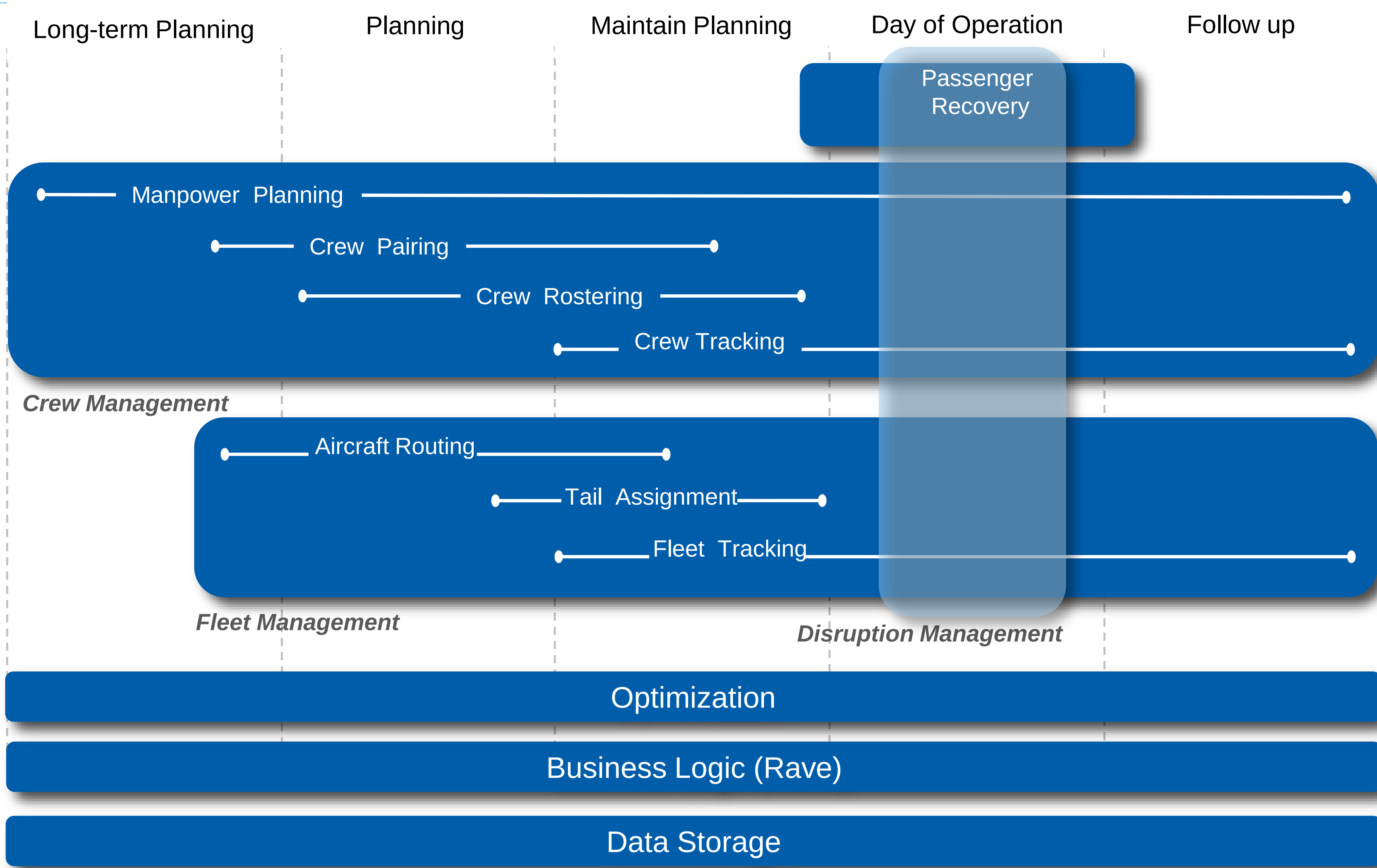
Agenda

- Planning process
- Planning concepts
- Basic Crew Pairing problem
- **Lunch 12:30 – 13:30**
- Complicating factors
- Solution approaches
- Course evaluation

Coffee break around 10.00 and 14.30

All times are approximate – changes may/will occur
Short breaks every ~40 minutes or so

Crew & Fleet Portfolio

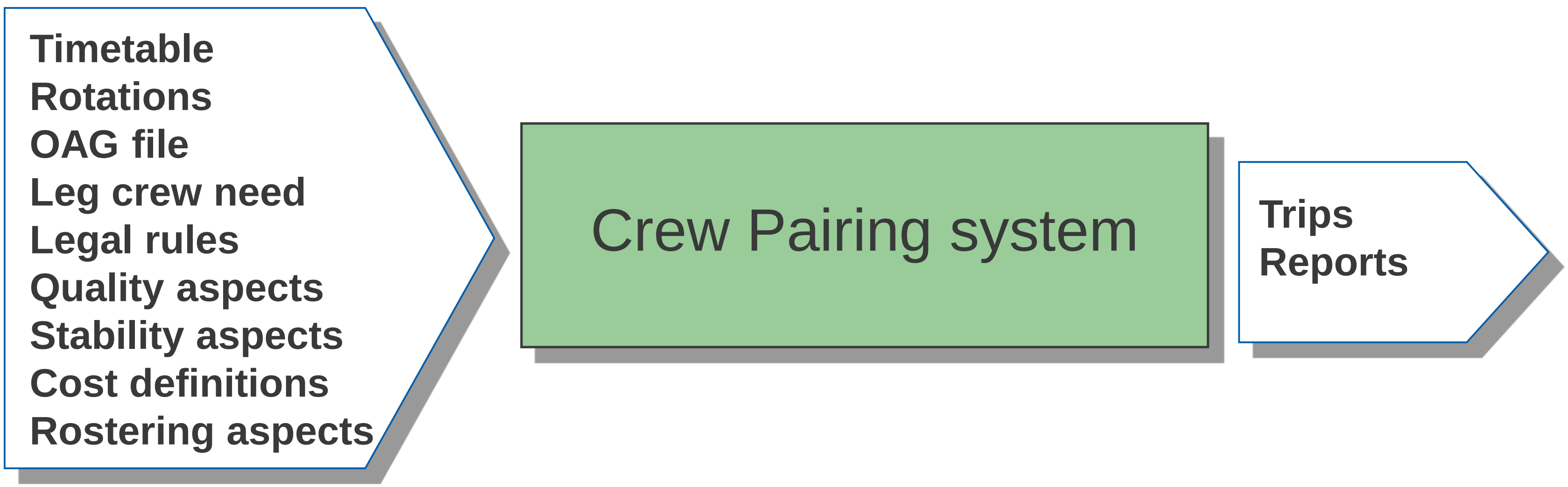


Crew planning problem

Due to problem complexity, the problem is normally divided into pairing and rostering.

Crew Pairing

- Create anonymous flight sequences respecting flight regulations.
- Minimize cost, maximize quality of life and stability.



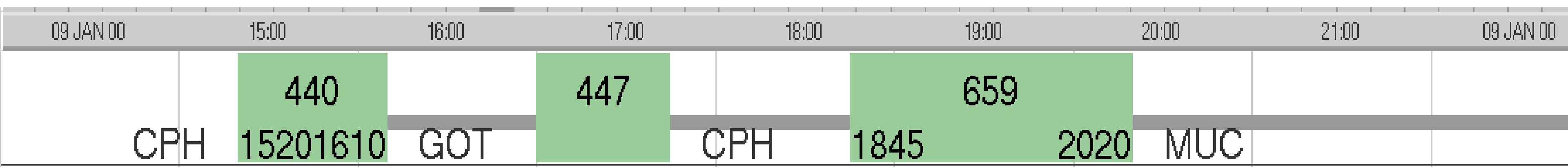
Crew Pairing planning is done between 3 and 8 weeks before day of operation.

Crew Pairing – example

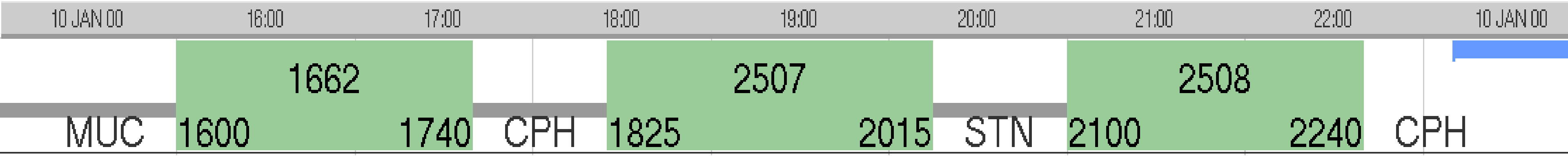
A captain and a first officer are based in Copenhagen.

They fly a two-day trip with a layover in Munich.

Monday's duty:

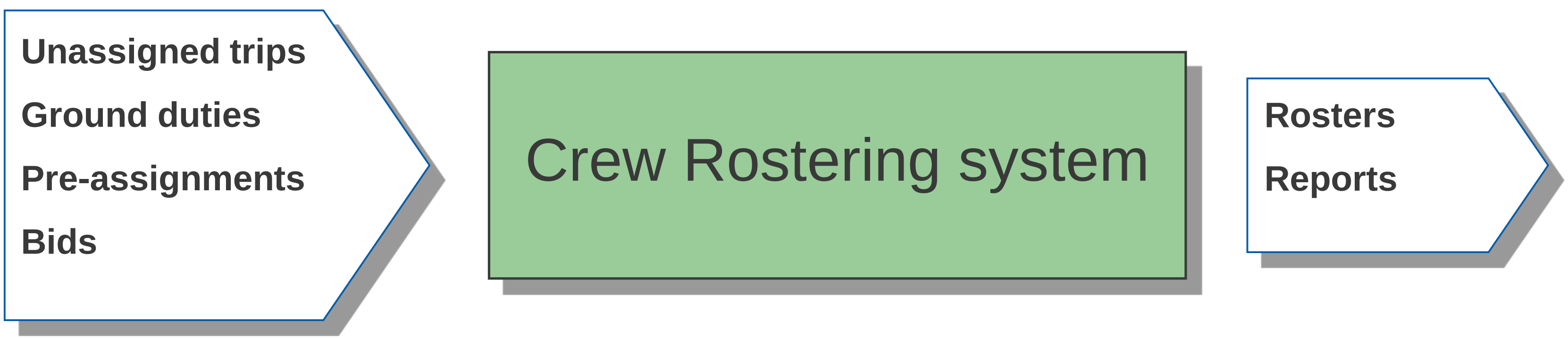


…and Tuesday's duty:



Crew Rostering

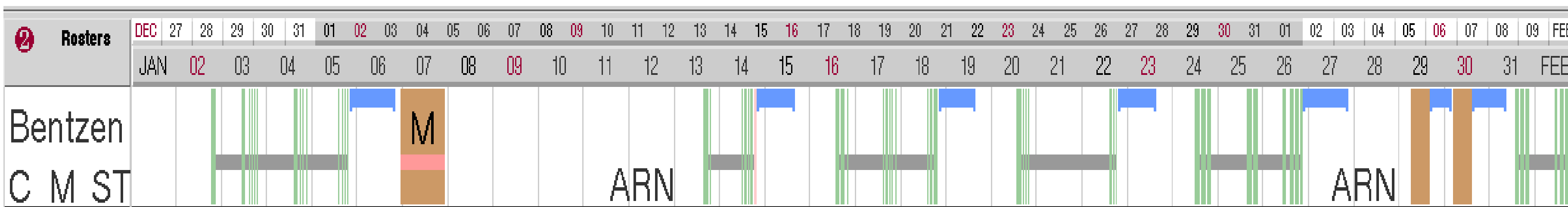
- Create detailed working plans for crew, including flights, ground duties, days off, vacation etc.
- Maximize fairness and satisfaction, minimize cost.



Crew Rostering planning is done between 1 and 6 weeks before day of operation.

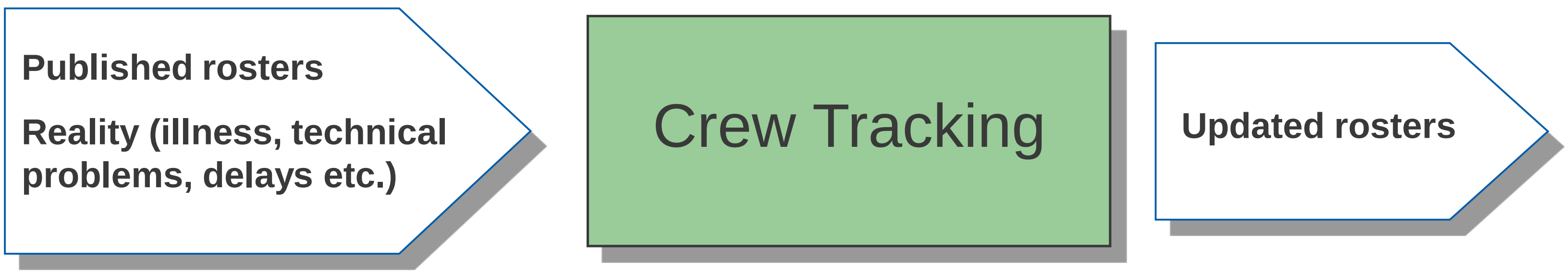
Crew Rostering – example

The January roster for a captain includes flight duties, ground duties (simulators, medical checks) and days off:



Crew Tracking

- Maintain rosters after publication
- Minimize costs and impact on published rosters



Crew Tracking is done from roster publication to operation. The closer to operation, the more important on-line updates gets.

Planning concept – leg

The smallest (atomic) planning component is the **leg**.

A leg is the operation between a departure station and the next arrival station.

It has a unique combination of flight carrier, flight number and
leg number per day.

Example ARN-CPH leg, the second leg of SK 709

Planning concept – flight

A **flight** is a commercial and administrative concept.

A flight can consist of one or several legs.

It has a unique combination of flight carrier and flight number per day.

Example SK 709, HEL-CPH, a two-leg flight.

Planning concept – deadhead

A **deadhead** (also known as positioning or passive flight) is a leg in which the crew member is transported as a normal passenger.

If the **deadhead** takes place on another airline's flight, it is usually called **other carrier deadhead** flight.

Example deadhead flight

	2527		2528		1589	
ARN	0600 0825		0930 1140	ARN	1305 1515	BRU

Planning concept – duty

Duty is a sequence of legs constituting a day's work (i.e. work between required rest periods) for a crew member.

A duty begins with a **briefing** before the first leg and ends with a **debriefing** after the last leg.

Example duty beginning in WAW and ending in MUC

	754			657			658			1661		
WAW	0545	0710	CPH	0805	0935	STR	1100	1240	CPH	1340	1520	MUC

Planning concept – base

A **home base** is the station at which a crew member resides. All trips must begin and end at a home base.

A **base** can be a **city** and cover several airports: for example PAR = CDG + ORY).

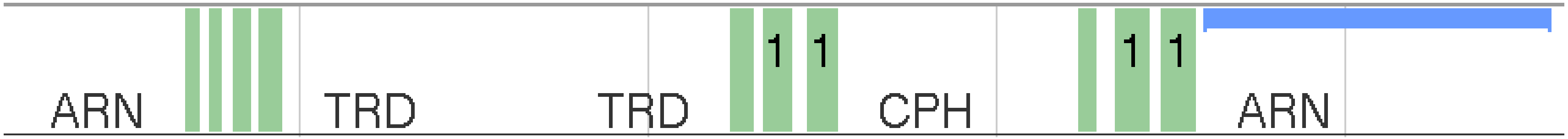
An airline can have several bases, but a crew member is always attached to one base only.

Example
SAS has three home bases: Copenhagen, Stockholm (ARN, BMA) and Oslo.

Planning concept – trip

Trip is a sequence of duties beginning and ending at the same base.

Example of a 4-day trip with three duties:



A trip always has a **crew complement** indicating the crew supposed to service the trip.

* Other (obsolete) terms for trip: pairing, crew rotation, CRR

Planning concept – crew position

A flight activity needs crew carrying out various tasks.

Therefore, crew is divided into **crew positions**.

The number of crew positions and crew position types vary from airline to airline.

Example
Flight Deck crew: captain – first officer – second officer
Cabin crew: purser – assistant purser – cabin attendant

Planning concept – crew need

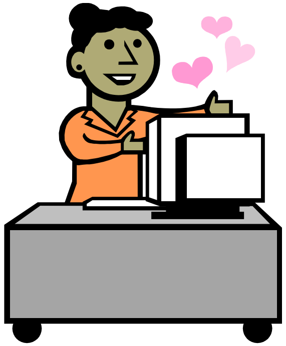
Each leg has a **crew need** describing the required amount of crew in each crew position.
A crew vector is used to represent the crew need.

Example
Crew need = 1/1/0 // 1/1/3
This trip should be assigned to:
2 flight deck crew (1 captain + 1 first officer)
5 cabin crew (1 purser + 1 assistant purser + 3 flight attendants)

The crew need can be fixed or leg dependent, it is defined by the rules.

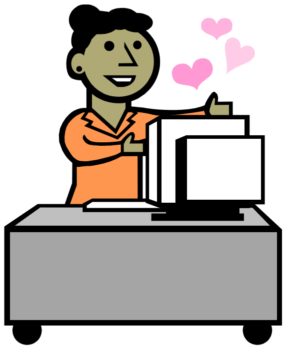
Exercise 1

Crew planning process
Planning concepts



Exercise 1 – summary

Summary of exercise 1

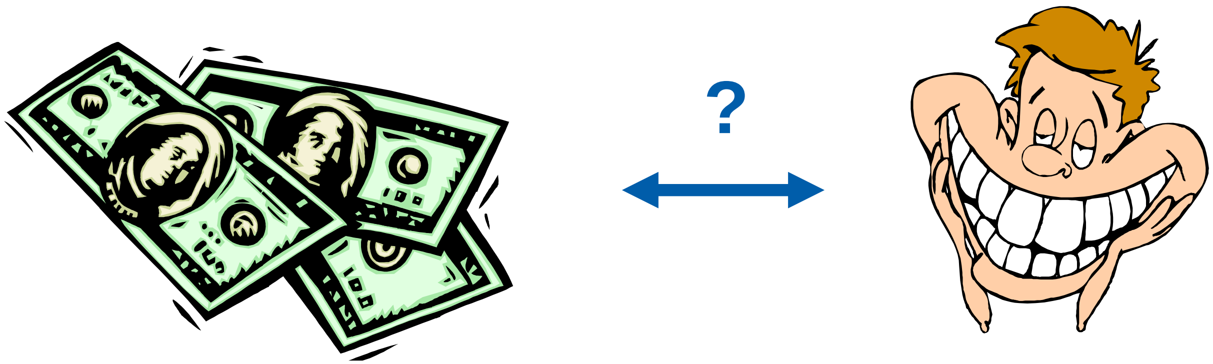


Objectives

- Cover all flights
- Create only trips complying with regulations, union rules
- Minimize total cost
- Maximize crew quality of life
- Maximize stability
- ...

Objectives

Some objectives are potential conflicts, for example costs and quality of life.



Planners usually solve these problems manually by experience, rules of thumb etc. However, this experience often differs among planners. It may be difficult to generalize.

Rules

Trips must be created according to rules.

There are different kind of rules:

- legal
- union
- quality

In the pairing system, rules are **always** enforced strictly.
Trips not complying with rules are called **illegal trips**.

Social quality

Social quality are characteristics of a trip that the vast majority of crew members consider as good.

Examples

“Not more than two early starts in a trip”

“No repetitive duties in a trip”

“No long connection times”

Stability

Stability means that the roster is not very sensitive to delays and other changes. Good stability simplifies maintenance of the trips.

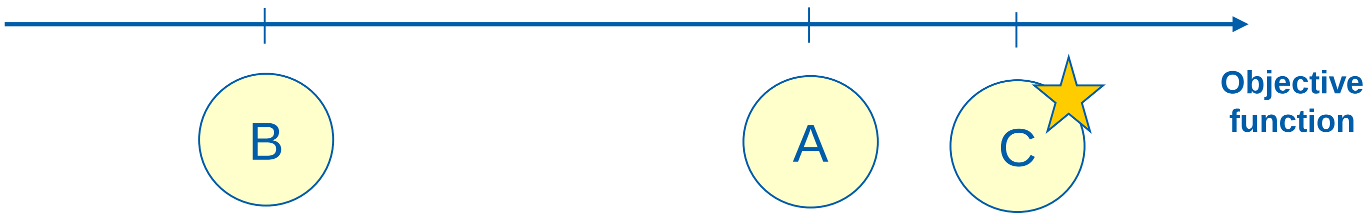
Examples

“Not too short connection time between legs”

“No aircraft changes within a duty”

Objective function

When solving problems automatically, all Crew Pairing solutions should be **uniquely ordered**. This is the only way to identify the **best solution**.



Solution A is better than solution B, but solution C is better than both and therefore the best.

Objective function

The objective function:

- guides the optimizer when generating solutions
- is modelled in Rave
- returns a value for every solution

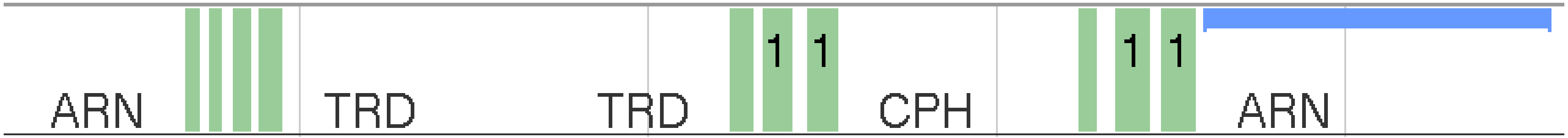
Objective function

The objective function contains two parts:

- real costs (for example hotel costs)
- penalties/relative costs for lack of quality or stability (for example penalties for unpopular trips)

The **best solution** is uniquely identified as the one with **lowest value** of the objective function.

Objective function – example



Given a certain objective function, the value of the objective function (often called **total cost**) for the trip above is:

Real costs	18,400 Jeppesen$
Penalties	4,210 Jeppesen$
Total costs	22,610 Jeppesen$

Quantifying quality and stability

Defining penalties (and hereby quantifying quality and stability) is always difficult, but often a very rewarding process.

It forces planning departments to:

- prioritize quality issues
- decide how much quality is worth

Rules vs. objective function

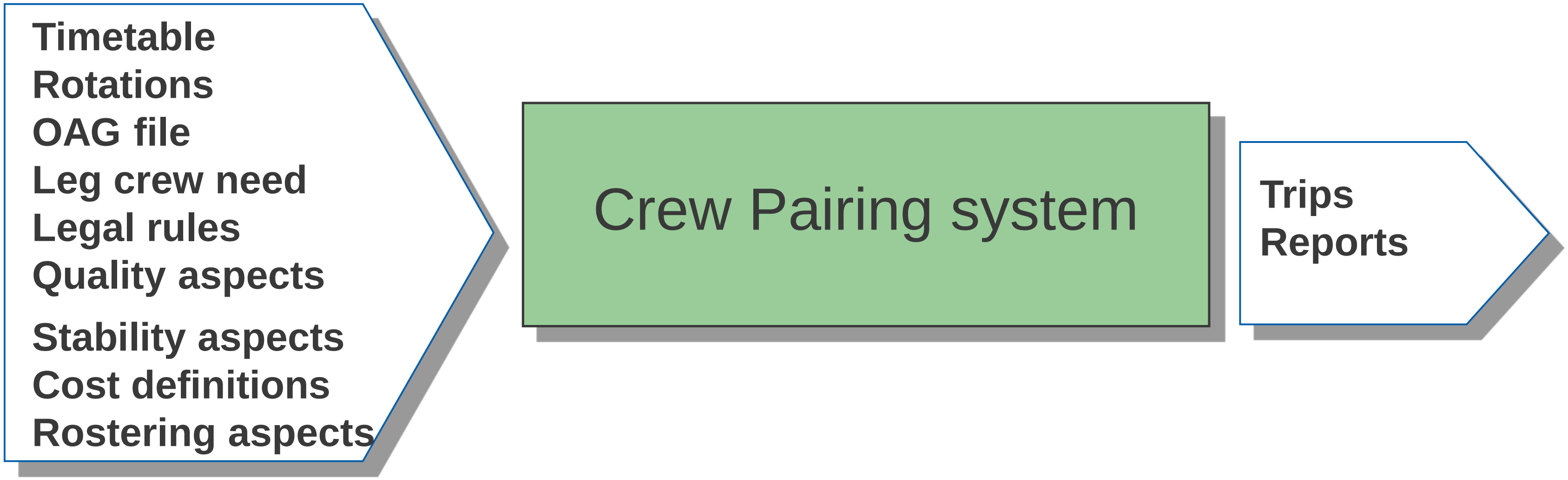
If a rule may be violated in certain cases, it should be considered as a quality issue and be a penalty instead.

Example

Rule: “Do not allow crew change after charter flights.”

Penalty: “Crew change after charter flights should be penalized by 5000 Jeppesen$.”

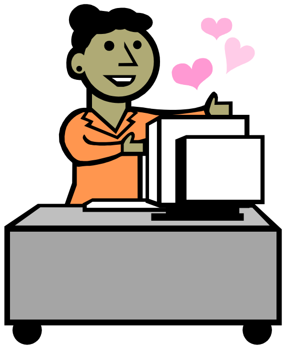
Basic Crew Pairing problem



All legs have identical crew need, only one base.

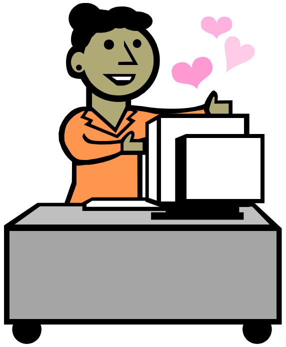
Exercise 2

Costs and rules



Exercise 2 – summary

Summary of exercise 2



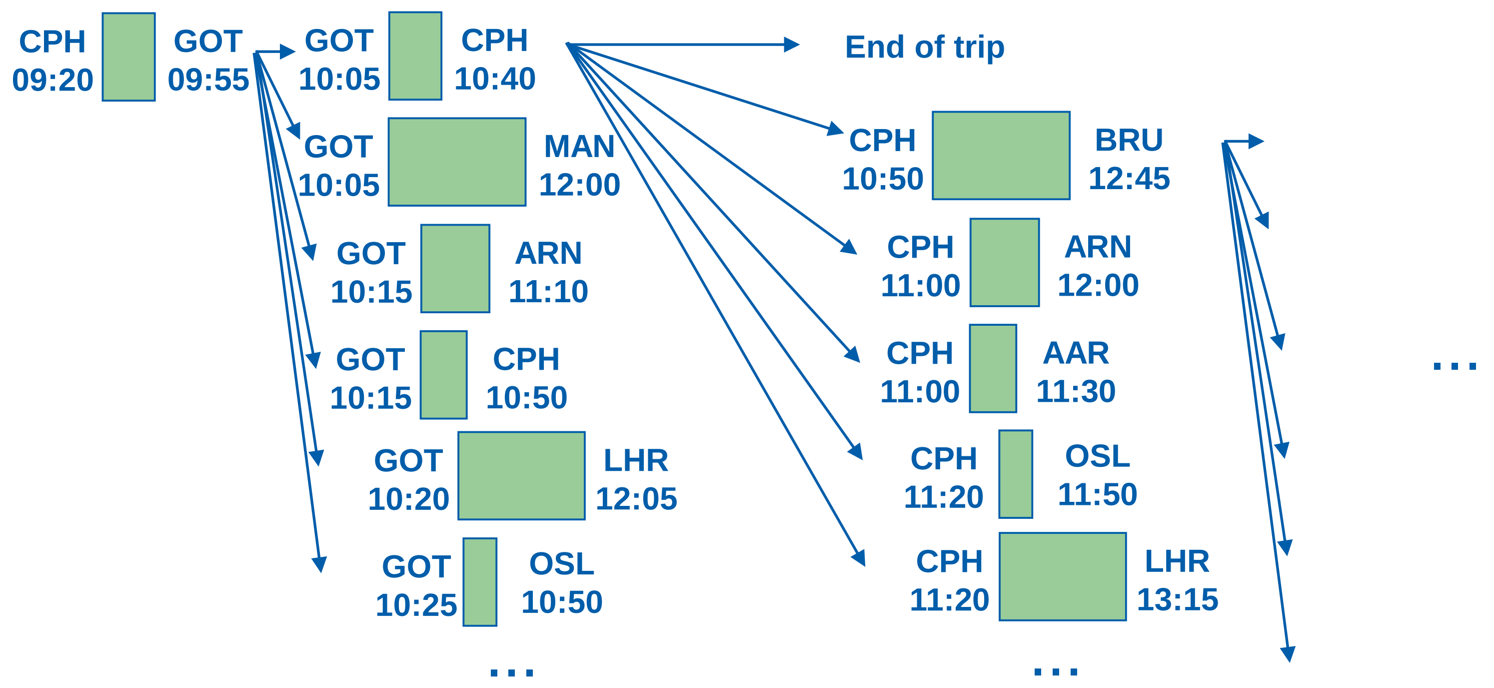
Number of solutions

The number of solutions to the Crew Pairing problem depends on the timetable and the rules.

Generally, the number of solutions grows exponentially with the number of flight legs. This is an example of a phenomenon known as the **combinatorial explosion**.

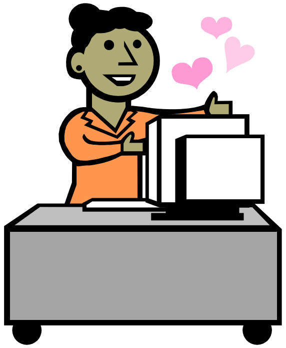
Number of solutions – example

Creation of trips from CPH home base



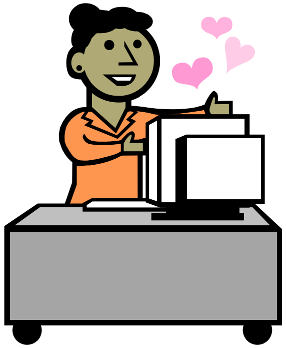
Exercise 3

Basic Crew Pairing problem



Exercise 3 – summary

Summary of exercise 3



Complicating factors

The basic Crew Pairing problem may be extended (and made more difficult) in several ways:

- varying crew need
- augmentation
- multiple bases
- co-terminals
- ground transportation
- deadheads from other carriers
- imitation
- regularity
- above/below rank

Varying crew need

Crew need differs from leg to leg, but is not duty dependent. This typically arises when solving cross- qualification cabin crew problems.

Example

An airline has four aircraft types with varying cabin crew need, everybody is qualified for all aircraft types:

F100 (1/1/1)

A320 (1/1/2)

B727 (1/1/2)

B757 (1/1/3)

Varying crew need

A trip always has a crew complement:
the positions covered by the trip.

Basic Crew Pairing problem
All trips have identical crew complements
(for example 1/1/1).

Varying crew need problem
Different trips will have varying crew complements
(for example 1/1/1, 1/1/2, 0/0/1).

Varying crew need

Variable crew need problems can be solved in a number of ways.

A. Sub-problems with identical crew need are solved separately.

B. Two different crew complements: One basic solution with trips for the maximum common crew need, covering all legs. One jumper solution with trips for one crew member.

C. Different methods combining the above.

Varying crew need - example

Sub-Problem Approach:
Three independent sub-problems:

A. F100 flight legs (1/1/1)
B. A320 + B727 flight legs (1/1/2)
C. B757 flight legs (1/1/3)

Varying crew need - example

Jumper Approach:
A two step procedure:

1. The Basic solution: All legs are included, creating trips with crew complement 1/1/1.
2. The Jumper solution: Trips are created with a crew complement of 0/0/1. A320 + B727 legs are included once. B757 legs are included twice.

Augmentation

Crew need depends on the duty.
This typically arises in long-haul flight deck problems.

Example
For a particular airline, the flight deck crew need for A320 legs is normally 1/1/0.
If duty time exceeds 12:00 hours, one extra first officer is needed, changing the crew need to 1/2/0.

Augmentation

Basic Crew Pairing problem

The total cost of a trip is calculated directly from the trip.

Augmentation problem

If a trip causes augmentation, the total cost of the trip includes the total cost of covering the augmented leg(s).

Augmentation – example

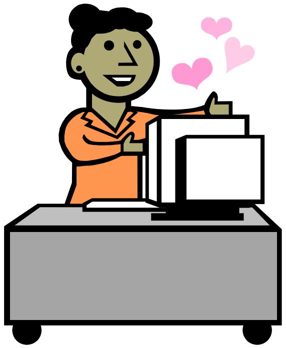
Crew complement: 1/1/0

The first duty is longer than 12:00 hours. The two first legs have a crew need of 1/2/0.

The cost of covering this extra position (0/1/0) depends on the structure of other trips.

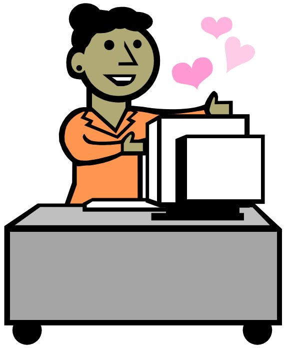
Exercise 4

Varying crew need



Exercise 4 – summary

Summary of exercise 4



Complicating factors

The basic Crew Pairing problem may be extended (and made more difficult) in several ways:

- varying crew need
- augmentation
- multiple bases
- co-terminals
- ground transportation
- other carrier deadhead flights
- imitation
- regularity
- above/below rank

Multiple bases

If crew is located in more than one base, trips must accommodate crew distribution.

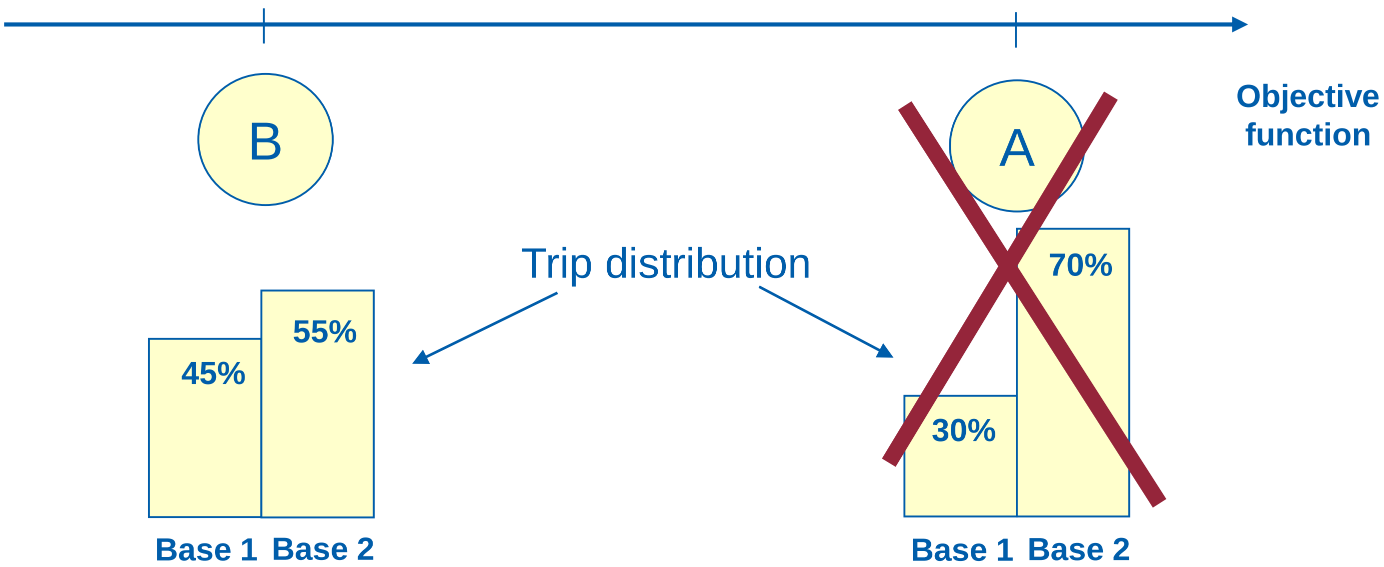
Examples

SAS has bases in:
Copenhagen, Stockholm and Oslo.

Alitalia has bases in:
Rome and Milan.

Multiple bases

More often than not, crew distribution is non-optimal.



Trip distribution is controlled with **base constraints**.

Multiple bases

Basic Crew Pairing problem

When generating trips, all flight legs are allocated to the same base.

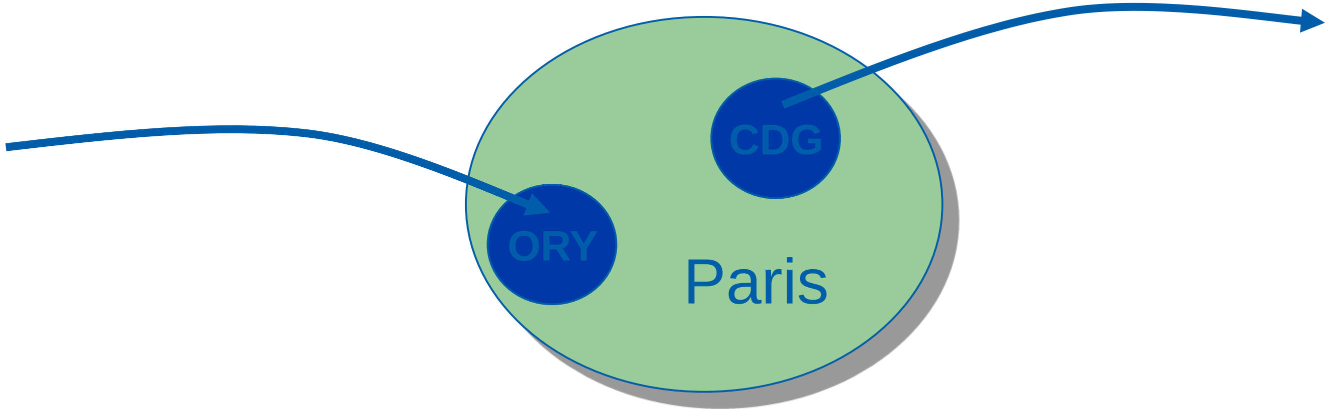
Multiple bases problem

Since you don't know to which base a given flight leg will be allocated, the problem will grow exponentially.
Thus, there are more combinations to be considered.

Co-terminals

Exploiting close vicinity of airports.

Example



Co-terminals are mainly used **between** duties.

Ground transports

Ground transports are similar to deadheads using other means of transportation, such as:

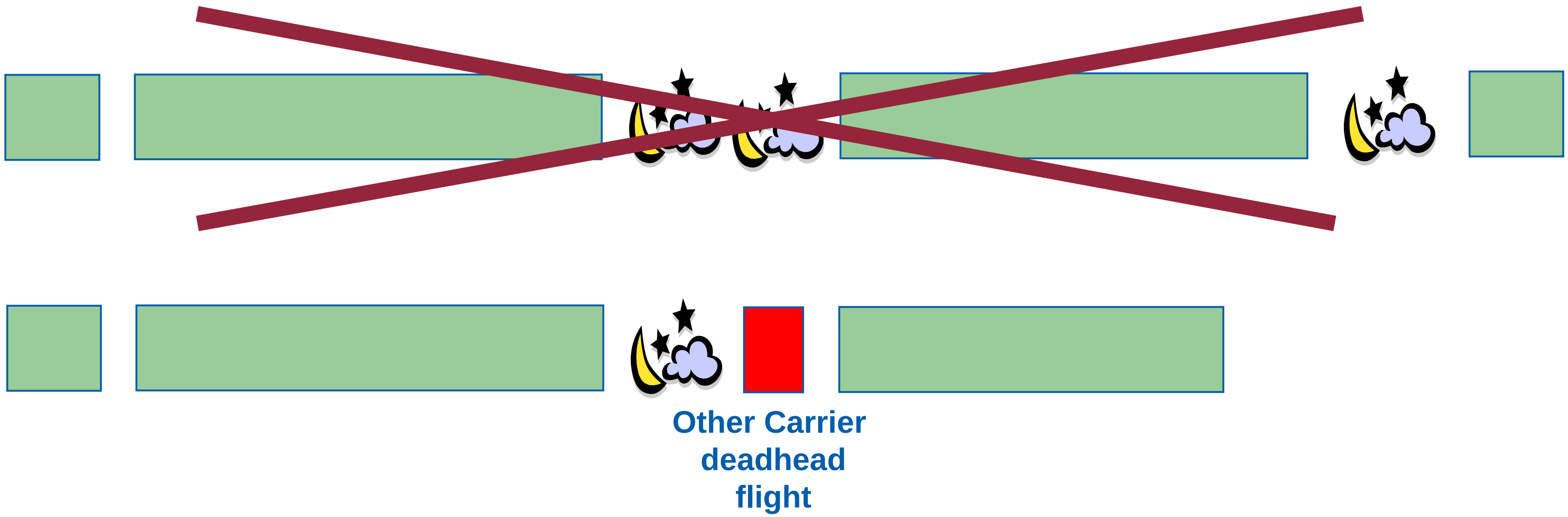
- bus
- train
- taxi flights
- limousine service

Example

Qantas uses the Shinkansen train between Tokyo and Osaka.

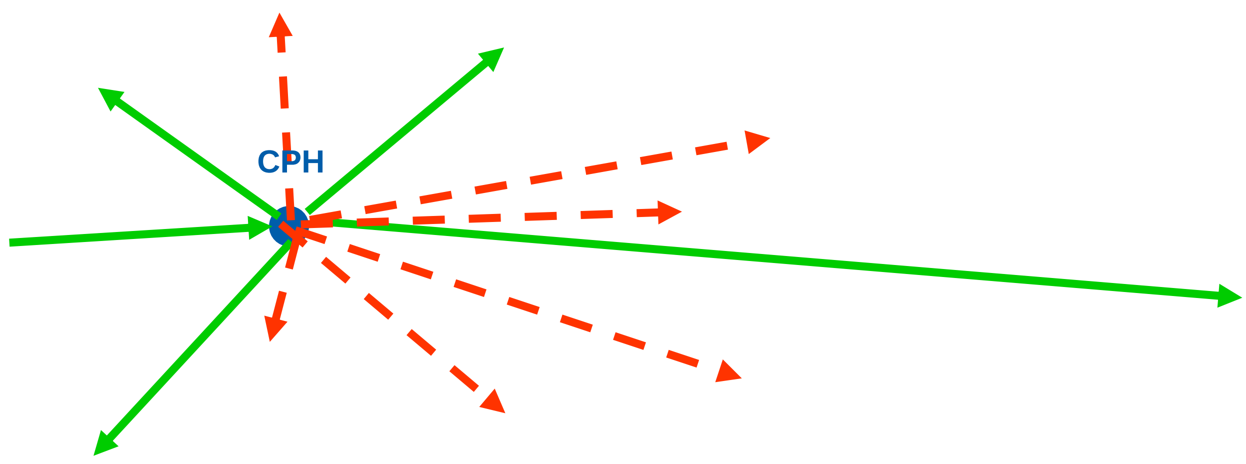
Other Carrier deadhead flights

It may be advantageous to position crew using flights on other airlines. You do this to avoid long layovers or to break less productive patterns.



Other carrier deadhead flights

Other carrier deadheads flights may increase the search domain (number of possible trips) exponentially.



Own airline flights   Other carrier deadhead flights

Complicating factors

The basic Crew Pairing problem may be extended (and made more difficult) in several ways:

- varying crew need
- augmentation
- multiple bases
- co-terminals
- ground transportation
- Other carrier deadhead flight
- imitation
- regularity
- above/below rank

Imitation

Creating trips imitating other trips as much as possible. Typically used when generating trips for cabin crew, based on flight deck trips.

Problems

- it is non-trivial to quantify imitation
- imitation definitions differ from airline to airline
- solutions are most often non-optimal (compared to solutions where imitation is not considered)

* Imitation is used for operational stability.

Regularity

Designing trips that are more or less identical from one period to another (typically from week to week and from day to day).

Reasons for regularity may be

- union requirement
- it eases maintenance (day of operation)

Fly Above/Below rank

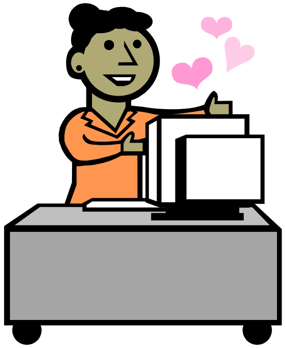
Crew can be assigned in a different position than the usual, for example:

- Captain working as First Officer
- Purser working as Assistant Purser

This is normally part of the rostering problem, but can be taken into account already in the pairing problem.

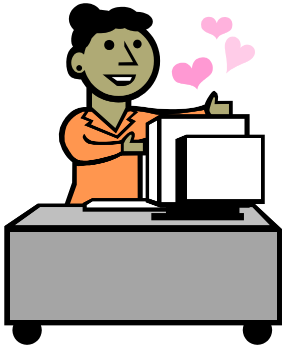
Exercise 5

Complicating factors



Exercise 5 – summary

Summary of exercise



Problem types

	Long-haul	Short-haul
Flight Deck	• No varying crew need • Augmentation • Other carrier deadheads • Small number of solutions	• No varying crew need • No augmentation • Few other carrier deadheads • Large number of solutions
Cabin	• Varying crew need • Other carrier deadheads • Imitation not relevant • Small number of solutions	• Varying crew need • No augmentation • Few other carrier deadheads • Imitation of flight deck wanted • Large number of solutions

Short- and long-haul flight deck in one problem

Example

Characteristics of long-haul problems:

- augmentation
- other carrier deadheads needed

Characteristics of short-haul problems:

- large number of flights and combinations

$\Rightarrow$ **complex pairing problem**

Solution approaches

Solution approaches:

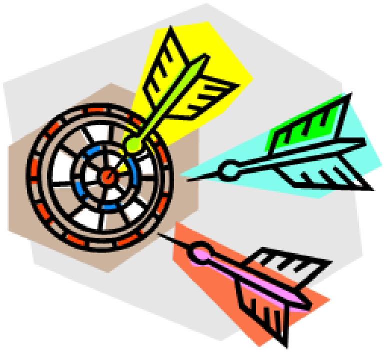
- Breakdown into smaller sub-problems

  For example run short-haul and long-haul separately
- Solve a problem in several steps

  For example: daily $\Rightarrow$ weekly $\Rightarrow$ dated

Course summary

- Planning process
- Planning concepts
- Rules and costs
- Planning objective
- Basic planning problem
- Complicating factors
  (varying crew need, augmentation, multiple bases, co-terminals, ground transports, deadheads, imitation, regularity)
- Problem types
- Solution approaches



Course Evaluation

Please take a few minutes to complete the evaluation form, it will help us improve the courses for you and your colleagues:

- Login:

- Start Explorer:

- Fill in the course information
- …and your role (Internal for Jeppesen)

The end

This was Pairing Introduction.
Welcome back to Pairing I and Jeppesen Crew Academy!