

# Welcome to Pairing I

Developed by  
Jeppesen Crew Academy

for version 22 of Crew Pairing



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**Born** 1988  
**Started at Jeppesen** 2012  
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## **Head Teacher**

Introduction to Pairing, Pairing I

## **Position**

Service Manager, CSS  
Product Owner, TD

## **Academic background**

M.Sc. Computer Science

## **Experience**

Support for clients after implementation  
(SAS, KLM and Saudia)

*"I enjoy working at Jeppesen because we solve interesting problems and continuously learn new things about our products"*

# Participants presentation

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- 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

## Enable you to:

- Create production trips using Crew Pairing
- Use manual and automatic tools
- Perform simple simulations



# Prerequisites

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- Pairing Introduction  
(or equivalent knowledge)

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



# Course material

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- Course slides
- Online documentation
- Crew Pairing and Crew Rostering User Guide



# Agenda day 1

- Basic functionality in Crew Pairing
- Planning concepts
- Create a standard solution
- **Lunch around 12.30**
- Introduction to optimization
- Influence the solution
- Create a dated solution

**Coffee break around 10.30 and 15.00**





# Agenda day 2

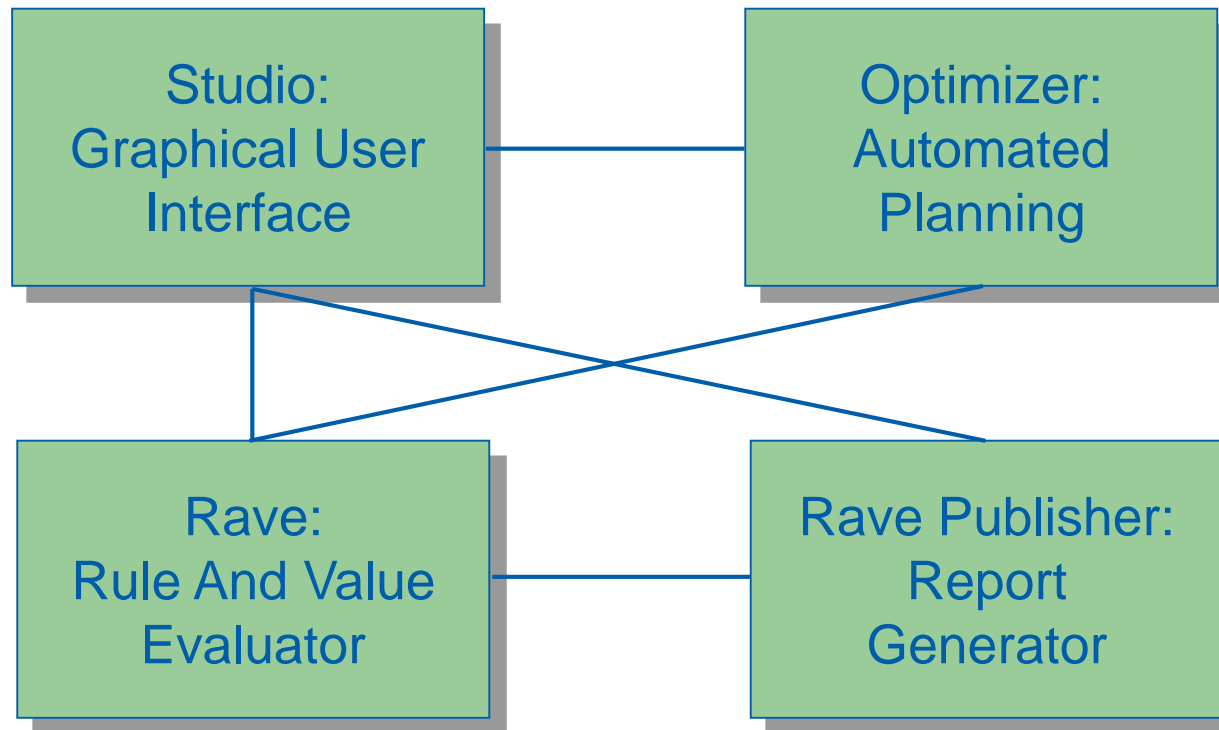
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- Create a dated solution, continuation
- Variable crew need approaches
- Summary and course evaluation

**Coffee break around 10.30**



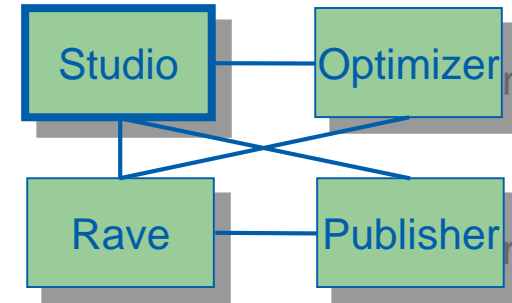
# Crew Pairing



# Studio

Includes tools for:

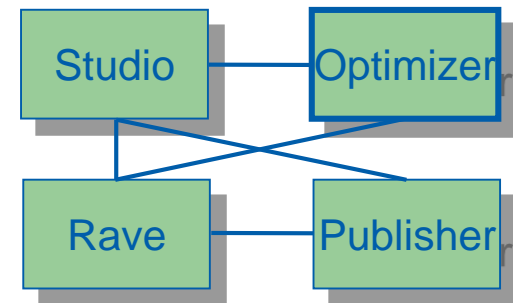
- importing timetable and OAG files
- modifying timetable information
- building rotations
- switching rules on and off
- changing parameters (costs, penalties, global constraints etc.)
- building/modifying duties and trips manually, either according to rules or violating rules deliberately
- creation of reports using Rave Publisher
- sending problems to and getting solutions from Crew Pairing Optimizer



# Optimizer

Crew Paring Optimizer solves Crew Pairing problems to optimality (or near optimality) using different optimal or heuristic methods designed for various problems:

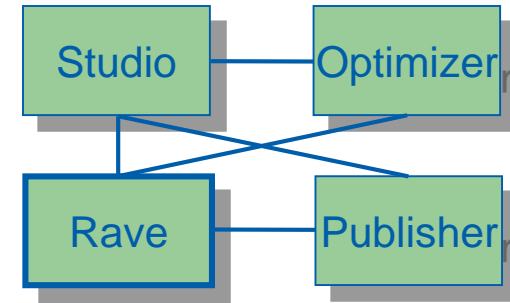
- daily, weekly and dated problems
- short-haul and long-haul problems
- other carrier deadheading
- deadhead optimization



All trips comply with rules as defined in Rave.

# Rave

Rave is a programming language for modelling rules, costs and report definitions. It is specifically designed for modelling crew scheduling problems.



## Rave:

- is internally developed
- is easy to learn
- allows systems to change with reality
- allows turning rules on/off and parameters to be changed by planners

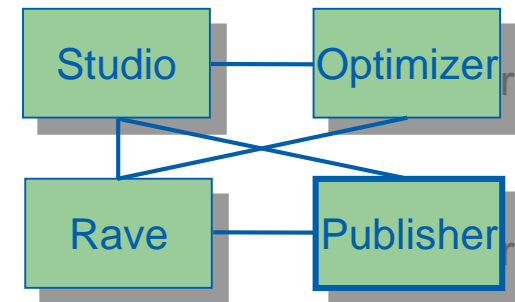
Rule code is administered by rule writers at the customer (or by Jeppesen on consulting basis).

Jeppesen offers several courses in Rave

# Rave Publisher

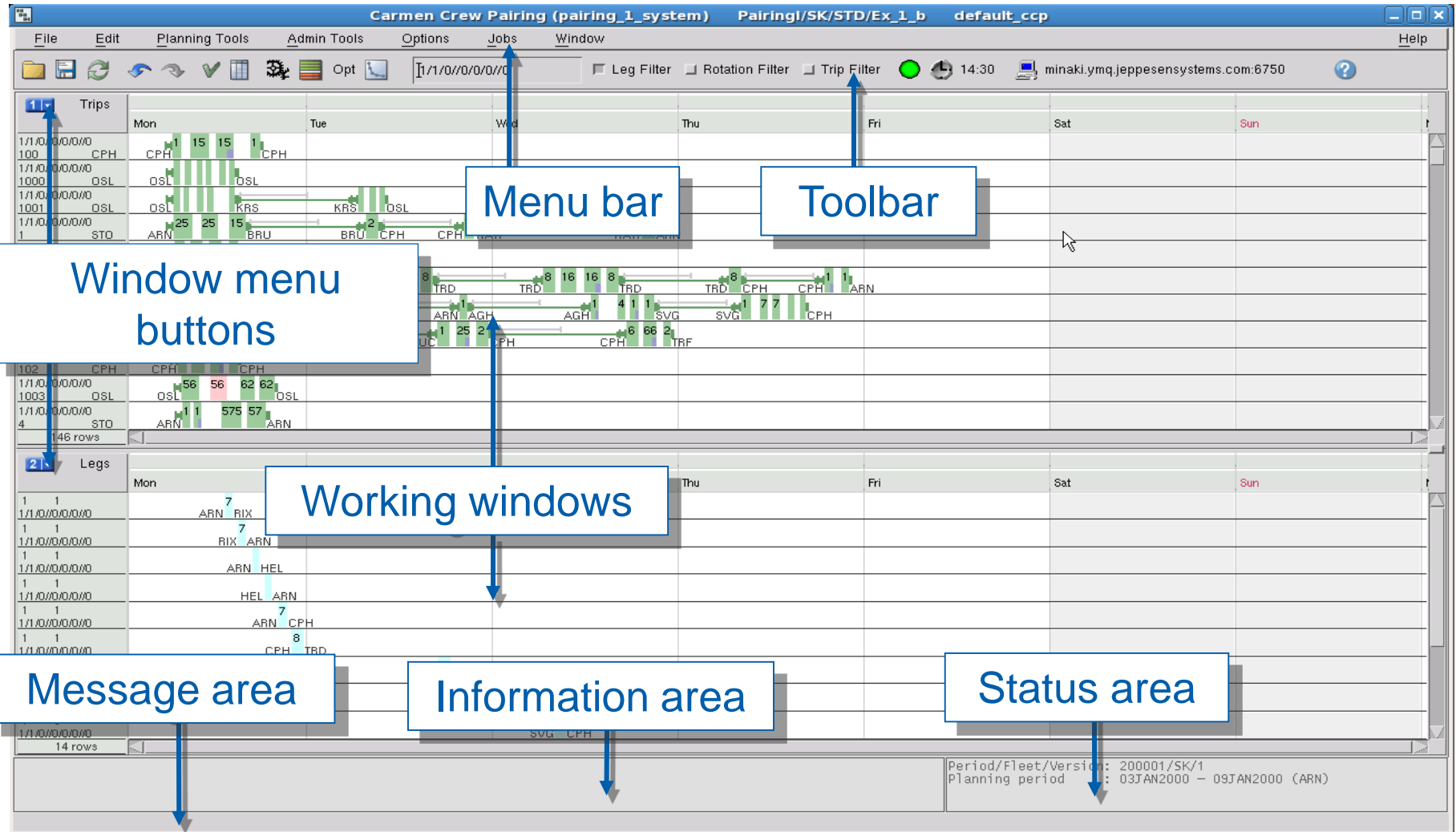
## Rave Publisher:

- is an internally developed language for generating reports
- generates graphical, typeset and pure ASCII reports (for system input/output)



Report code is administered by report writers at the customer (or by Jeppesen on consulting basis)  
Jeppesen offers several report courses.

# Studio



The screenshot shows the Carmen Crew Pairing software interface. The title bar reads "Carmen Crew Pairing (pairing\_1\_system) PairingI/SK/STD/Ex\_1\_b default\_ccp". The menu bar includes File, Edit, Planning Tools, Admin Tools, Options, Jobs, and Window. The toolbar contains various icons for file operations and filtering. The main workspace is divided into two panes: "Trips" (top) and "Legs" (bottom). The "Trips" pane shows a calendar view with flight paths and numbers. The "Legs" pane shows a list of flight legs. The status bar at the bottom displays "Period/Fleet/Version: 200001/SK/1" and "Planning period: 03JAN2000 - 09JAN2000 (ARN)".

Annotations with arrows pointing to specific UI elements:

- Menu bar**: Points to the menu bar.
- Toolbar**: Points to the toolbar.
- Window menu buttons**: Points to the Window menu.
- Working windows**: Points to the main workspace area.
- Message area**: Points to the message area at the bottom left.
- Information area**: Points to the information area at the bottom center.
- Status area**: Points to the status area at the bottom right.

# Studio

**Carmen Crew Pairing (pairing\_1\_system) PairingI/SK/STD/Ex\_1\_b default\_ccp**

File Edit Planning Tools Admin Tools Options Jobs Window Help

1/1/0/0/0/0/0/0 Leg Filter Rotation Filter Trip Filter 14:30 minaki.ymq.jeppesensystems.com:6750

**1** Trips

1/1/0/0/0/0/0/0 CPH 1 15 15 1 CPH  
 1/1/0/0/0/0/0/0 1000 OSL  
 1/1/0/0/0/0/0/0 1001 OSL  
 1/1/0/0/0/0/0/0 1 STD ARN  
 1/1/0/0/0/0/0/0 3 STD ARN  
 1/1/0/0/0/0/0/0 2 STD ARN  
 1/1/0/0/0/0/0/0 101 CPH  
 1/1/0/0/0/0/0/0 1002 OSL  
 1/1/0/0/0/0/0/0 102 CPH  
 1/1/0/0/0/0/0/0 1003 OSL  
 1/1/0/0/0/0/0/0 4 STD ARN

**2** Show Leg Sets F5  
 Show Rotations F6  
 Show Legs F7  
 Show Duties  
 Show Trips F8  
 Show Legal/Illegal  
 Rows  
 Redraw  
 Clear  
 Remove

Period/Fleet/Version: 200001/SK/1  
 Planning period : 03JAN2000 - 09JAN2000 (ARN)

Different objects can be shown in different working windows

Window menu



## Leg values

SK 844 *	CPH - TRD	J 736							
U.T.C.:	21:10 - 22:50	LEG:	Block	1:40	Cxn	-		Booked:	0/0/0//0/0/0//0
Local :	22:10 - 23:50	DUTY:	Block	1:40	Duty	3:10	Rest -	Need:	1/1/0//0/0/0//0
User tags:	.....	TRIP:	Block	1:40	Duty	3:10	Duty Days 2		

## Booked and needed crew

# Status area

default

Etable directory



```
Period/Fleet/Version: 200001/SK/1
Planning period      : 03JAN2000 - 09JAN2000 (ARN)
```

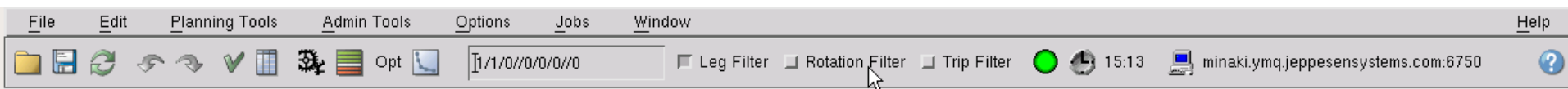


Local plan period



Default Base

# Menu bar



**File**

New, Open, Save etc.

**Edit**

Undo, Redo, Repeat

**Planning Tools**

Airport Manager, parameters, external tables etc.

- **Sub-plan**

Operations on the loaded Sub-plan

- **Local Plan**

Operations on the loaded Local Plan

**Admin Tools**

Rule/report development, system files etc.

**Options**

Studio settings, colours etc.

**Jobs**

Start Optimization, Batch Job Manager, Process Manager

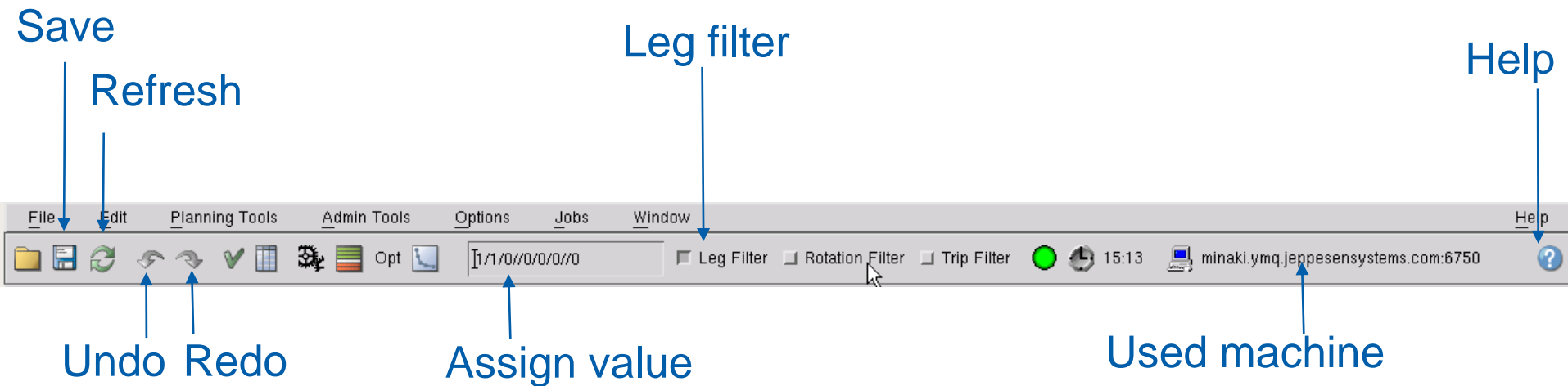
**Window**

Number of windows and their contents

**Help**

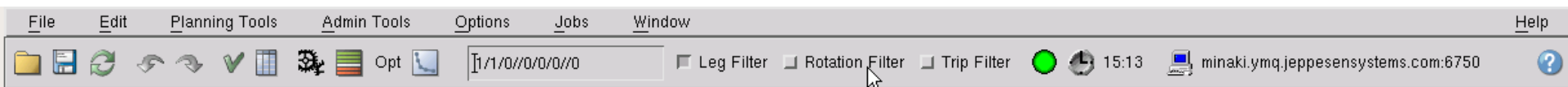
Help etc.

# Toolbar



The other toolbar buttons are described in detail soon.

# Toolbar – Plan Manager



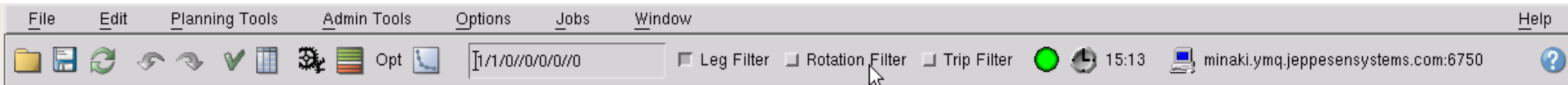
Plan Manager

PairingI/SK STD Ex\_1\_test\_run Standard Solution\_5 is best

Timetables	Versions	Local Plans	Sub-plans	Solutions
PairingI	MX SK	DATED_735_dec99 DATED_dec99 STD	Ex_1 Ex_1_b ? Ex_1_test_run	best_solution input Solution_7 Solution_6 Solution_5 Solution_4 Solution_3 Solution_2 Solution_1

Close Open Plan Access Unlock Delete Copy Select Deselect Keep Best Solutions View Opt. Report Properties

# Toolbar – Rule Parameters



**Rule Parameters**

Basic Settings AC Rotations Build Basic Rules FAR Rules EU Rules CAP Rules CAAC Rules DGCA Rules Augmentation Retiming

**Briefing / Debriefing**

(STD 3.1) Briefing time before duty starting with active leg..... 1:00

(STD 3.2) Briefing time before duty starting with deadhead..... 0:30

(STD 3.3) Debriefing time after duty ending with active leg..... 0:30

(STD 3.4) Debriefing time after duty ending with deadhead..... 0:15

(STD 3.6) Briefing time override table..... SpLocal/briefing\_override.etab

(STD 3.7) Debriefing time override table..... SpLocal/debriefing\_override.etab

(Studio 1.2) Show markers for briefing and debriefing time..... ☒ True

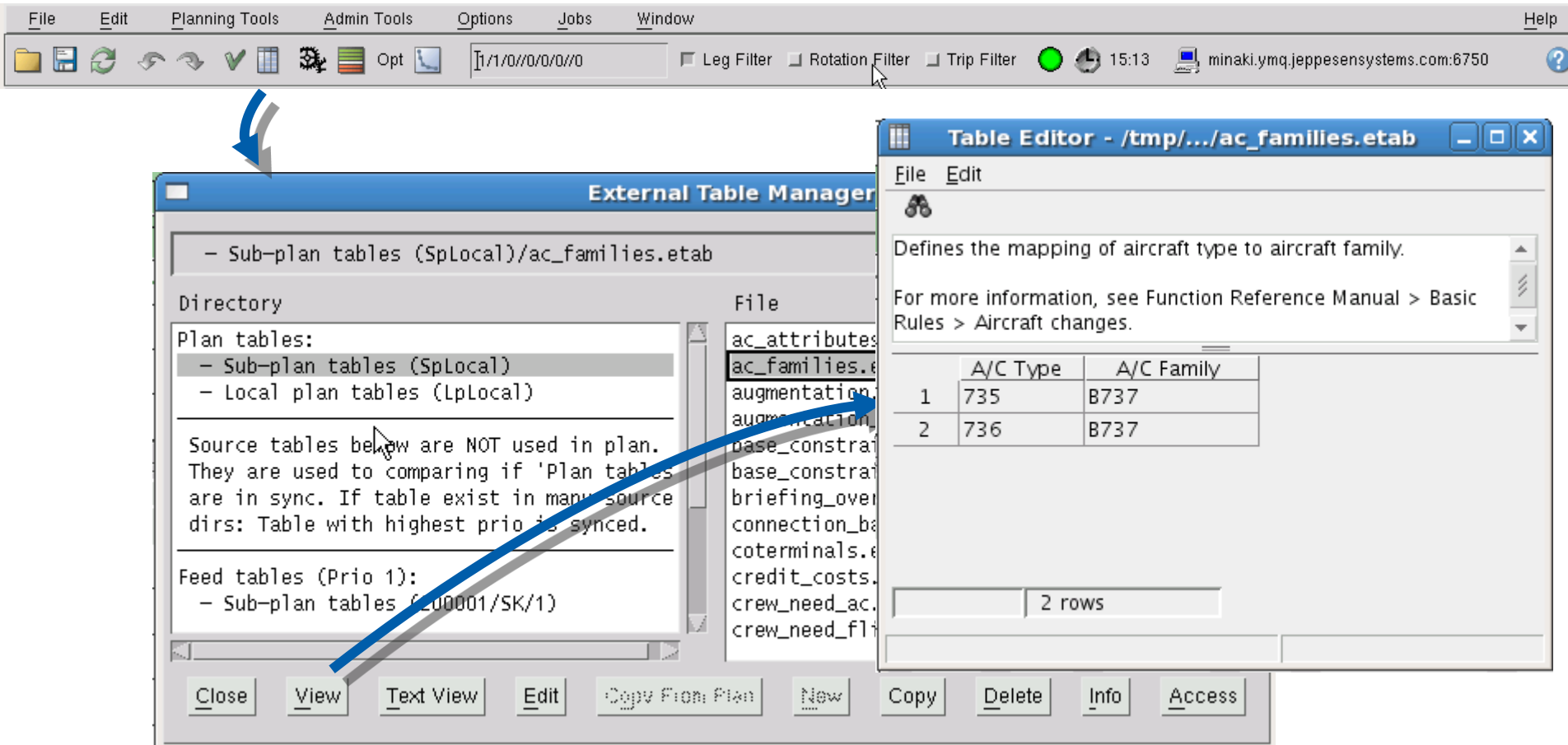
**Early start / Late end**

(STD 4.1) Early duty period start..... 4:00

(STD 4.2) Early duty period end..... 7:00

OK Cancel Load from File Load from Sub-plan Save to File... Reset Print Default diff Search Help

# Toolbar – External Table Manager



The screenshot shows the 'External Table Manager' window with the following content:

Sub-plan tables (SpLocal)/ac\_families.etab

Directory

- Plan tables:
  - Sub-plan tables (SpLocal)
  - Local plan tables (LpLocal)

Source tables below are NOT used in plan. They are used to comparing if 'Plan tables' are in sync. If table exist in many source dirs: Table with highest prio is synced.

Feed tables (Prio 1):

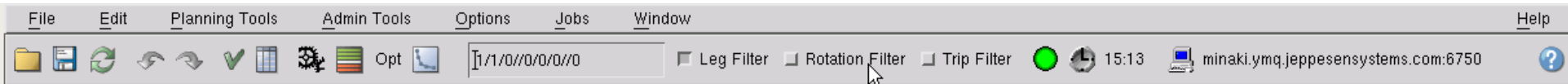
- Sub-plan tables (200001/SK/1)

The 'Table Editor - /tmp/.../ac\_families.etab' window shows the following table:

	A/C Type	A/C Family
1	735	B737
2	736	B737

The toolbar at the bottom of the External Table Manager window includes: Close, View, Text View, Edit, Copy From Plan, New, Copy, Delete, Info, Access.

# Toolbar – Start Optimization Job



**Start Optimization Job**

Job Parameters

Sub-plan name:

Sub-plan comment:

Input legs/rotations:

Reference rotations:

Restart: ☐ No

Optimizer:

Slots:

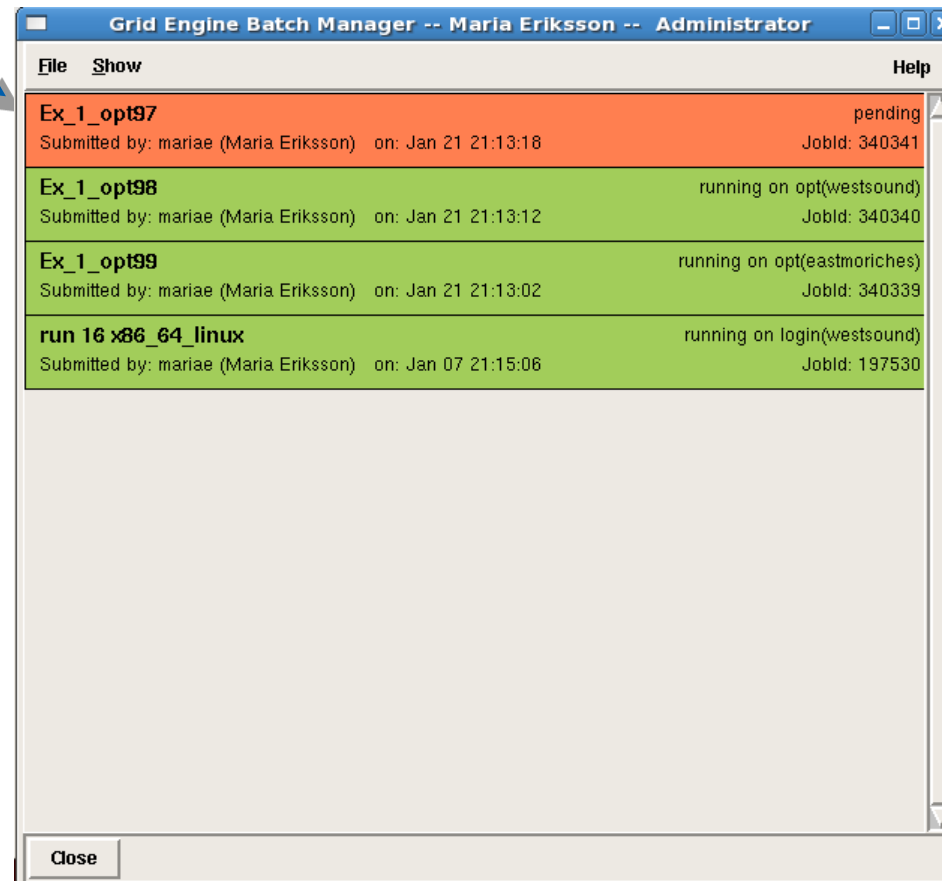
Batch Options:

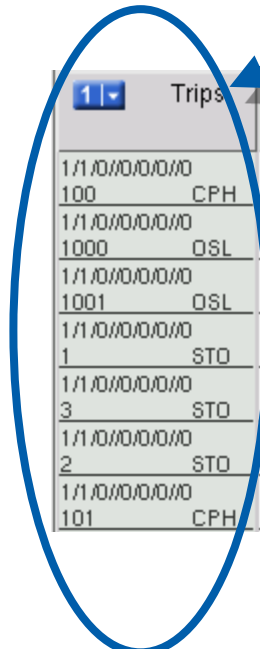
Helper Jobs:

Helper Options:



# Toolbar – Batch Job Manager

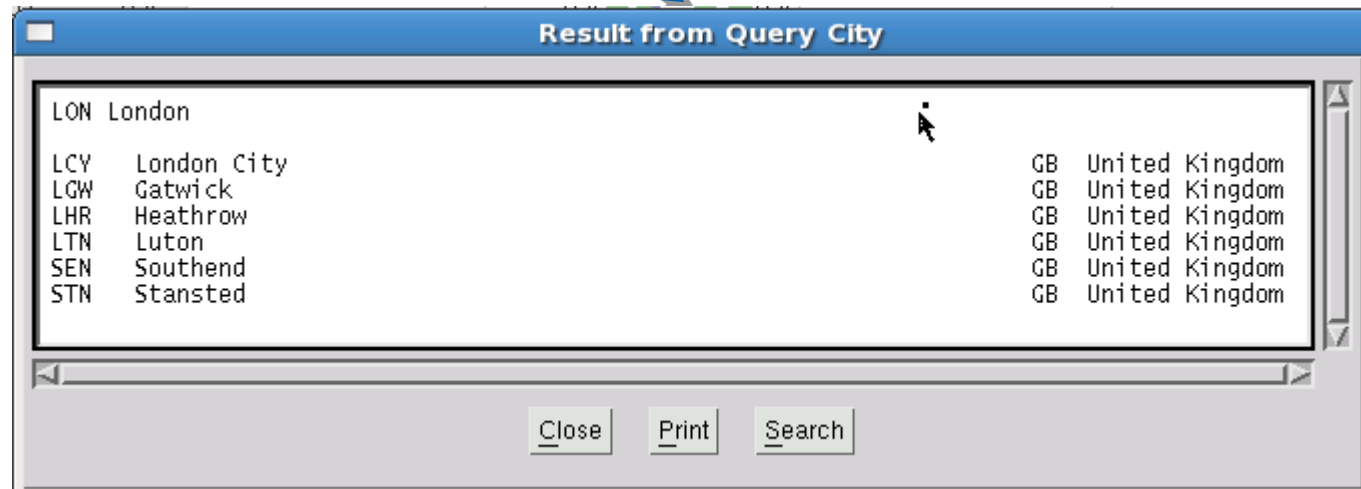


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# Airport Manager

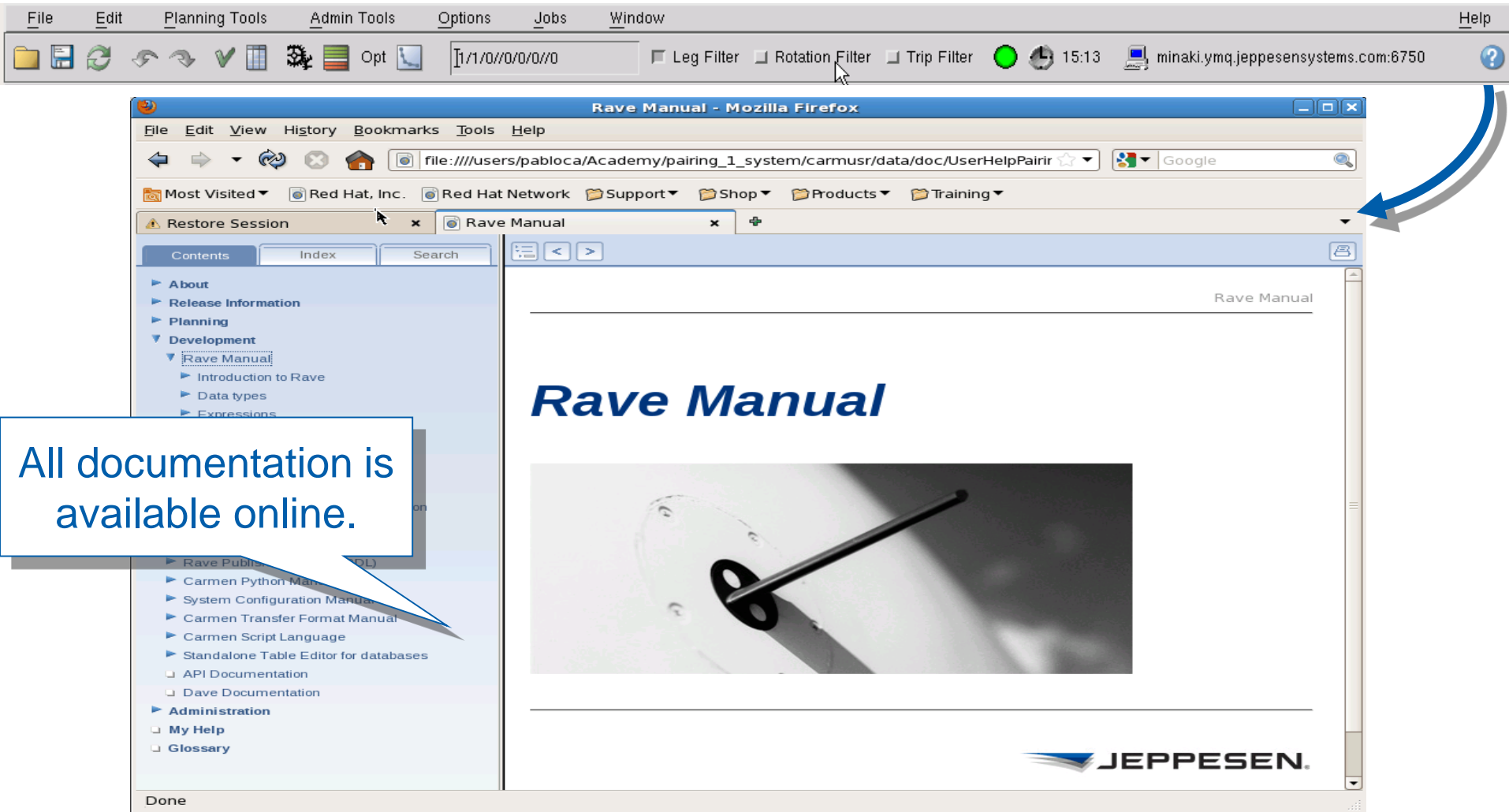


Airport Manager holds information on airports (time zone, daylight savings time rules etc.)



LON	London		
LCY	London City	GB	United Kingdom
LGW	Gatwick	GB	United Kingdom
LHR	Heathrow	GB	United Kingdom
LTN	Luton	GB	United Kingdom
SEN	Southend	GB	United Kingdom
STN	Stansted	GB	United Kingdom

# Help



The screenshot shows a software application window with a menu bar (File, Edit, Planning Tools, Admin Tools, Options, Jobs, Window, Help) and a toolbar. Below the toolbar is a status bar with various filters (Leg Filter, Rotation Filter, Trip Filter) and a clock showing 15:13. A Mozilla Firefox window is open, displaying the 'Rave Manual'. The browser's address bar shows a file path: `file:///users/pabloca/Academy/pairing_1_system/carmusr/data/doc/UserHelpPairir`. The browser's search bar contains 'Google'. The browser's tabs show 'Restore Session' and 'Rave Manual'. The browser's content area displays the 'Rave Manual' title and a large image of a mechanical part. A callout box with the text 'All documentation is available online.' points to the 'Rave Manual' content area.

File Edit View History Bookmarks Tools Help

file:///users/pabloca/Academy/pairing\_1\_system/carmusr/data/doc/UserHelpPairir

Google

Most Visited Red Hat, Inc. Red Hat Network Support Shop Products Training

Restore Session x Rave Manual x

Contents Index Search

- About
- Release Information
- Planning
- Development
  - Rave Manual
    - Introduction to Rave
    - Data types
    - Expressions

Rave Manual

**Rave Manual**

JEPPesen.

Done

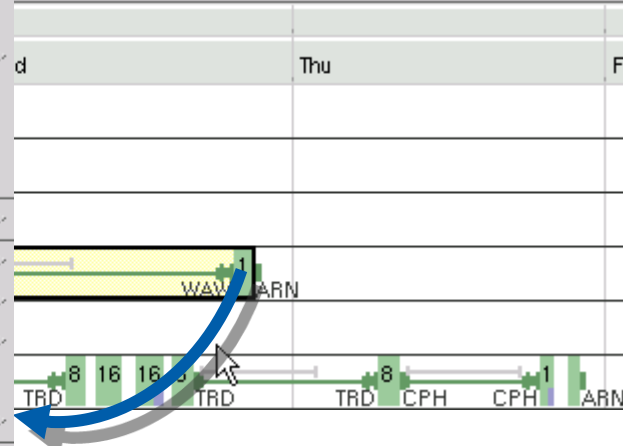
All documentation is available online.



# Object pop-up

Trips		Mon	Tue	Wed	Thu	Fri
1/1/0/0/0/0/0	CPH	CPH	15	15		1
1/1/0/0/0/0/0	OSL	OSL				
1/1/0/0/0/0/0	OSL	OSL				
1/1/0/0/0/0/0	STO	ARN	25	25	15	
1/1/0/0/0/0/0	STO	ARN	1	1	1	4
1/1/0/0/0/0/0	STO	ARN	58	59		

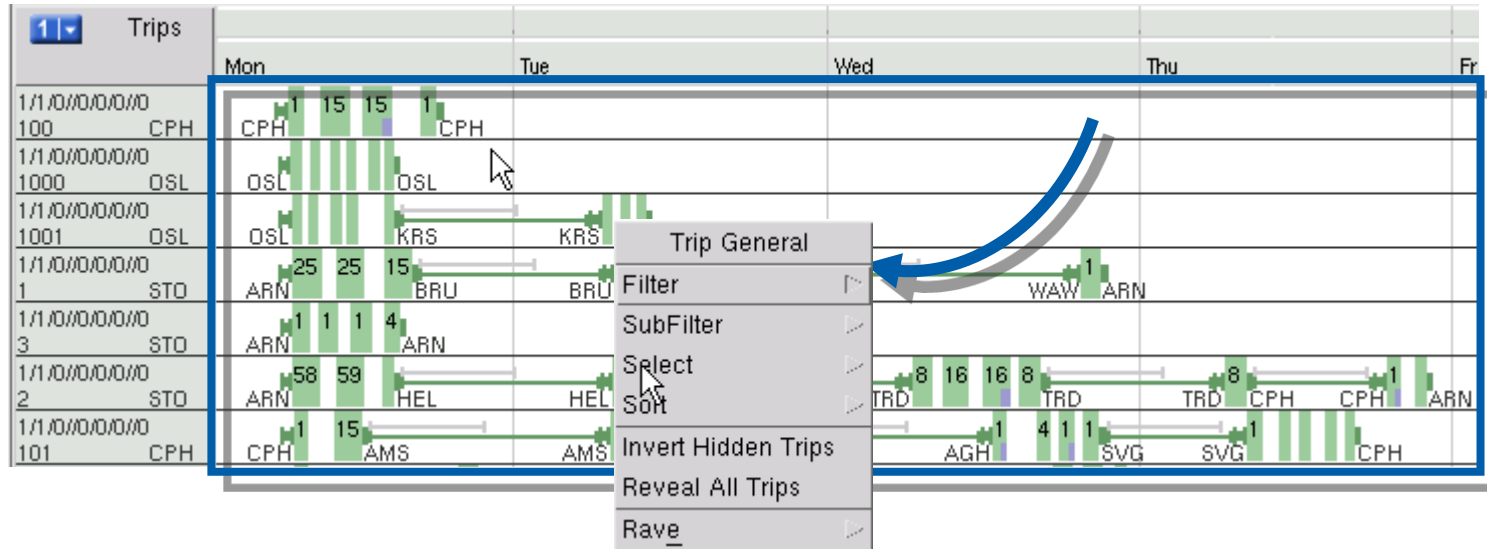
Trip Object

- Move
- Split
- Build Trip...
- Swap Trailing Legs
- Hide
- Tags
- Get Next
- Get Previous
- Copy
- Merge Identical
- Delete
- Check Legality...
- Generate Report...
- Set Names...
- Optional Variants
- Daily
- Leg
- Hard Locks
- Remove Change Indicators
- Find Change Possibilities
- Retime
- Reference Plans
- Rave
- Properties...
- TOR



# General pop-up



# Cancel command

1   Trips	Mon	Tue	Wed	Thu	Fr
1/1/0/0/0/0/0 100 CPH	CPH 1 15 15 1 CPH				
1/1/0/0/0/0/0 1000 OSL	OSL OSL OSL OSL OSL				
1/1/0/0/0/0/0 1001 OSL	OSL KRS	KRS OSL			
1/1/0/0/0/0/0 1 STO	ARN 25 25 15 BRU	BRU 2 CPH CPH 7 WAW	WAW 1 ARN		
1/1/0/0/0/0/0 3 STO	ARN 1 1 1 4 ARN				
1/1/0/0/0/0/0 2 STO	ARN 58 59 HEL	HEL 71 7 7 8 TRD	TRD 8 16 16 8 TRD	TRD 8 CPH CPH 1 ARN	
1/1/0/0/0/0/0 101 CPH	CPH 1 15 AMS	AMS 15 ARN ARN AGH	AGH 1 4 1 1 SVG	SVG 1 CPH CPH CPH	



# Manual planning

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- Filter
- SubFilter
- Select
- Sort
- Drag and drop
- Get Next/Get Previous
- Run reports
- ...



# Sorting

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Objects in the working windows may be sorted according to any sorting criteria.

For trips:

- departure time
- arrival time
- departure airport
- arrival airport
- crew complement
- ...

# Filter – form

**Trip Filter**

Time Base: LDOP Filter Principle: ANY Select: NONE  
 Reference Airport: LHR Filter Method: REPLACE

**Leg Values**

Flight

Airline Designator: SK **SK flights**

Flight Number: \*

Flight Suffix: \*

Leg Number: \*

Service Type: \*

Traffic Days: \*

**Other Properties**

Chain User Tags: \*

Tags: \*

Ground Duty: \*

Deadhead: \*

**Departure**

Airport: FRA **From FRA**

City: \*

Date: \*

Time: >10:00 **After 10:00 am**

**Arrival**

Airport: \*

City: \*

Date: \*

Time: \*

**Touched**

Airport: \*

City: \*

Date: \*

Time: \*

**Aircraft**

IATA Aircraft Type: \*

Custom Aircraft Type: \*

**Duty Values**

Basic

Number of:

Aircraft Changes: \*

On Duty Legs: \*

Legs: \*

**Departure**

Airport: \*

City: \*

Date: \*

Time: \*

Traffic Days: \*

**Arrival**

Airport: \*

City: \*

Date: \*

Time: \*

Traffic Days: \*

**Trip Values**

Basic

Home Base: STO **STO trips**

Trip Name: \*

Legal Trips: \*

Plausible Trips: \*

Block Time: \*

Area Trip: \*

**Number of**

Aircraft Changes: \*

Aircraft Types: \*

On Duty Legs: \*

Legs: \*

Duty Days: \*

Duties: \*

**Departure**

Airport: \*

City: \*

Date: \*

Time: \*

Traffic Days: \*

**Arrival**

Airport: \*

City: \*

Date: >=10Jan2000 **Not before 10JAN**

Time: \*

Traffic Days: \*

OK Cancel Reset Default Print

# Filter – form - expressions

Different expressions can be used in the filter form:

- <, <=, >, >=
- / interval (e.g. 1Jan2008/31Jan2008)
- ! not
- \* replacing several characters
- ? replacing one character

For more information, see Help

# Filter – fast

Commonly used filter criteria should be included as fast filters in menus.

Trip General	
Filter	by...
SubFilter	Optimizer input
Select	NOP Leg
Soft	Overbooked
Invert Hidden Trips	Selected Trips
Reveal All Trips	Selected Legs
Rave	Trips not selected
	Tagged
	Starts in PP
	Starts Before PP End (Excl Pre-Booked)
	Pre-Booked
	Trips Using Default Hotel
	Trips Has Split-Duty Rest
	Crew Complement
	Trips with Low Alertness
	Trips with Retiming Alternatives
	Repeat Last

# Select-and-operate

## Select

**Rubber-banding possible  
when start beside object**

- Left mouse button **ON ANY LEG**
  - Use Ctrl to extend the selection (or to deselect)
  - Double-click to select leg **ON LEG**

## Pop-up menus

- Right mouse button
  - On leg: Object menu ← **Only operates on selected objects**
  - Beside legs: General menu

## Drag-and-drop

- Between and inside windows
  - Drag with left mouse button
  - (Drag with right mouse button if want to use menu)

# Select-and-operate – Left Margin

## Select rows

Not supported in Leg Set and Leg window

Rubber-banding not possible

- Left mouse button
  - Use Ctrl or Shift to extend the selection

## Drag-and-drop (same result left and right mouse button)

- Within a window -> “sort”
- To another window:
  - drag -> “move”
  - Ctrl + drag -> “copy”

# Select-and-operate – Useful keys

## Delete



Trip, Duty: delete to single legs

Legs: delete from sub-plan

Object pop-up menu

General pop-up menu

Ctrl-A

Select all legs in current main window

Ctrl-M

Select with form

Ctrl-Z

Undo

40



# Exercise 1

---

## Basic functionality

### Purpose

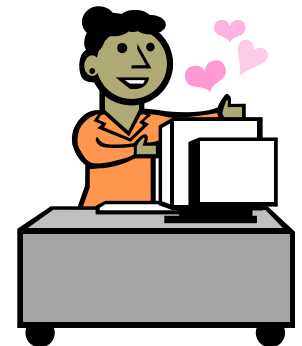
- Get familiar with working screen and menus
- Learn to use manual planning tools and reports



# Exercise 1 – summary

---

## Summary of exercise 1



# Planning concepts – local plan

## Contains

- all the timetable data: Leg Sets
- the aircraft rotations (turns): Rotations

Many sub-plans can use the same local plan

Leg Set = a set of legs that are equal except for operation date

Rotation = a chain of legs associated with an aircraft

# Planning concept – sub-plan

- Contains all the legs (references) you want to plan right now
- Is a sub-selection of the local plan (sub-problem)
- Contains these planning objects: legs, duties, trips

A sub-plan contains one planning problem.

Flight Deck: one sub-plan per fleet

Cabin: typically one sub-plan for international operations and one for domestic operations

A sub-plan can be a scenario of any of the planning problems

# Planning concept – rule set

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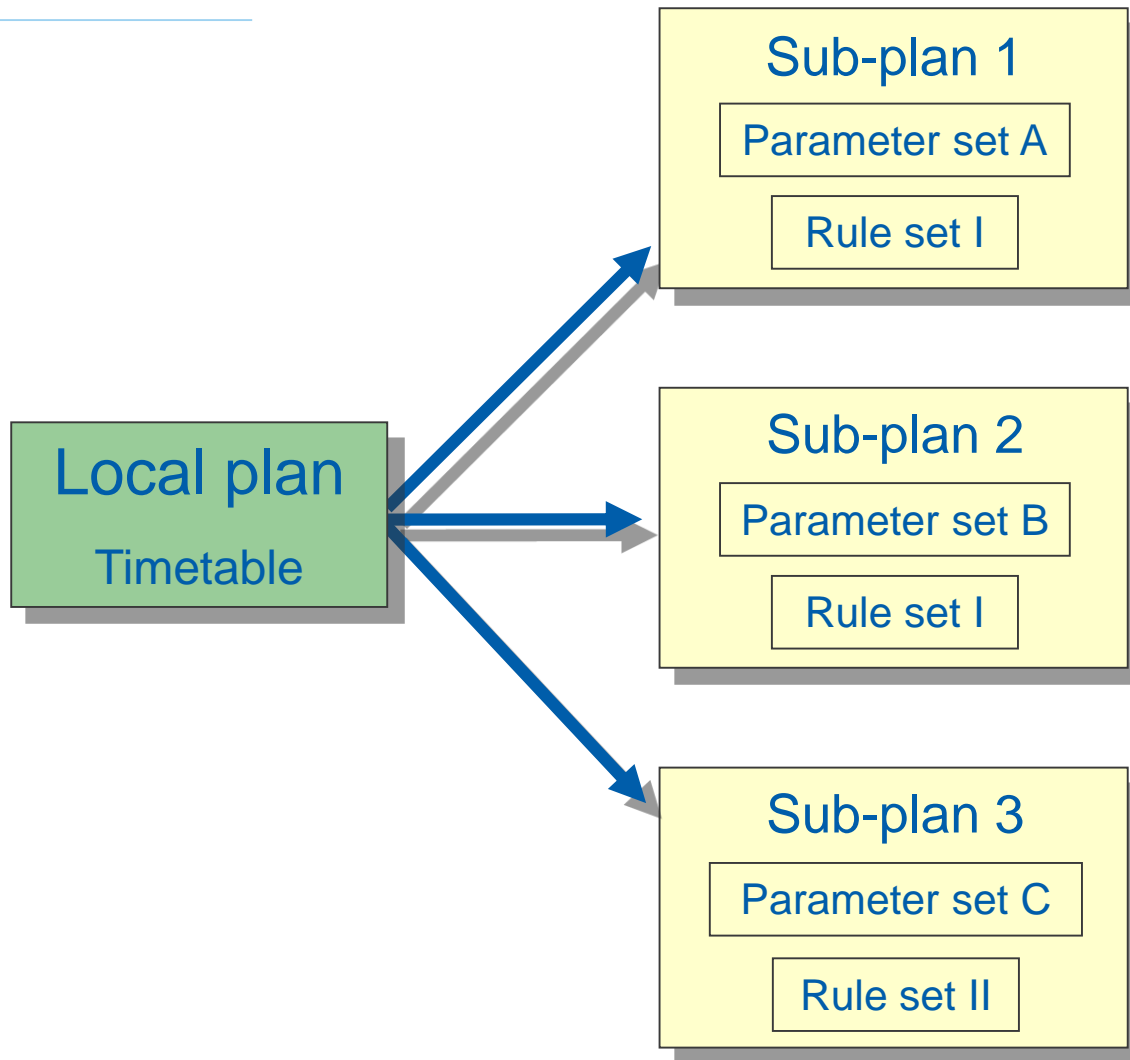
- Rave is a programming language
- Must be compiled for the system to understand
- A rule set is a compiled file with Rave definitions
- Includes rules, parameters, costs, crew need etc.
- Rule sets for long-/short haul, flight deck/cabin etc.

# Planning concept – parameter set

---

- A text file where good parameter settings are saved
- Rules can be turned on and off
- Cost values (parameters) can be changed
- The behaviour of the optimizer can be controlled
- Often loaded in the start of the planning process
- Often there are ‘monthly’ parameters that need to be changed manually

# Plan structure



# Planning concept – crew categories

A flight needs crew carrying out various tasks. Therefore, crew is divided into **crew categories**.

Crew categories differ between airlines. A typical example is:

**Flight Deck crew:** Captain / First Officer / Second Officer

**Cabin crew:** Purser / Assistant purser / Cabin attendant



# Planning concept – crew need

Each flight activity has a crew need, describing the required amount of crew in different crew categories.

Example (varies between airlines)

A leg has crew need:

1 / 1 / 0 // 1 / 1 / 3  
└──────────┘ └──────────┘  
Flight Deck crew   Cabin crew

This leg is covered by:

1 captain/1 first officer/0 second officer//

1 purser/1 assistant purser/3 cabin attendants

# Planning concept – crew need

The crew need (1/1/0) can be covered by several trips:

Captain 1/0/0:



First Officer 0/1/0:



# Planning concept – crew complement

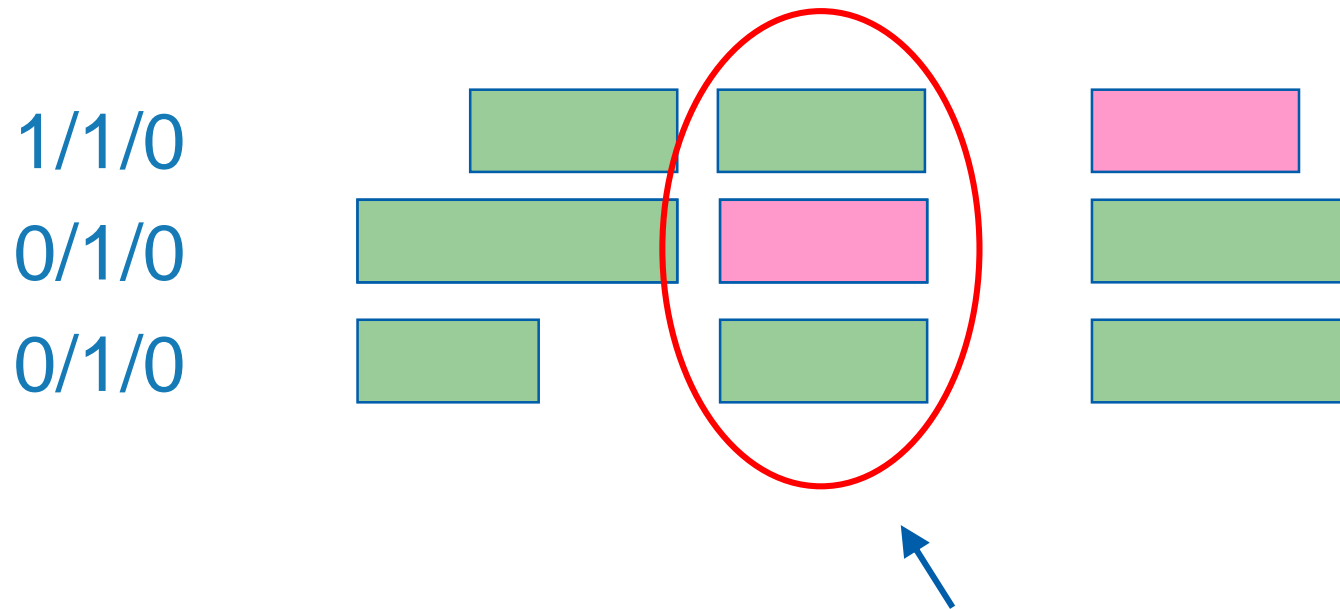
**Need (leg)** – the total number of crew required on the leg  
Example: 1/1/0//1/1/3

**Booked (leg)** – the sum of the crew complements for trips containing the leg (as on duty).  
Example: 0/0/0//0/0/3

**Crew complement (trip)** – the number of crew the trip is constructed for  
Example: 0/0/0//1/1/2

# Planning concept – booked value

The leg **booked** value, is the sum of all crew complement values for all trips the leg is part of:

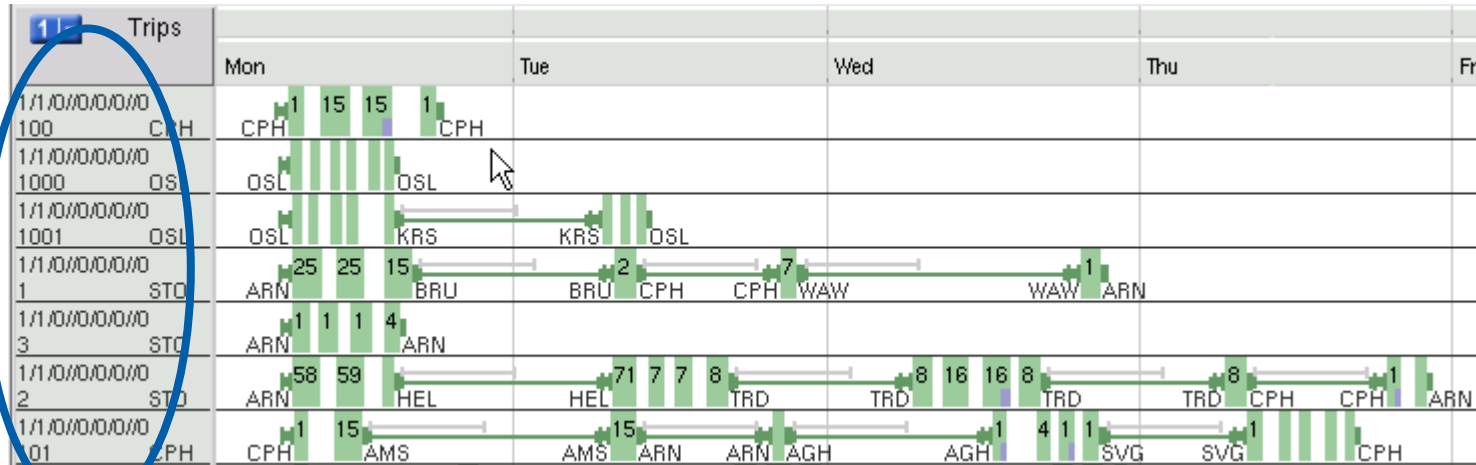


$$1/1/0 + \text{DH} + 0/1/0 = 1/2/0$$

# Planning concept – remaining need

2   ▾ Legs	Mon	Tue	Wed	Thu
1 1 1/1/0/0/0/0/0/0	ARN RIX			
1 1 1/1/0/0/0/0/0/0	RIX ARN			
1 1 1/1/0/0/0/0/0/0	ARN HEL			
1 1 1/1/0/0/0/0/0/0	HEL ARN			
1 1 1/1/0/0/0/0/0/0	ARN CPH			
1 1 1/1/0/0/0/0/0/0	CPH TRD			
1 2 1/1/0/0/0/0/0/0		TRD CPH		
1 2 1/1/0/0/0/0/0/0		CPH SVG		

# Planning concept – Crew Complement



# Exercise 2

---

## Crew complement

### Purpose

To understand how the crew complement works



# Exercise 2 – summary

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## Summary of exercise 2





# Looking back

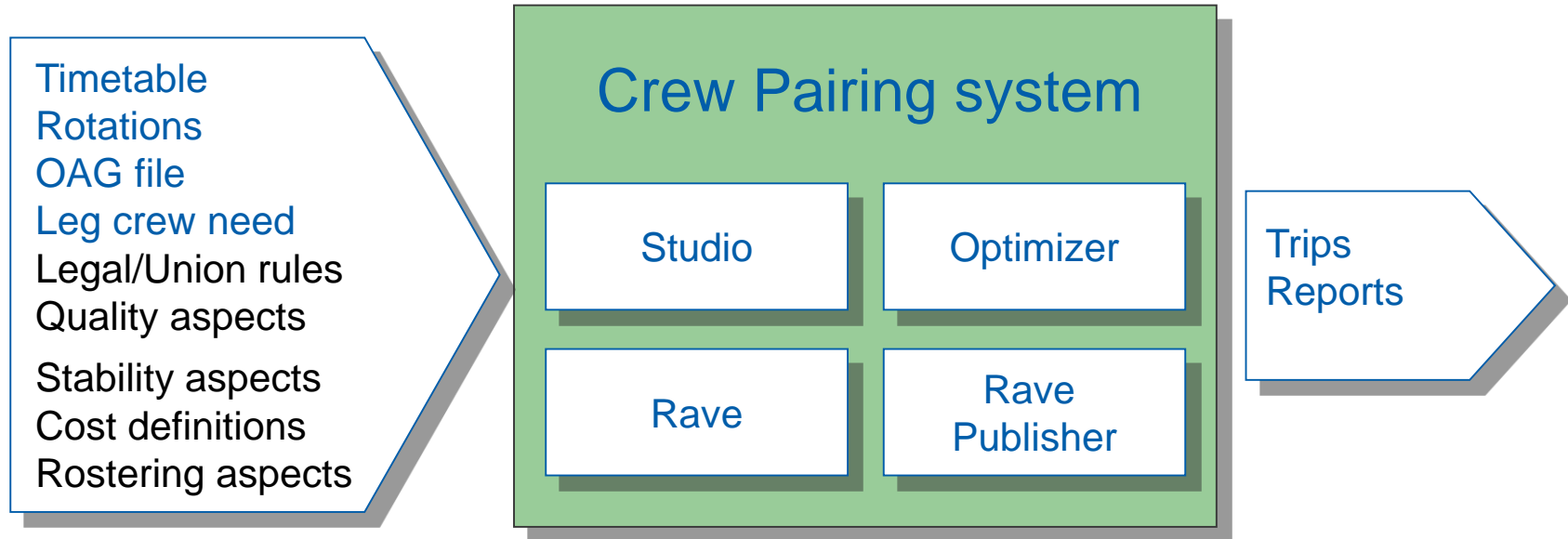
---

- The modules of the Jeppesen system
- The user interface of the Jeppesen system:
  - menus
  - filtering
  - selecting
  - reporting
- Planning concepts

# Looking ahead

- Input to the Crew Pairing problem
- Create a standard solution:
  1. Create a standard local plan
  2. Build rotations
  3. Load rules and parameters
  4. Create a sub-plan by adding legs
  5. Create trips:
    - manually in Studio
    - automatically with the optimizer
  6. Verify the solution

# Input and output



# Input – timetable

Timetables contain information on all own carrier flights in a given time period. Timetables are provided in SSIM\* format

```
3 SK 23820801J01NOV9900XXX00123456 KRS09300930+0100 OSL10151015+0100 735CSMBGHVTLK XX DD
M 00388406
```

```
3 SK 23830801J18MAY9906AUG99123456 OSL10051005+0200 KRS10551055+0200 735CSMBGHVTLK XX DD
M 00388430
```

```
3 SK 23830901J09AUG9930OCT99123456 OSL10051005+0200 KRS10551055+0200 735CSMBGHVTLK XX DD
M 00388433
```

```
3 SK 23840801J18APR9924OCT99          7 KRS11301130+0200 OSL12151215+0200 735CSMBGHVTLK XX DD
M 00388460
```

```
3 SK 23840901J18MAY9906AUG99123456 KRS11301130+0200 OSL12151215+0200 735CSMBGHVTLK XX DD
M 00388463
```

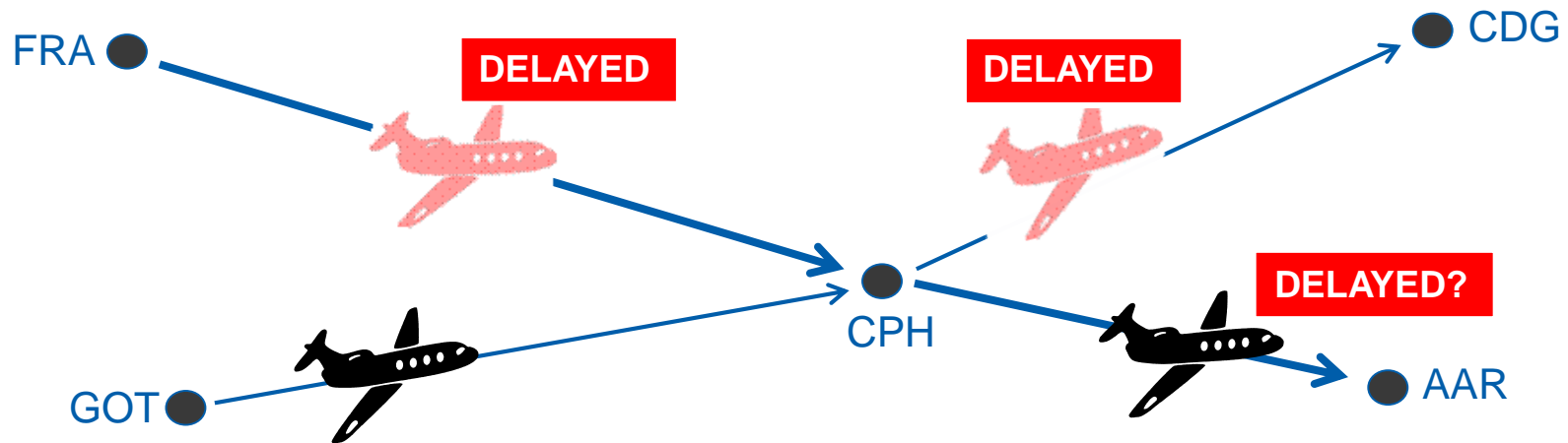
```
3 SK 23841001J09AUG9930OCT99123456 KRS11301130+0200 OSL12151215+0200 735CSMBGHVTLK XX DD
M 00388466
```

```
3 SK 23850101J25MAR9926MAR9912345 OSL14051405+0100 KRS14551455+0100 735CSMBGHVTLK XX DD
M 00388472
```

\*SSIM = Standard Schedules Information Manual

# Input – rotations

In short-haul and medium-haul, you wish to avoid too many aircraft changes in trips. Every aircraft change potentially transfers delays to other flights.



Rotations may be defined in the SSIM file, delivered in a separate file or built heuristically by the system (we can guess) if not known at the time of planning.

# Input – OAG file

---

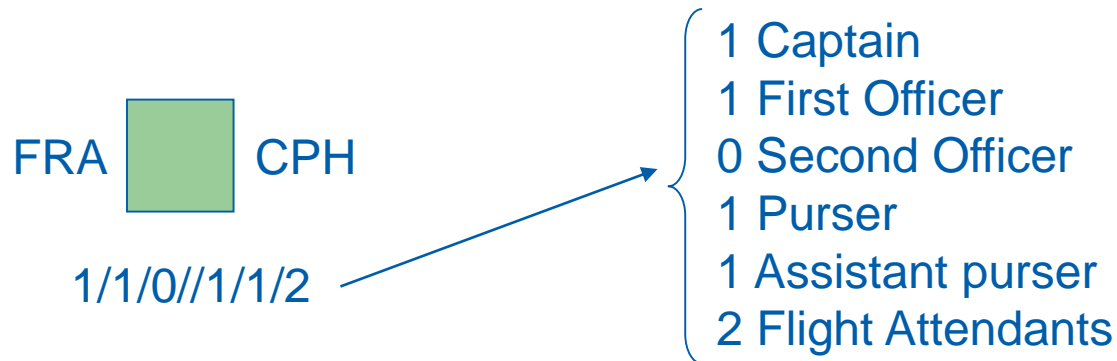
If deadheading with other carriers is needed, timetable information for these carriers is normally provided in an OAG file.

OAG files are provided in SSIM format.

\* OAG = Official Airline Guide

# Input – crew need

For every flight leg, a crew need must be defined. The crew need describes how many crew members of each crew category the leg requires.



The crew need is defined in the rule set. The crew need may be fixed or dependent on the duty in which it occurs (augmented crew)

# Input – legal and union rules

---

Legal and union rules are fixed by law or agreed with the union. They typically limit duty time, ensure minimum rest between duties etc.

## Examples:

- duty time must not exceed 12:00 hours
- block time in duty must not exceed 10:00 hours

Legal and union rules are implemented in Rave and can be turned on/off by the planner.



# Input – quality and stability aspects

Quality and stability aspects aim at increasing solution stability or crew quality of life.

Examples:

- more than one aircraft change per duty should be avoided
- more than two early consecutive departures should be avoided

Quality and stability aspects are implemented in Rave as rules or penalties or both.

(the planner can turn them on/off or change their value)

# Input – cost definitions

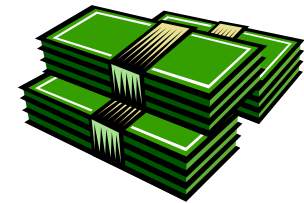
Includes real costs and penalties (quality/stability aspects).

## **Real costs** include:

duty-day costs, hotel costs, per diem, deadhead costs, overtime costs etc.

## **Penalties** include:

short connection penalty, excessive aircraft change penalty etc.



Costs and penalties are implemented in Rave and their value can be modified by the planner.

# Input – rostering aspects

---

The created trips must be possible to use for rostering.



Examples of demands to consider:

- the number of available crew members per base
- the qualifications of the crew members (per base)
- not too many long trips

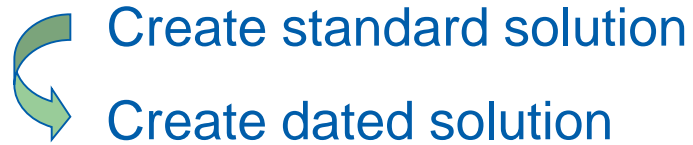
Rostering aspects are normally implemented as vertical rules (global constraints) in Rave.

# Output – trips

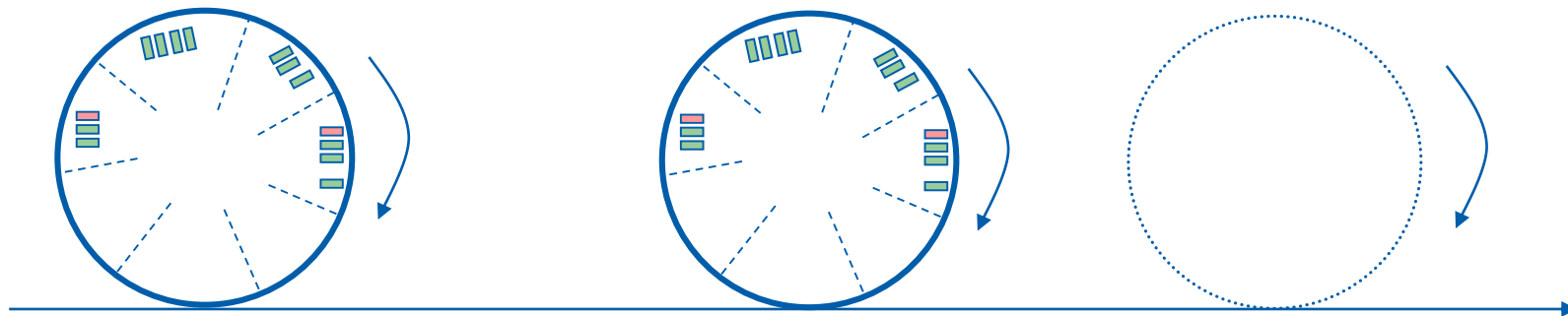
According to the steps in the planning process, trips are:

- 
- Daily** (all trips begin in one day)
- 
- Weekly** (all trips begin in one week)
- Dated** (all trips begin within a given time span,  
for example a month)

# Planning process



Standard week

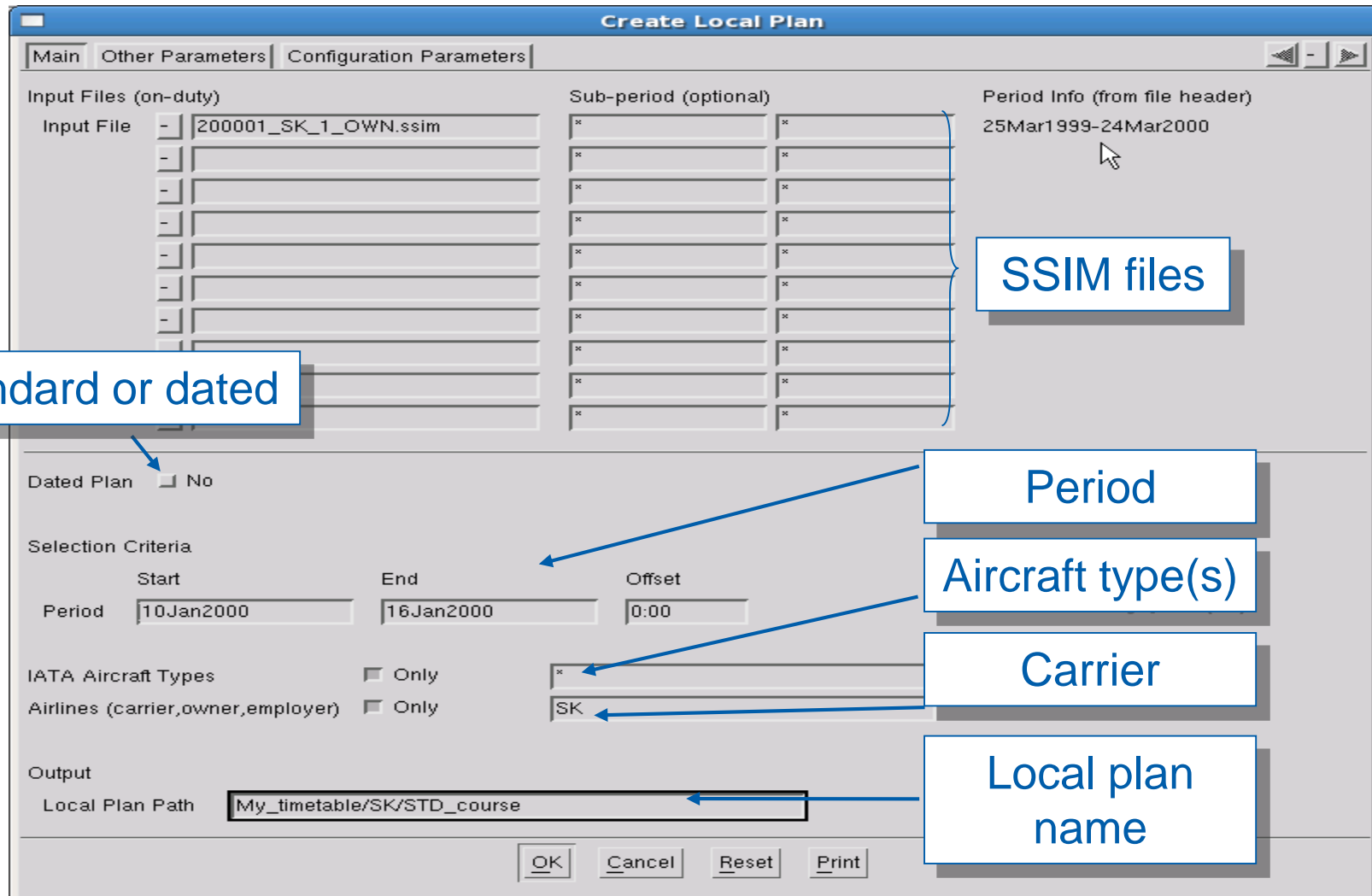


# Create a standard solution

- Create standard local plan (from SSIM file)
- Build rotations
- Load rules and parameters
- Create sub-plan by adding legs
- Prepare Optimization job  
(set parameters/apply hard locks)
- Run the Crew Pairing optimizer
- Verify solution

Create a standard solution

# Create a standard local plan



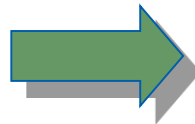
The screenshot shows the 'Create Local Plan' dialog box with the following fields and annotations:

- Input Files (on-duty):** A table with columns for 'Input File' and 'Sub-period (optional)'. The first row contains '200001\_SK\_1\_OWN.ssim'. A blue bracket on the right side of the table is labeled 'SSIM files'.
- Period Info (from file header):** Displays '25Mar1999-24Mar2000'.
- Dated Plan:** A checkbox labeled 'No'.
- Selection Criteria:**
  - Start:** '10Jan2000' (labeled 'Period' with an arrow).
  - End:** '16Jan2000' (labeled 'Aircraft type(s)' with an arrow).
  - Offset:** '0:00'.
  - IATA Aircraft Types:** A checkbox labeled 'Only'.
  - Airlines (carrier,owner,employer):** A checkbox labeled 'Only'.
  - Carrier:** A text field containing 'SK' (labeled 'Carrier' with an arrow).
- Output:**
  - Local Plan Path:** A text field containing 'My\_timetable/SK/STD\_course' (labeled 'Local plan name' with an arrow).
- Buttons:** 'OK', 'Cancel', 'Reset', and 'Print' at the bottom.

# Create a standard solution

## Build rotations

2 Rotations		Mon	Tue
1	735	OSD ARN	
1	736	TRD CPH	
1	736	CPH ARN	
1	736	WAW CPH	
1	735	KRS OSL	
1	735	OSL AES	



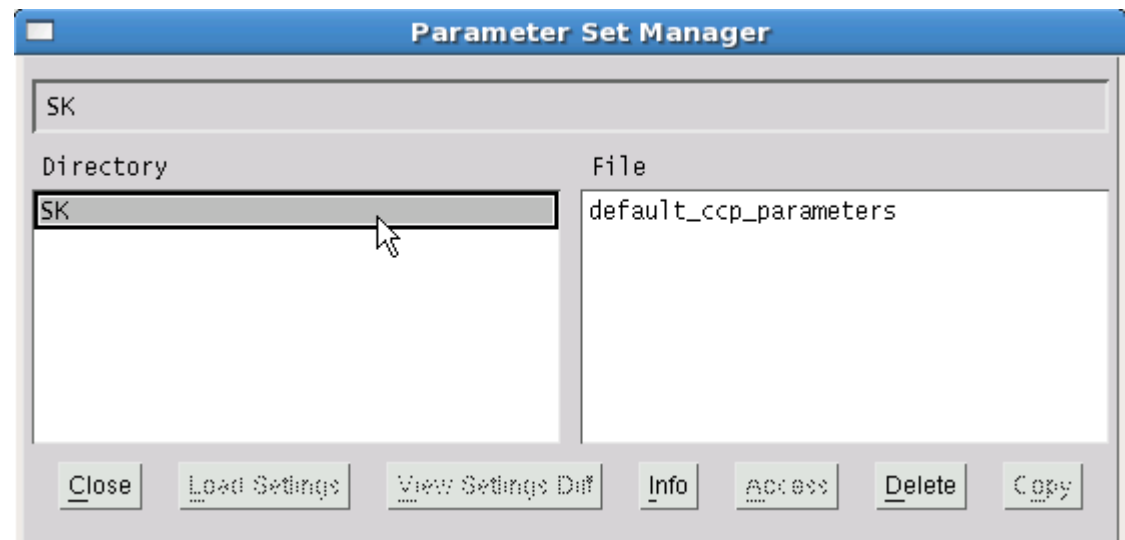
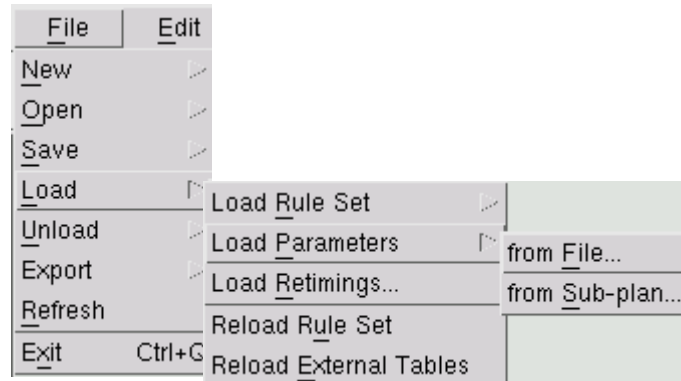
Planning Tools	Admin
Plan Manager...	
Scenario Analyzer...	
Local Plan	Add Legs to Sub-plan...
Sub-plan	Dissolve Rotations
Rule Parameters...	Build Rotations
External Table Manager...	Recalculate Crew Need
TOR Table Manager...	Merge...
Airport Manager...	Properties...
Saved Reports Manager...	Set Planning Problem...
Generate Report...	
Process Automation	

2 Rotations		Mon	Tue
1	735	OSD 1 OSD	
1	736	TRD 8 1 1 6 STR	
1	736	WAW 7 6 6 6 MUC	
1	736	CPH 1 15 15 1 7 WAW	
1	735	KRS	OSL
1	736	CDG 58 57 57 57 CDG	



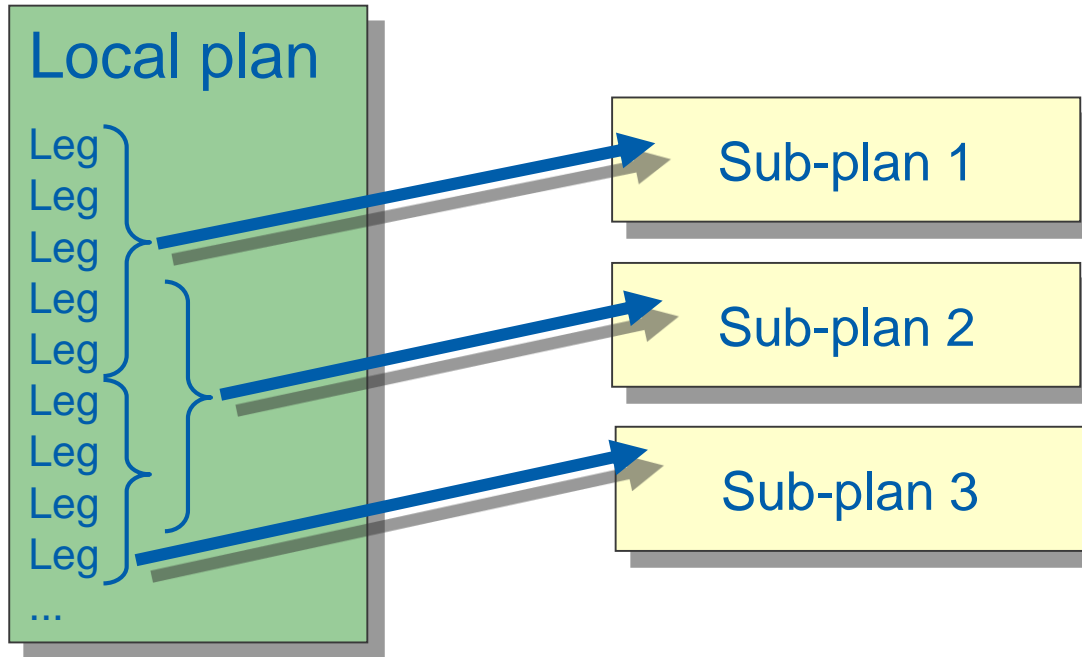
Create a standard solution

# Load parameters



Create a standard solution

## Add legs from local plan



- Legs are added from local plan
- One leg can be part of several sub-plans
- Content of sub-plan reflects the planning problem

# Create a standard solution

## Create sub-plan

Sub-plan name

Default assign value

Mask value

**Sub-plan Properties**

Identification

Sub-plan name:

Sub-plan comment:

Airline:

Planner:

Periods

Period 1 from:  to:

Period 2 from:  to:

Period 3 from:  to:

Area:

Crew Complement

Assign value:

Mask value:

Crew Filters

Leg Filter: ☐ On

Rotation Filter: ☐ Off

Trip Filter: ☐ Off

Save on file: ☒ On

Base files to initiate from

Base definitions file:

Base constraints file:

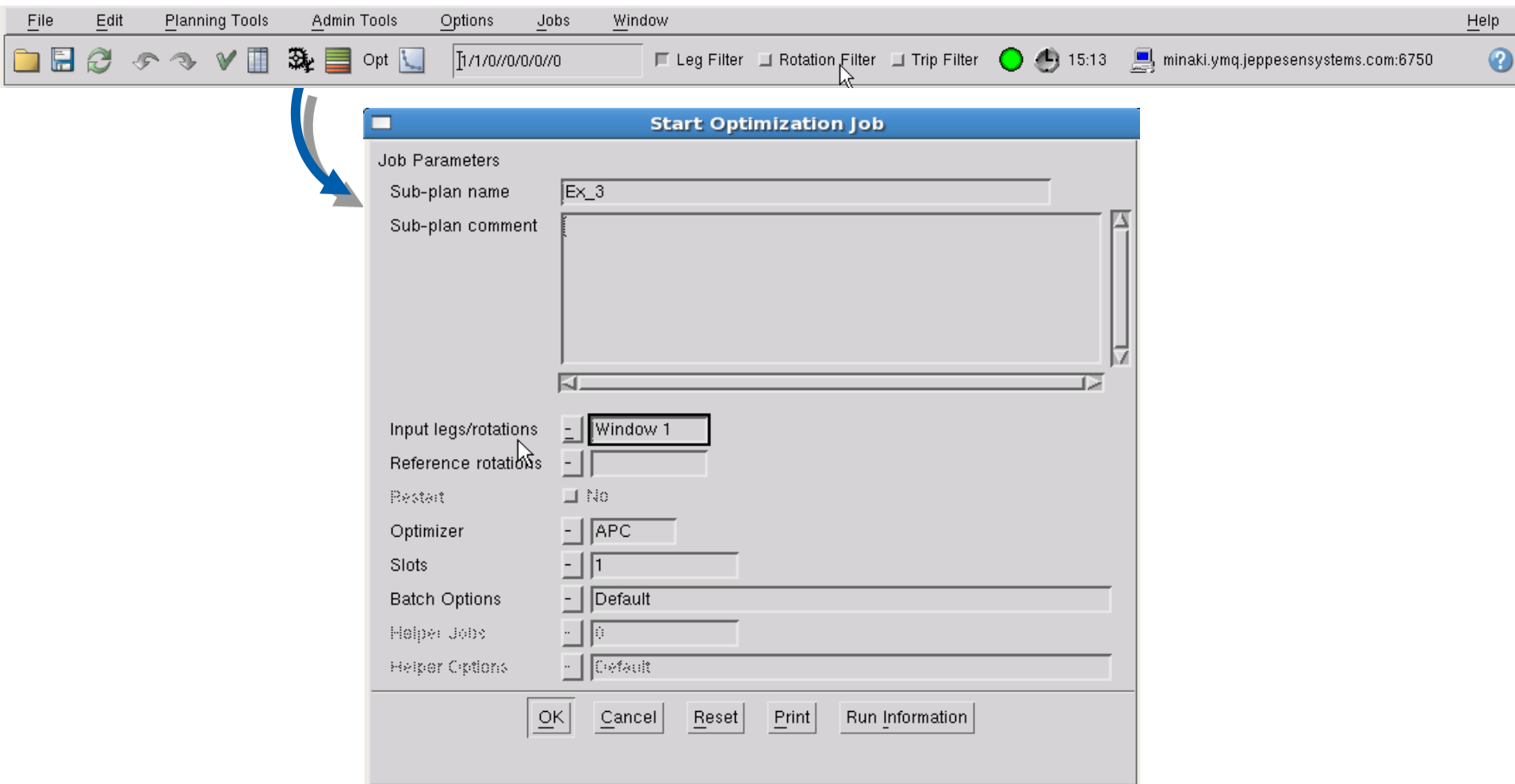
Create a standard solution

## Using the optimizer

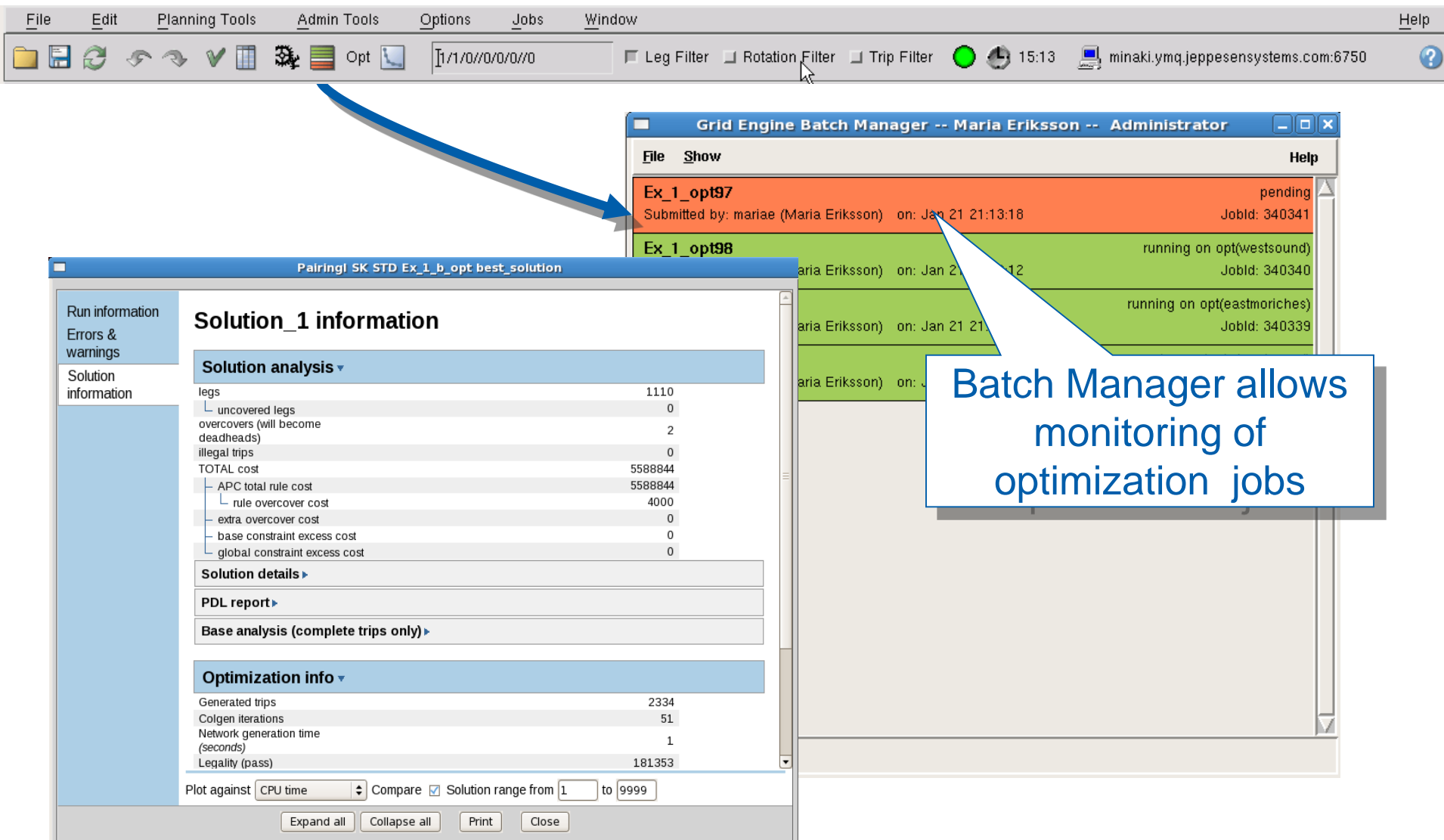
1. Start a job.
2. Monitor progress with
  - Batch Job Manager
  - Plan Manager.

# Create a standard solution

## Using the optimizer



# Create a standard solution Using the optimizer



The screenshot displays the Jeppesen software interface. The main window is titled "PairingI SK STD Ex\_1\_b\_opt best\_solution". It features a sidebar on the left with options: "Run information", "Errors & warnings", and "Solution information". The main content area is titled "Solution\_1 information" and contains several sections:

- Solution analysis** (expanded):
 

legs	1110
uncovered legs	0
overcovers (will become deadheads)	2
illegal trips	0
TOTAL cost	5588844
APC total rule cost	5588844
rule overcover cost	4000
extra overcover cost	0
base constraint excess cost	0
global constraint excess cost	0
- Solution details** (collapsed)
- PDL report** (collapsed)
- Base analysis (complete trips only)** (collapsed)
- Optimization info** (expanded):
 

Generated trips	2334
Colgen iterations	51
Network generation time (seconds)	1
Legality (pass)	181353

At the bottom of the main window, there is a "Plot against" dropdown set to "CPU time", a "Compare" checkbox checked, and a "Solution range from 1 to 9999". Buttons for "Expand all", "Collapse all", "Print", and "Close" are at the bottom.

Overlaid on the main window is a smaller window titled "Grid Engine Batch Manager -- Maria Eriksson -- Administrator". It has a menu bar with "File", "Show", and "Help". The main area lists optimization jobs:

Job Name	Status	Submitted by	on: Jan 21 21:13:18	JobId: 340341
Ex_1_opt97	pending	mariae (Maria Eriksson)		
Ex_1_opt98	running on opt(westsound)	mariae (Maria Eriksson)	on: Jan 21 21:13:12	JobId: 340340
	running on opt(eastmoriches)	mariae (Maria Eriksson)	on: Jan 21 21:13:12	JobId: 340339

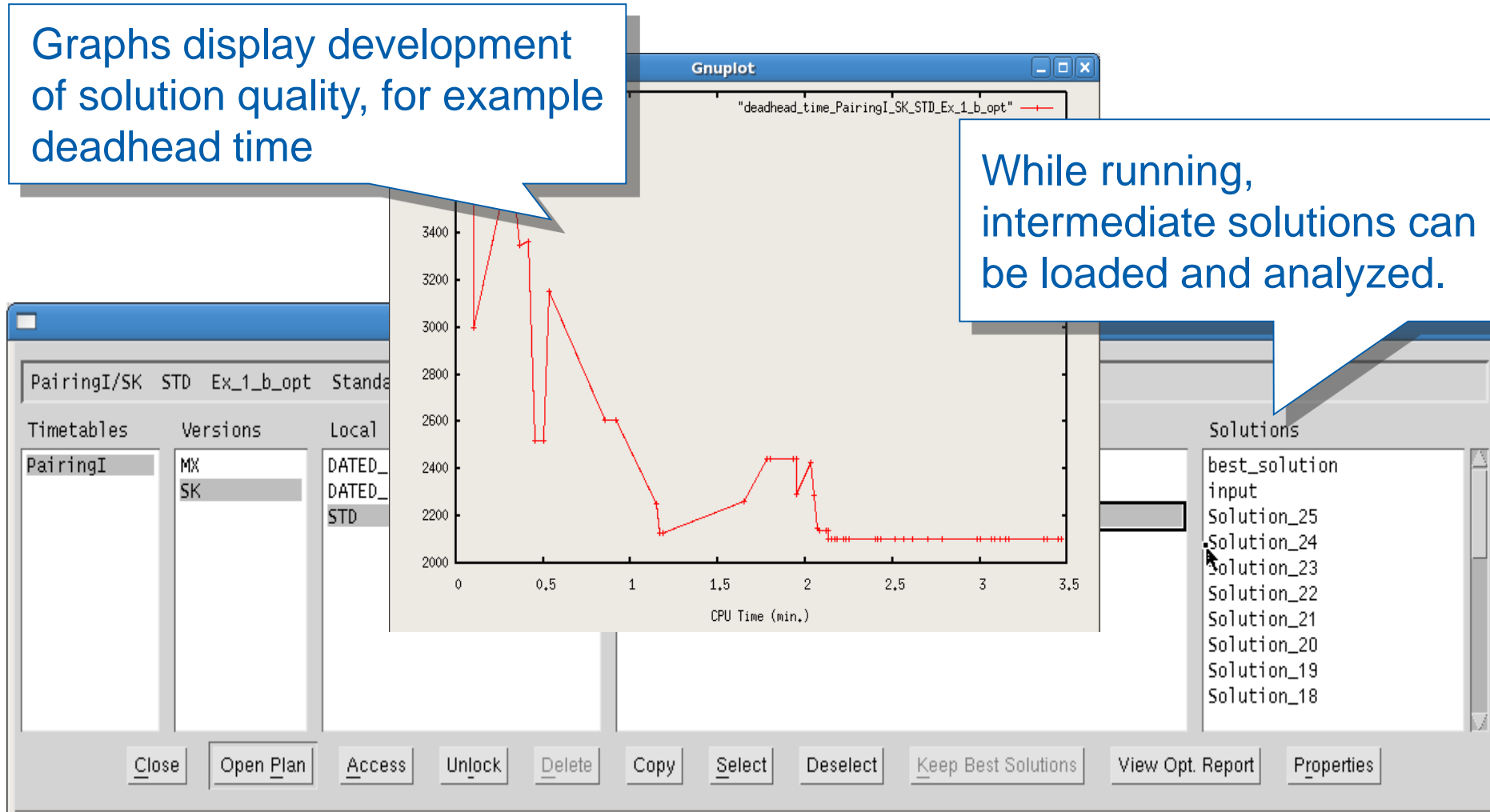
A blue arrow points from the "Opt" icon in the main window's toolbar to the "Grid Engine Batch Manager" window. A white callout box with a blue border points to the job list in the batch manager window, containing the text: "Batch Manager allows monitoring of optimization jobs".

Create a standard solution








## Using the optimizer

Graphs display development of solution quality, for example deadhead time

While running, intermediate solutions can be loaded and analyzed.



# Create a standard solution

-  Create standard local plan (from SSIM file)
-  Build rotations
-  Load rules and parameters
-  Create sub-plan by adding legs
-  Prepare optimization job  
(set parameters/apply hard locks)
-  Run Optimization
-  Verify solution



# Exercise 3

---

## Create standard solution

### Purpose

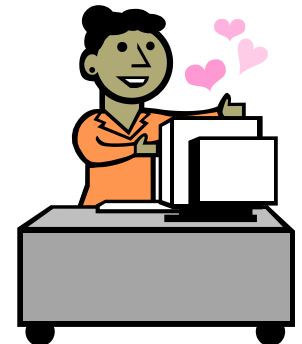
To learn all steps involved in creating a standard solution



# Exercise 3 – summary

---

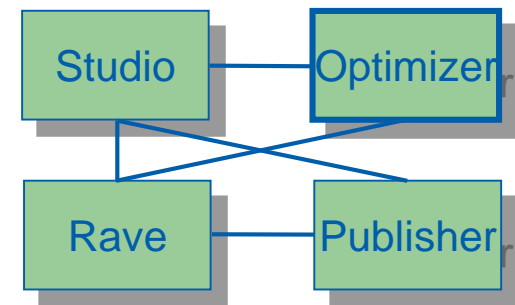
## Summary of exercise 3



# Optimizer

The Crew Pairing Optimizer solves Crew Pairing problems to optimality (or near optimality) using different optimal or heuristic methods designed for various problems:

- daily, weekly and dated problems
- short-haul and long-haul problems
- other carrier deadheading
- deadhead optimization.



All trips comply with rules as defined in Rave.

# Optimization – definition

---

Merriam Webster:

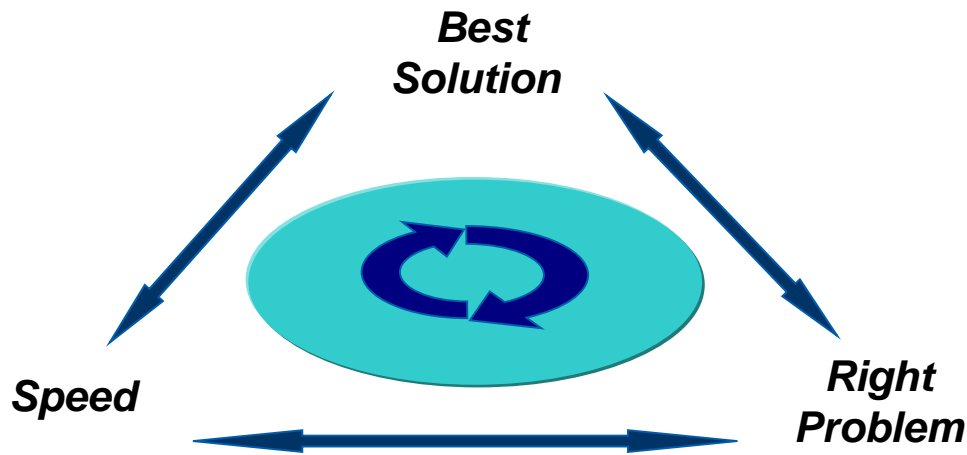
**op-ti-mi-za-tion** n (1857) : an act, process or methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible; specif: the mathematical procedures (as finding the maximum of a function) involved in this.

# Optimization – definition

## Our view

**Optimization** = Finding the best possible solution to the right problem as fast as possible.

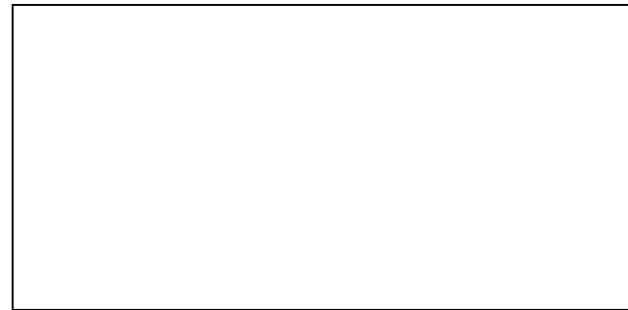
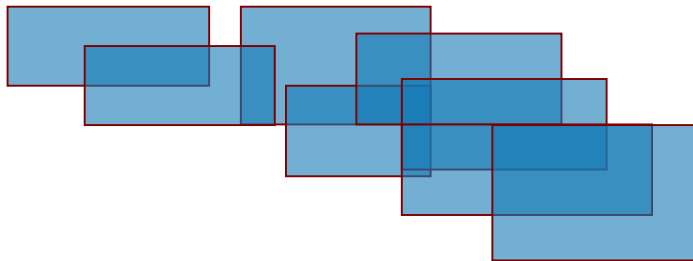
## The three dimensions



# Optimization – examples

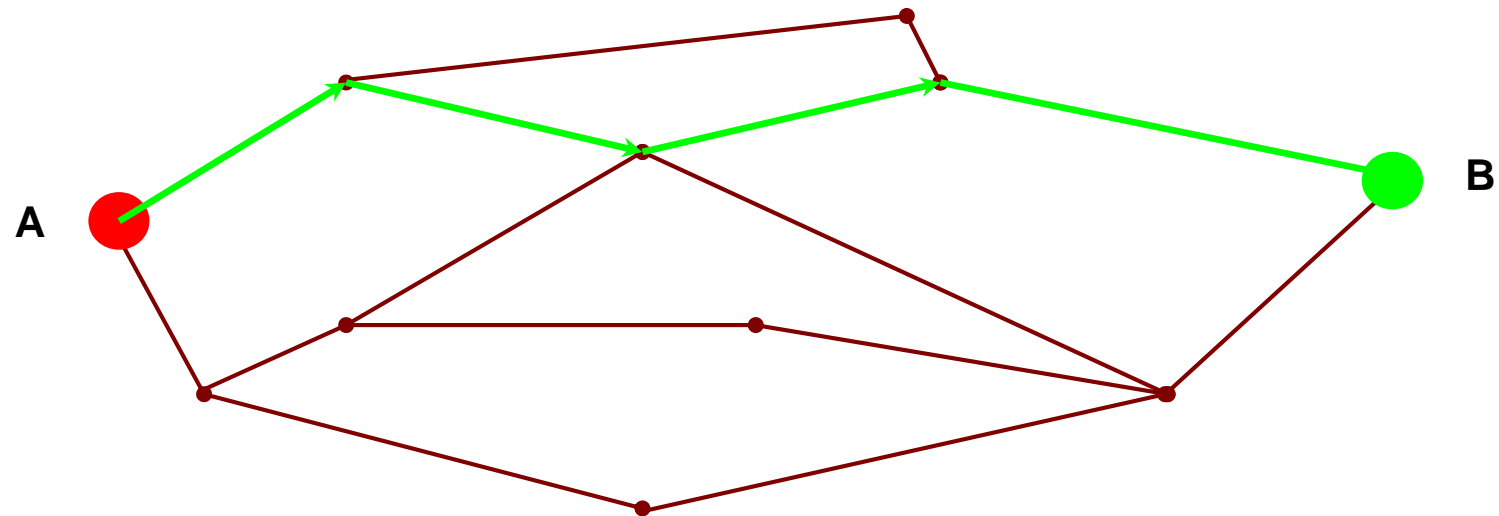
## Packing

- Fit as much as you can in your bag



# Optimization – examples

## Shortest-Path

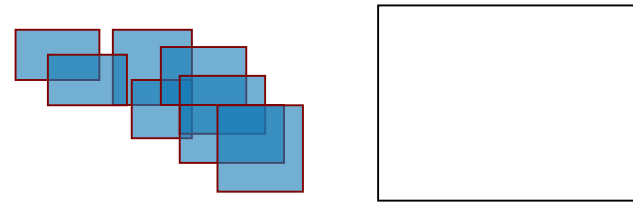
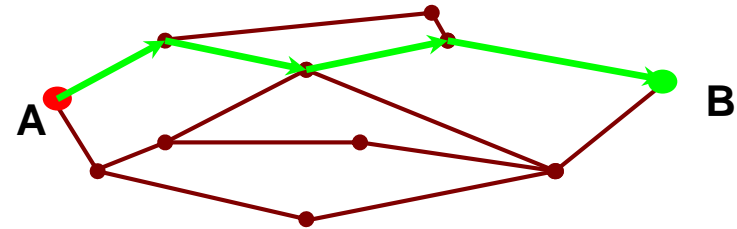


Find the shortest route in the network taking you from **A** to **B**.

# Optimization – Objective function

What is the best solution?

- Quickest?
- Shortest?
- Cheapest?
- Nicest?
  
- Weight?
- Volume?
- Value?





# Optimization

---

Two main steps:

- **Model** the problem:  
Define the objective function and the rules/constraints
- **Solve** the problem:  
Apply the best algorithm(s) to the problem

For step 2 we want to implement a **computer program** doing it automatically.

**Algorithm** = description in mechanical steps of how to solve a problem.

# Optimization

---

A simple way of finding the optimal solution to the pairing problem:

generate all possible solutions (sets of trips)  
select the best solution.

Is this possible?

# The beggar made a deal with the King

Doubling rice grains

1, 2, 4...

8, 16, 32, 64, 128



A week later, he brought a teaspoon for 128 grains

256, 512, 1024, 2048, 4096, 8192, 16384, 32768

In two weeks it was a non-negligible amount of half a kilo

65536, 131072, 262144, 524288, 1048576,

..., 1073741824, 2147483648

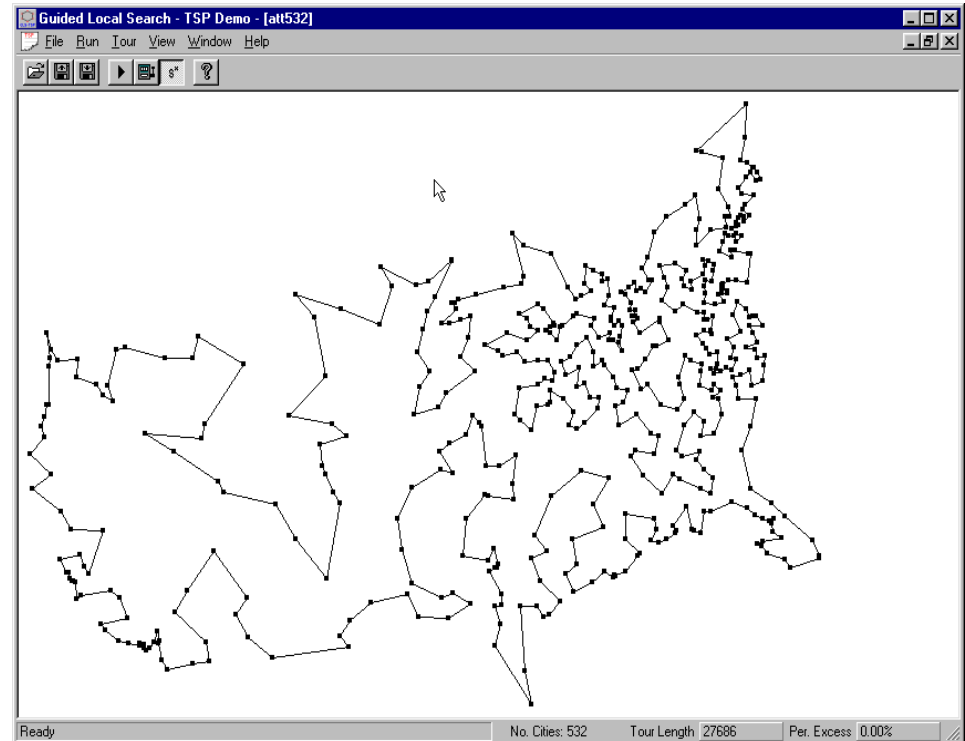
At the end of the month it had grown to a whopping 35 ton

A few days later the king had to declare bankruptcy.



# Optimization – Travelling salesman problem

Given a set of cities, find the shortest way to visit each city exactly once.



**Combinatorial Explosion**  
for example a 41 city problem has

$41! = 334,525,266,131,638,071,081,700,620,534,407,516,651,520,000,000$   
possible **cyclic tours**.

# Optimization – TSP – Sweden

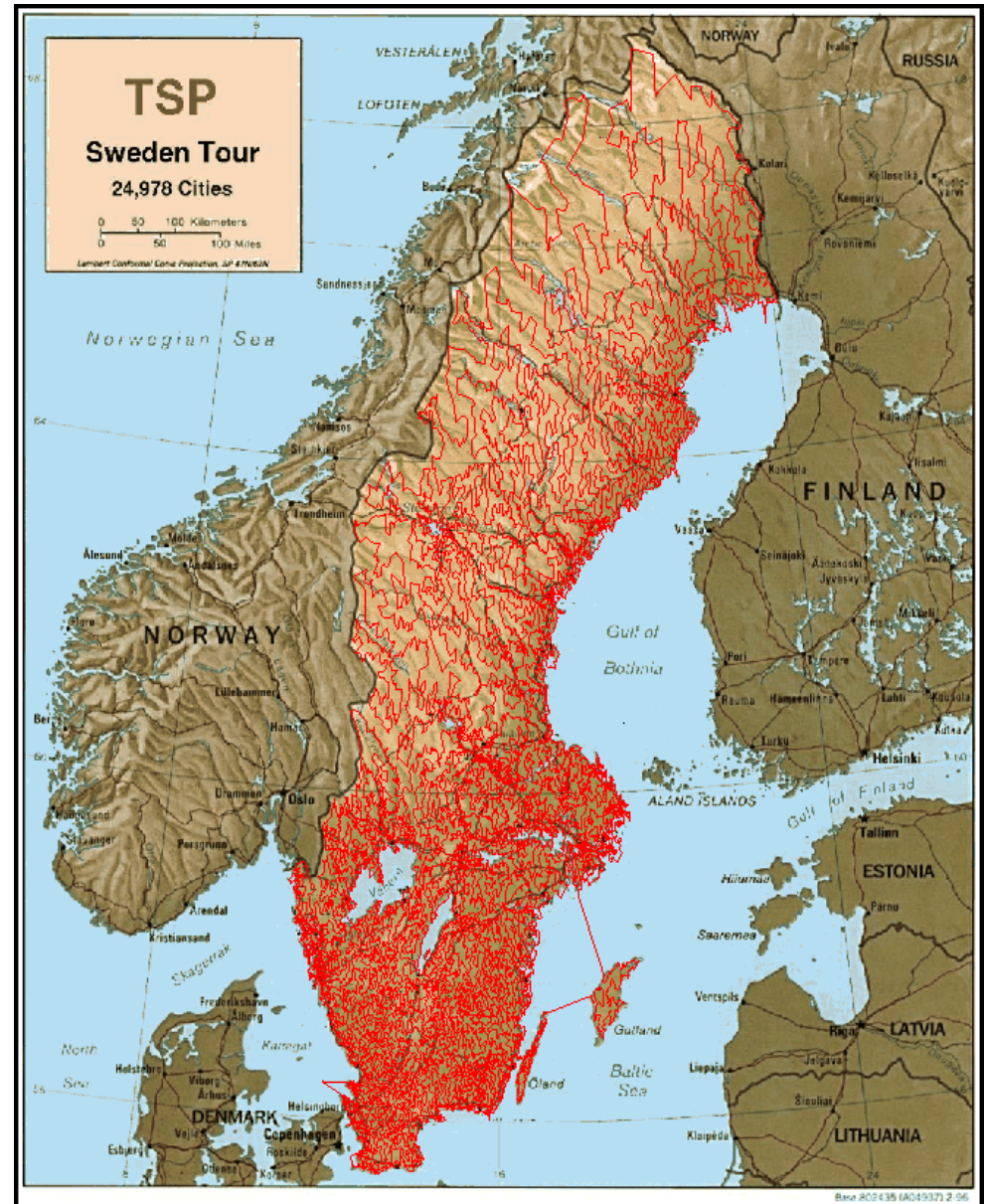
24,978 cities

Solved by Applegate, Bixby, Chvatal, Cook, Helsgaun in May 2004

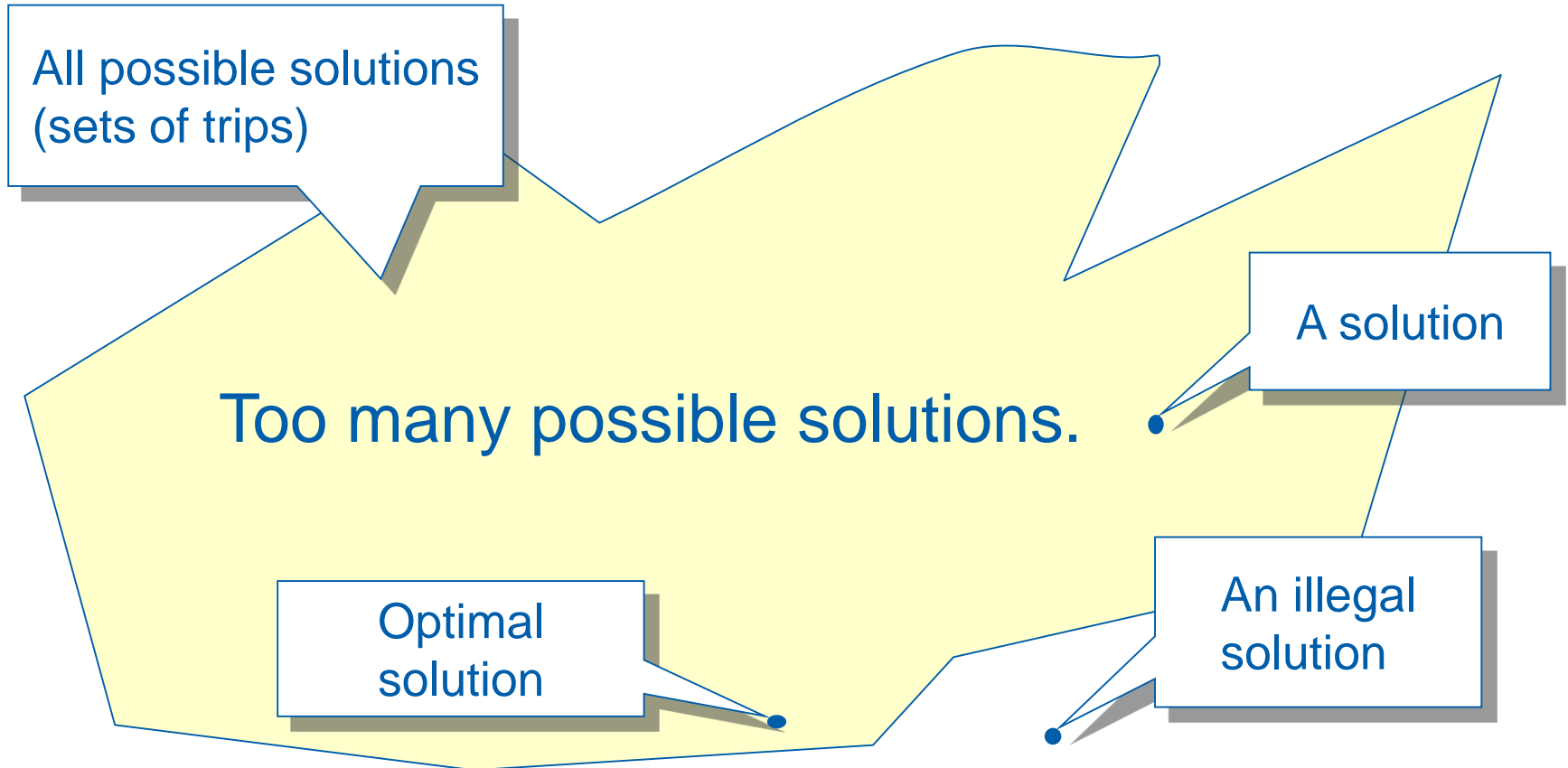
Length about 72,500 km

Applied latest optimization algorithms

Total CPU time 91.9 years (on one CPU)



# Optimization



# Optimization

---

We need to limit the solution space and/or only search in parts of it:

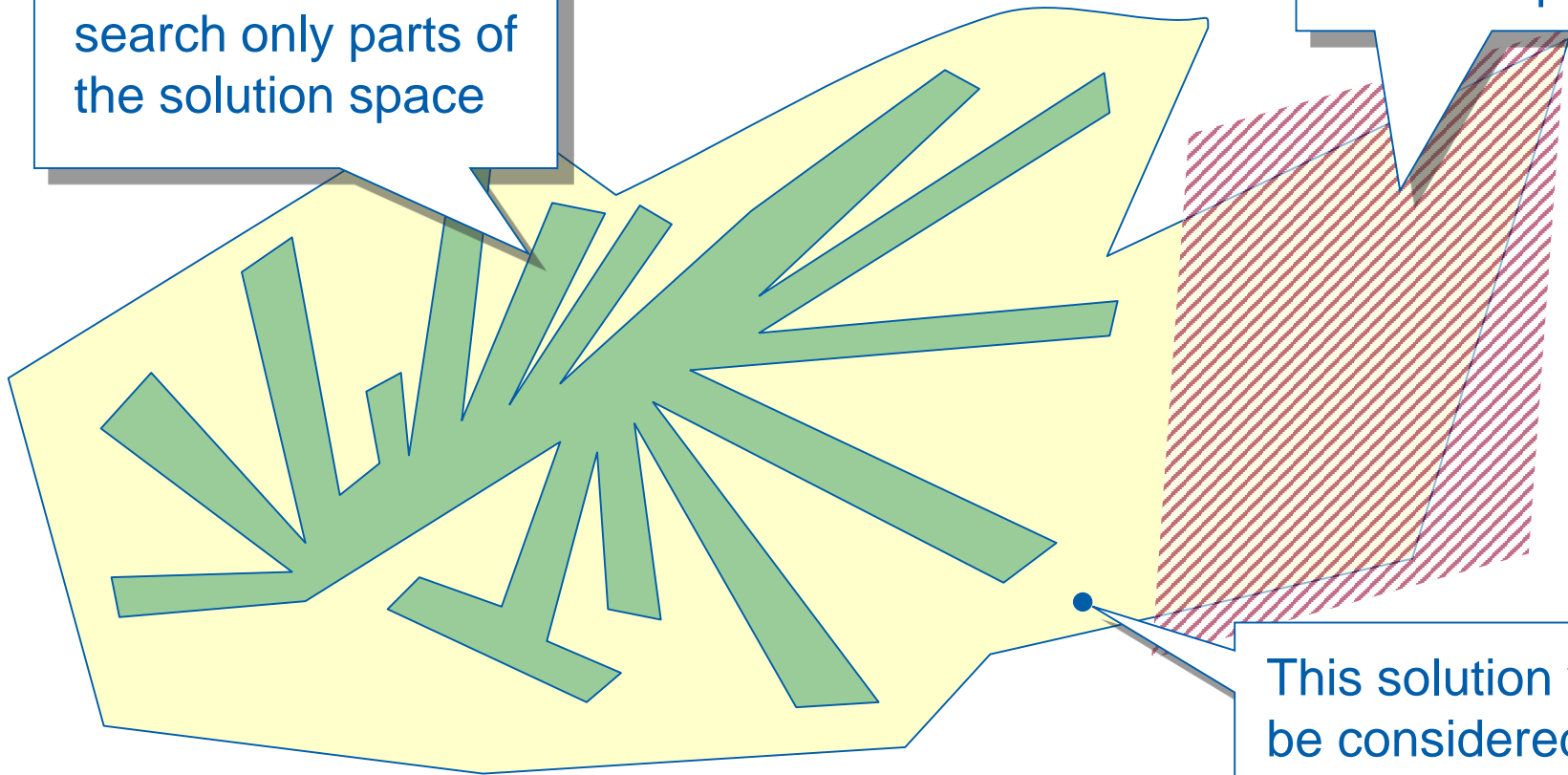
- quality rules limit the solution space
- optimization methods limit the solution space search

# Optimization

The used methods search only parts of the solution space

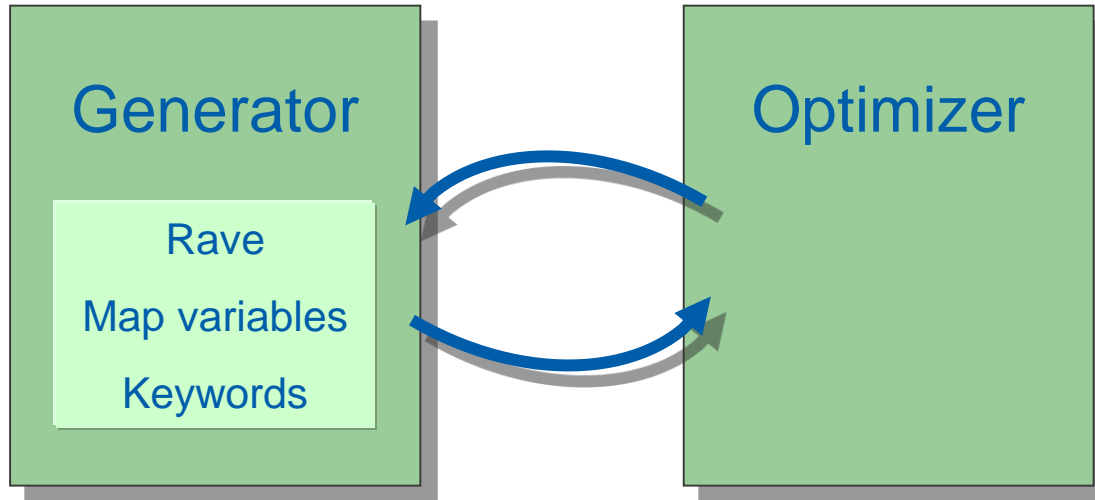
A quality rule limits solution space

This solution will not be considered





# Optimization



**Generator** generates legal subsets

**Optimizer** finds the cheapest combination

# Optimization

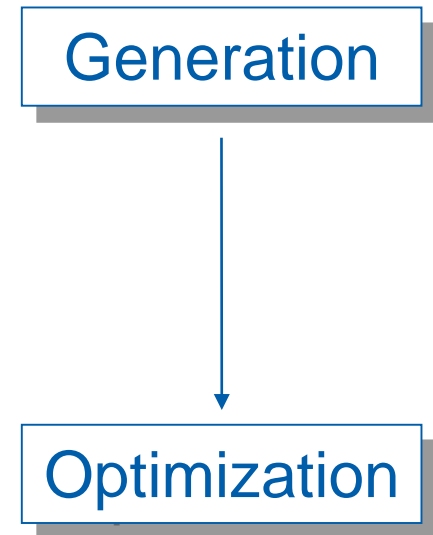
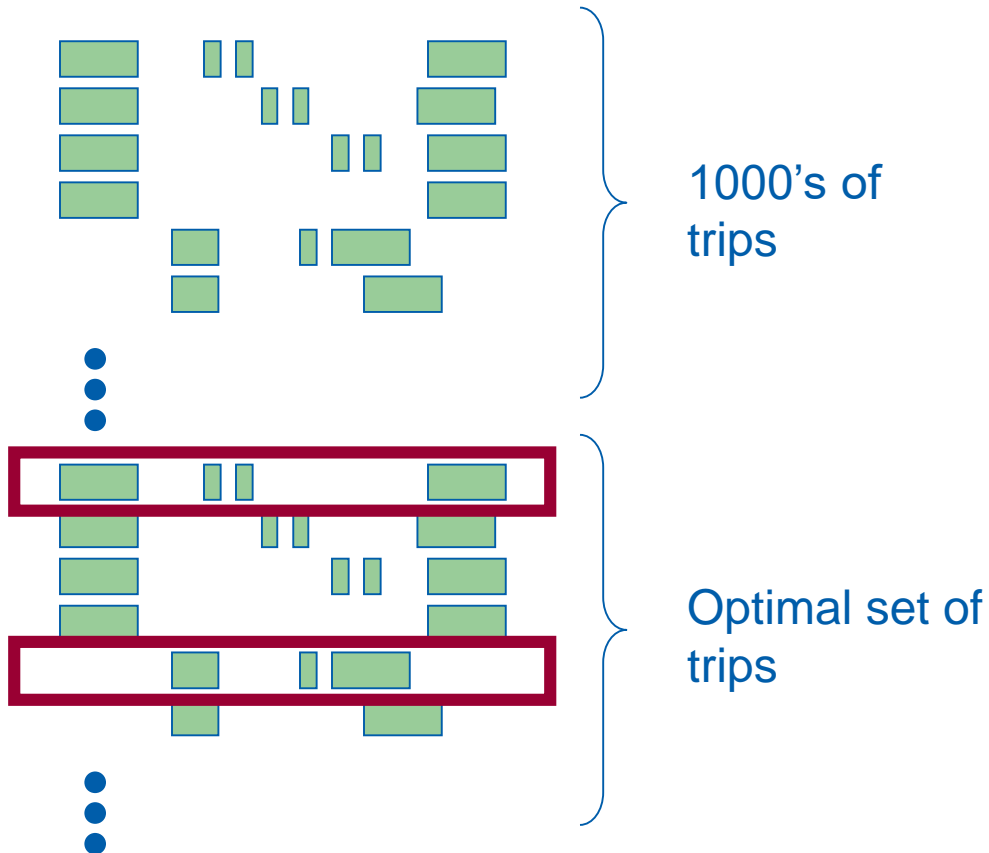
---

The optimizer selects a subset of trips which:

- does not overcover any trips
- has the lowest total penalty

Penalty definitions typically include a high penalty for leaving legs uncovered.

# Optimization



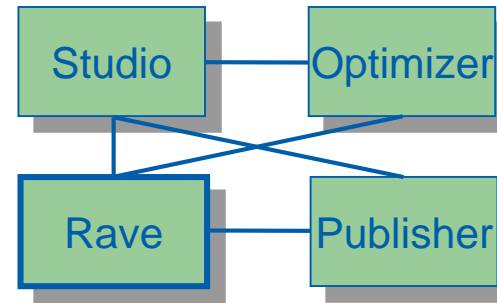
# Optimization

---

Keep in mind that the objective function depends on penalty parameter settings. Hereby the planner controls solutions produced by the optimizer.

# Rules and objectives

Rules and objectives are defined in Rave



# Objectives

---

Cover all flights

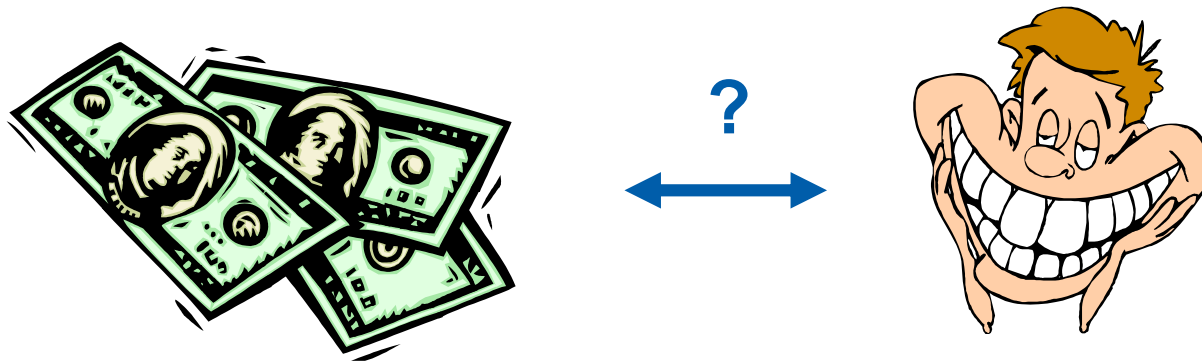
Create only trips complying with regulations, union rules

Minimize total cost

- Maximize productivity
- 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 system, rules are **always** enforced strictly.

Trips not complying with rules are called **illegal trips**.



# Rules

**Rule Parameters**

Basic Settings | AC Rotations Build | **Basic Rules** | FAR Rules | EU Rules | CAP Rules | CAAC Rules | DGCA Rules | Augmentation | Retiming

### 1. Connection Time Limits

(EXP 1.1) Min connection time for A/C change..... ☒ On

(EXP 1.1.1) Min connection time for A/C change (both legs on-duty)..... 0:30

(EXP 1.1.2) Min connection time for A/C change (at least one deadhead)..... 0:30

(EXP 1.1.3) Table with per-station override settings..... SpLocal/min\_connection\_time\_override

(C&P 6.1) Co-terminal external table..... SpLocal/coterminals.etab

(EXP 1.2) Max connection time..... ☒ On

(EXP 1.2.1) Max connection time..... 3:00

(EXP 1.2.2) Only apply rule when crew changes aircraft..... ☒ True

(C&P 6.1) Co-terminal external table..... SpLocal/coterminals.etab

### 2. Block & Duty Time Limits

(EXP 2.1) Max duty block time..... ☐ Off

(EXP 2.1.1) Max duty block time..... 8:00

**Active rule**

**Parameterized rule limit**

**Rule switched off**

OK Cancel Load from File Load from Sub-plan Save to File... Reset Print Default diff Search Help

# Rules

**Carmen Crew Pairing (pairing\_1\_system) PairingI/SK/STD/Ex\_1\_b default\_ccp**

File Edit Planning Tools Admin Tools Options Jobs Window Help

1/1/0/0/0/0/0/0 Leg Filter Rotation Filter Trip Filter 10:13

**Trips**

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1/1/0/0/0/0/0/0 1003 OSL	OSL 56 56 6 6 OSL						
1/1/0/0/0/0/0/0 1004 OSL	OSL 25 STN	STN 2 1	WAW 7	1 MUC	MUC 6 1 1 2 2	OSL	
1/1/0/0/0/0/0/0 1006 OSL	OSL	KRS					
1/1/0/0/0/0/0/0 1011 OSL		OSL 5 5 5 5 OSL					
1/1/0/0/0/0/0/0 1009 OSL		OSL 56 CDG	CDG 58				
1/1/0/0/0/0/0/0 1007 OSL		OSL OSL					
1/1/0/0/0/0/0/0 1005 OSL	OSL 1 1 5 5 OSL						
1/1/0/0/0/0/0/0 1001 OSL		OSL KRS	KRS OSL				
1/1/0/0/0/0/0/0 1010 OSL		OSL ARN ARN 57 CDG CDG 56					

146 rows

**Legs**

	Mon	Tue	Wed	Fri	Sat	Sun
1 2						
1/1/0/0/0/0/0/0		KRS OSL				
1 2						
1/1/0/0/0/0/0/0		KRS OSL				

2 rows

Layover: 14:25  
Local: 1525 - 0550 14:25 at airport KRS

Period/Fleet/Version: 200001/SK/1  
Planning period : 03JAN2000 - 09JAN2000 (ARN)

Only legal continuations are suggested when using Studio's manual tools.

# Quality

---

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 trip is not too sensitive to delays and other changes. Good stability simplifies maintenance of the trips.

## Examples

“Connection time between legs not too short”

“No aircraft change 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

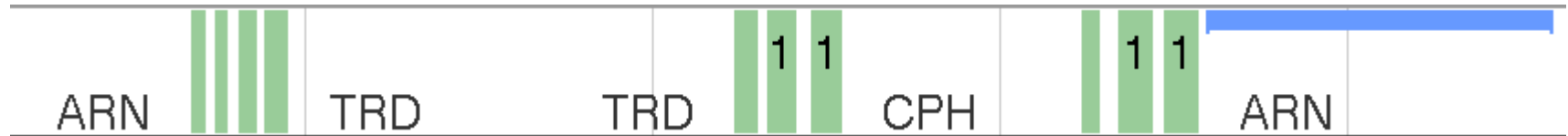
---

The objective function contains two parts:

- real costs (e.g. hotel costs)
- penalties or costs for poor quality/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\$
<b>Total costs</b>	<b>22,610 Jeppesen\$</b>



# Quantifying quality

---

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

It forces planning departments to:

- prioritize quality issues
- decide how much quality is worth

# Defining a Scenario

---

A Scenario is defined by a Sub-plan

Within the Sub-plan the planner can change

- Parameter settings
- E-table settings

# Defining a Scenario

## Defining Parameter Settings

**Rule Parameters**

Basic Settings | AC Rotations Build | **Basic Rules** | FAR Rules | EU Rules | CAP Rules | CAAC Rules | DGCA Rules | Augmentation | Retiming

1. Connection Time Limits

(EXP 1.1) Min connection time for A/C change..... ☒ On

(EXP 1.1.1) Min connection time for A/C change (both legs on-duty)..... 0:30

(EXP 1.1.2) Min connection time for A/C change (at least one deadhead leg)..... 0:30

(EXP 1.1.3) Table with per-station override settings..... SpLocal/min\_connection\_time\_override

(C&P 6.1) Co-terminal external table..... SpLocal/coterminals.etab

(EXP 1.2) Max connection time..... ☒ On

(EXP 1.2.1) Max connection time..... 3:00

(EXP 1.2.2) Only apply rule when crew changes aircraft..... ☒ True

(C&P 6.1) Co-terminal external table..... SpLocal/coterminals.etab

2. Block & Duty Time Limits

(EXP 2.1) Max duty block time..... ☐ Off

(EXP 2.1.1) Max duty block time..... 8:00

OK Cancel Load from File Load from Sub-plan Save to File... Reset Print Default diff Search Help

# Defining a Scenario

## Defining e-table settings

Differences in Sub-plan e-tables					
Name:	200001/SK/1:	default SK:	default:	Status:	Edit In Plan Import to Plan S
ac_attributes.etab		X		OK	Edit
ac_families.etab		X		OK	Edit
augmentation.etab			X	OK	Edit
augmentation_configuration.etab			X	OK	Edit
base_constraints_credit.etab			X	OK	Edit
base_constraints_duty_days.etab			X	OK	Edit
briefing_override.etab			X	OK	Edit
connection_banks.etab			X	OK	Edit
coterminals.etab			X	OK	Edit
credit_costs.etab			X	OK	Edit
crew_need_ac.etab		X		OK	Edit
crew_need_flight.etab			X	OK	Edit
debriefing_override.etab			X	OK	Edit
duty_day_costs.etab			X	OK	Edit
exterior_passenger_flow.etab			X	OK	Edit
ground_transport.etab			X	OK	Edit
hotel.etab			!	Missing in Sub-plan	Import
illegal_deadhead_flights.etab			X	OK	Edit



Sub-plan e-tables in sync with source



Sub-plan e-table content differs (scenario)



Sub-plan e-table missing (error)

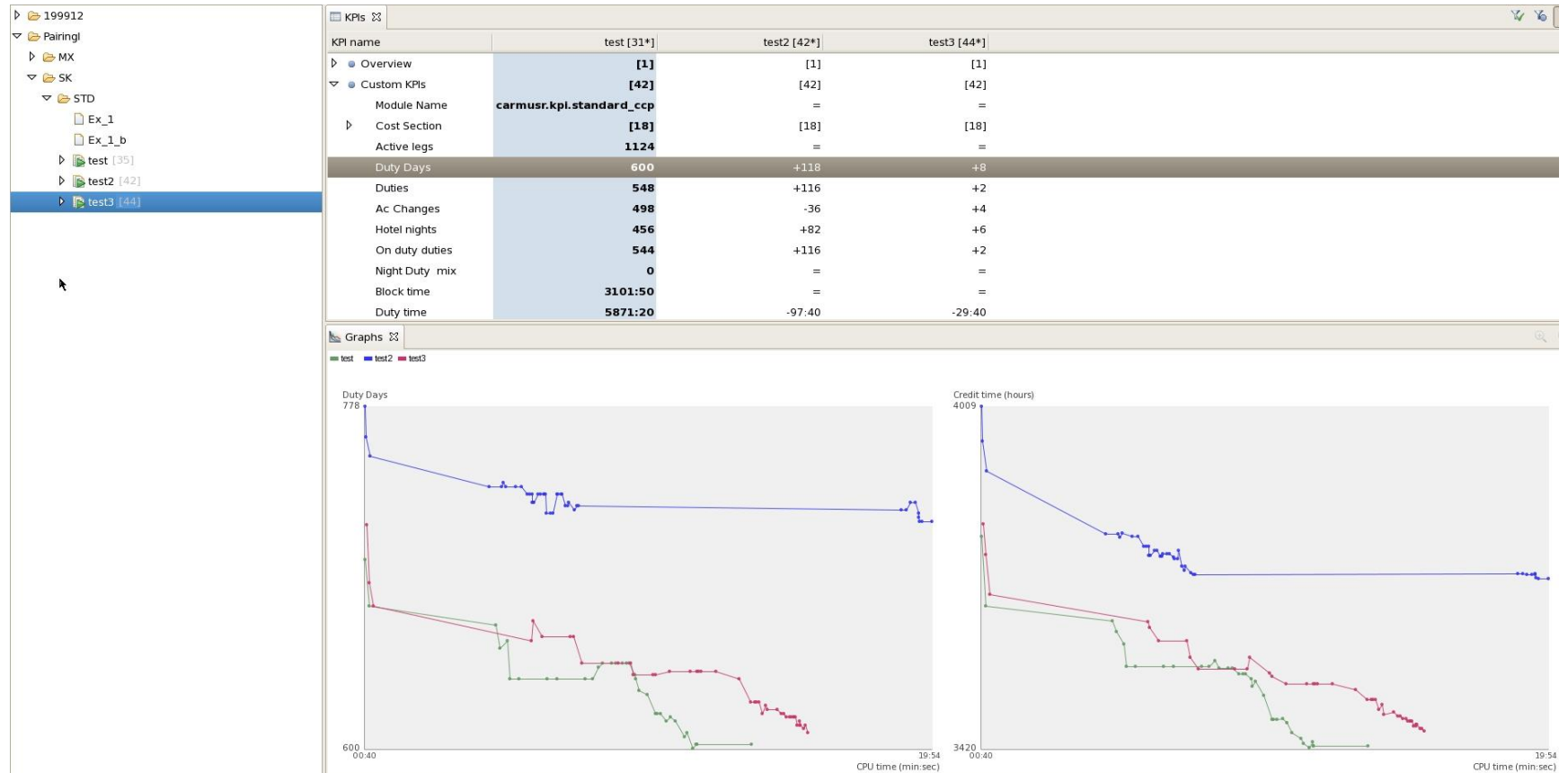
# Analyzing the Solution

---

Four major ways to analyze the solution:

- Scenario Analyzer
- Optimization Report
- Customer Specific Reports
- Gantt View (manual inspection)

# Analyzing the Solution



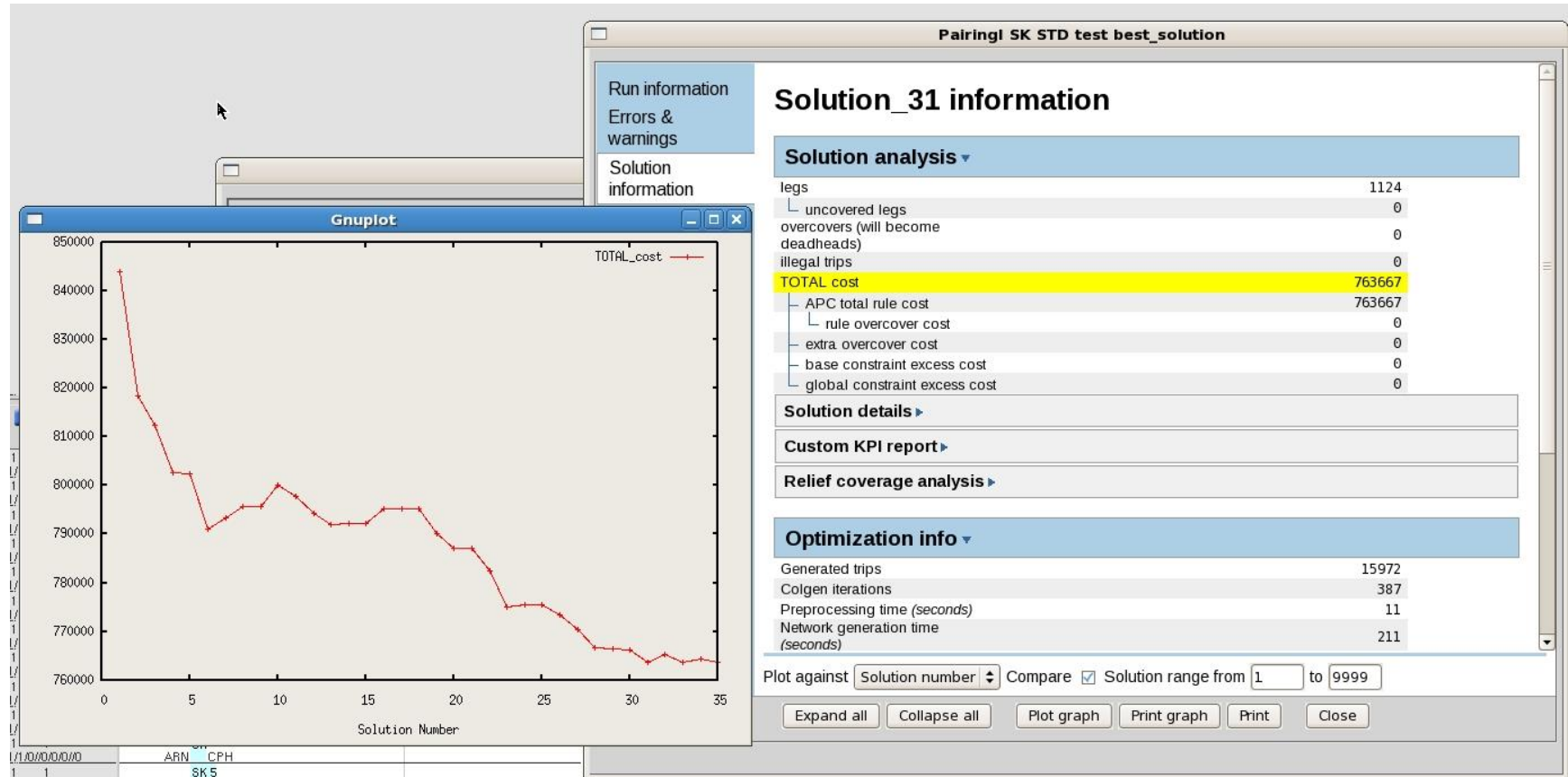
# Analyzing the Solution

---

KPIs from Scenario Analyzer can be exported to for example Excel:

1. Select KPIs to export with Ctrl or Shift
2. Click Ctrl+C to copy the selected data
3. Paste the data in e.g. Excel using Paste or Ctrl+V

# Analyzing the Solution





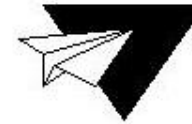
# Analyzing the Solution

## Trip Statistics

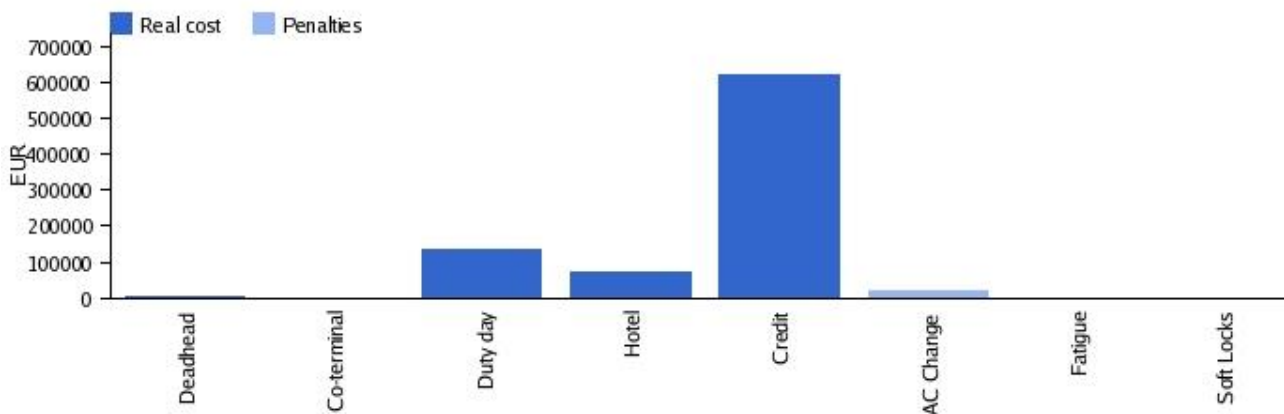
**Planning Period:** 03JAN2000-09JAN2000

**Rule Set Name:** default\_ccp ()

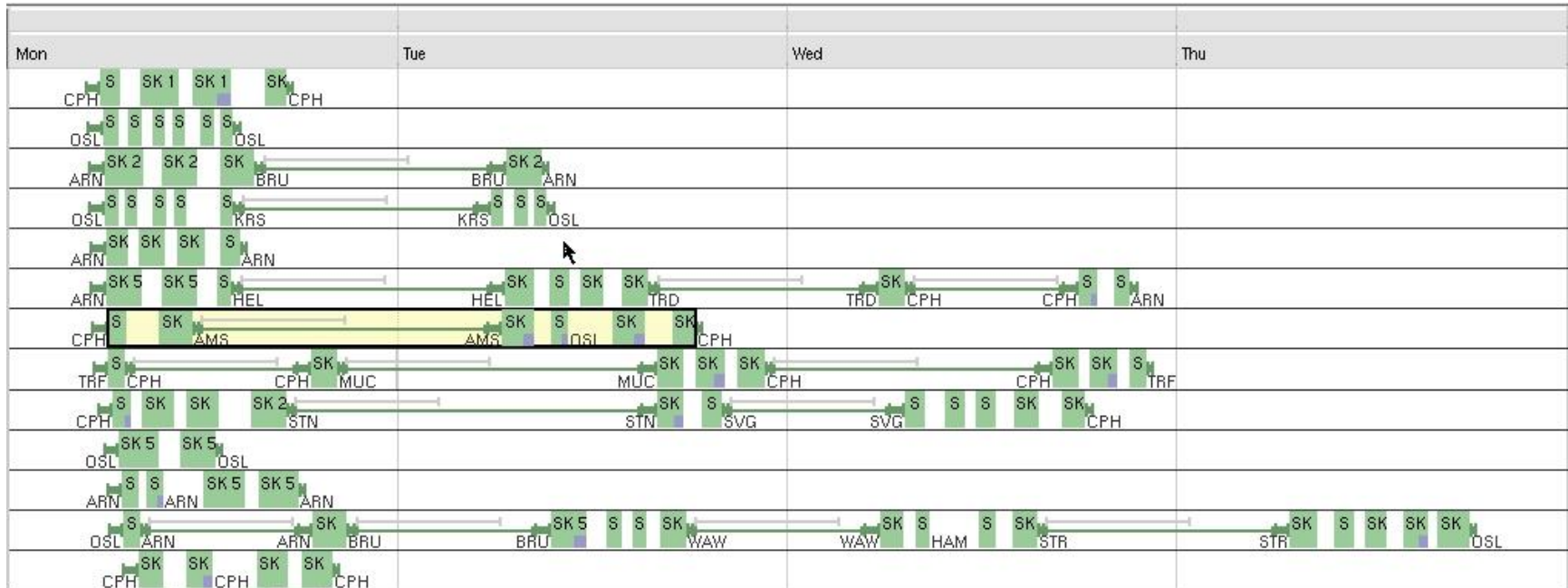
**Plan:** PairingI / SK / STD / Ex\_1



Cost Table	
Element	Cost
<b>Real Cost</b>	<b>830303</b>
Deadhead	6166
Co-terminal	0
Duty day	135200
Hotel	70840
Credit	618097
<b>Penalties</b>	<b>21000</b>
AC Change	21000
Fatigue	0
Soft Locks	0



# Analyzing the Solution



# Exercise 4

---

## Influence the solution

### Purpose

Learn to change the priorities of the cost function



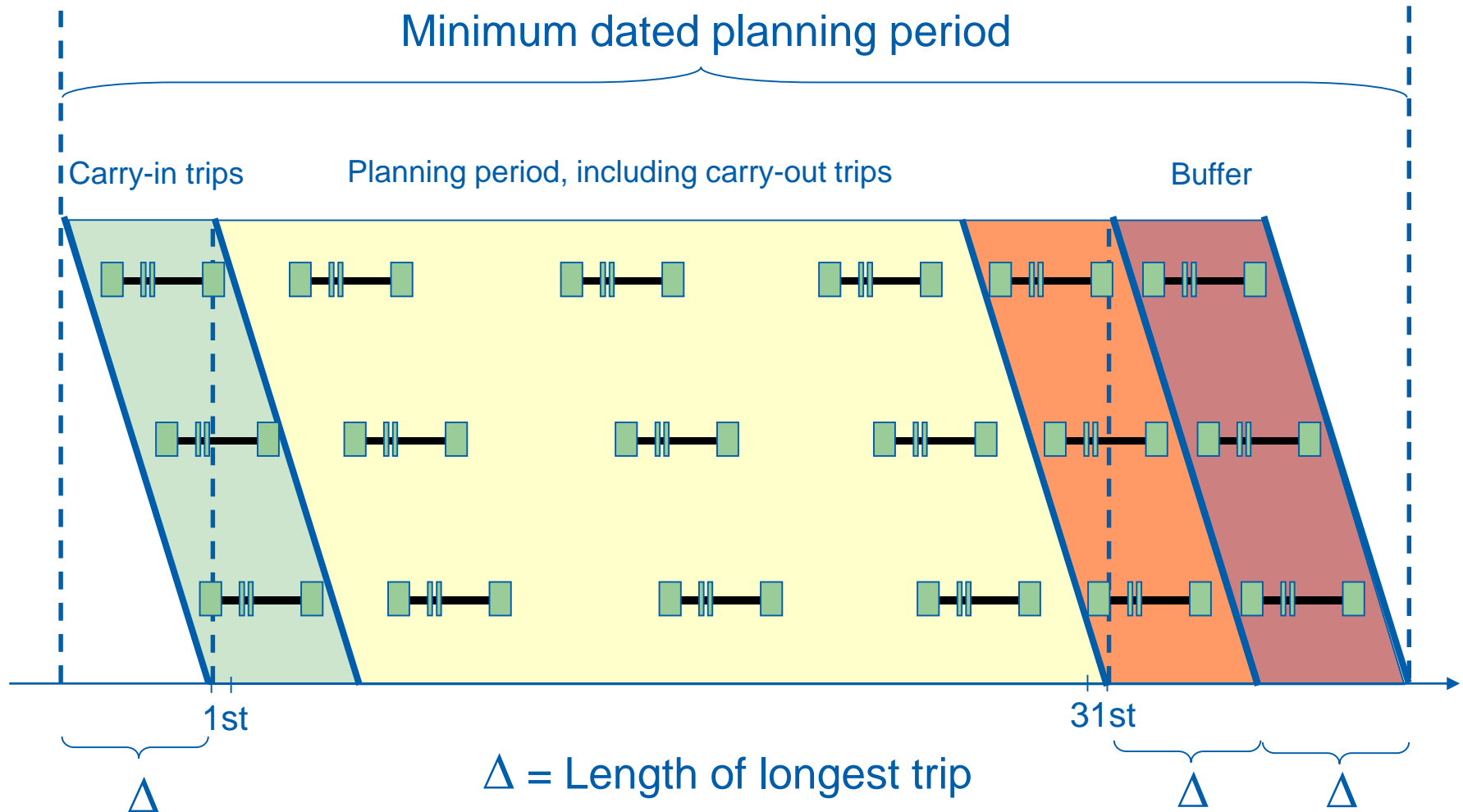
# Exercise 4 – summary

---

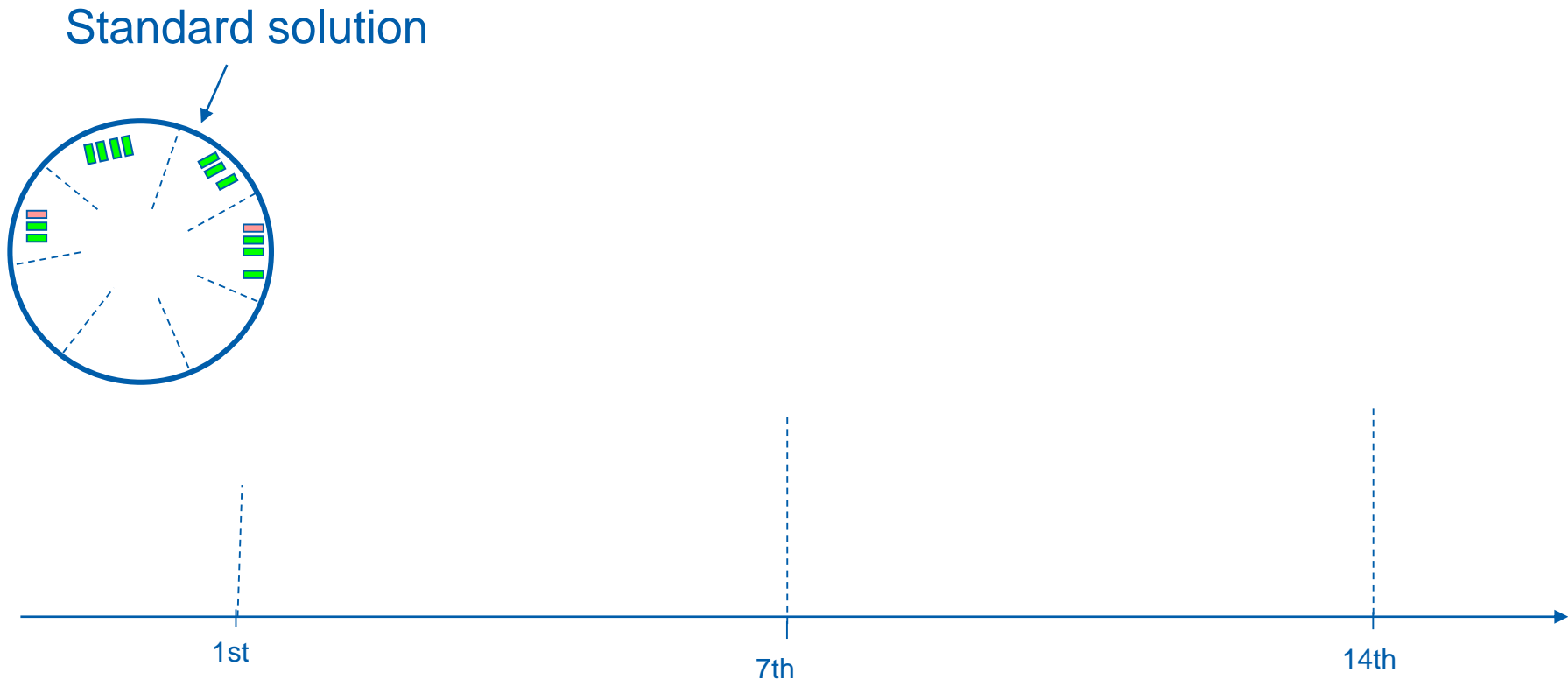
## Summary of exercise 4



# A dated local plan



# Create a dated solution – the idea

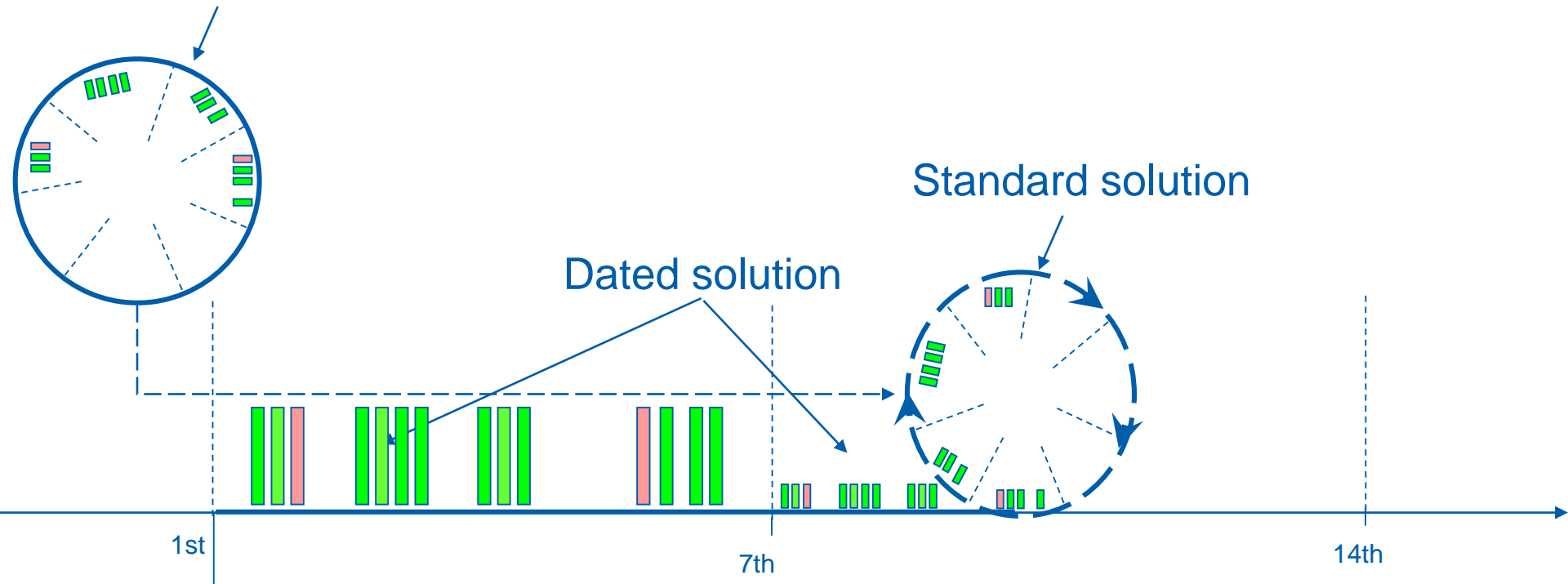


# Create a dated solution – the idea

Standard solution

Dated solution

Standard solution



# Standard to dated issues

---

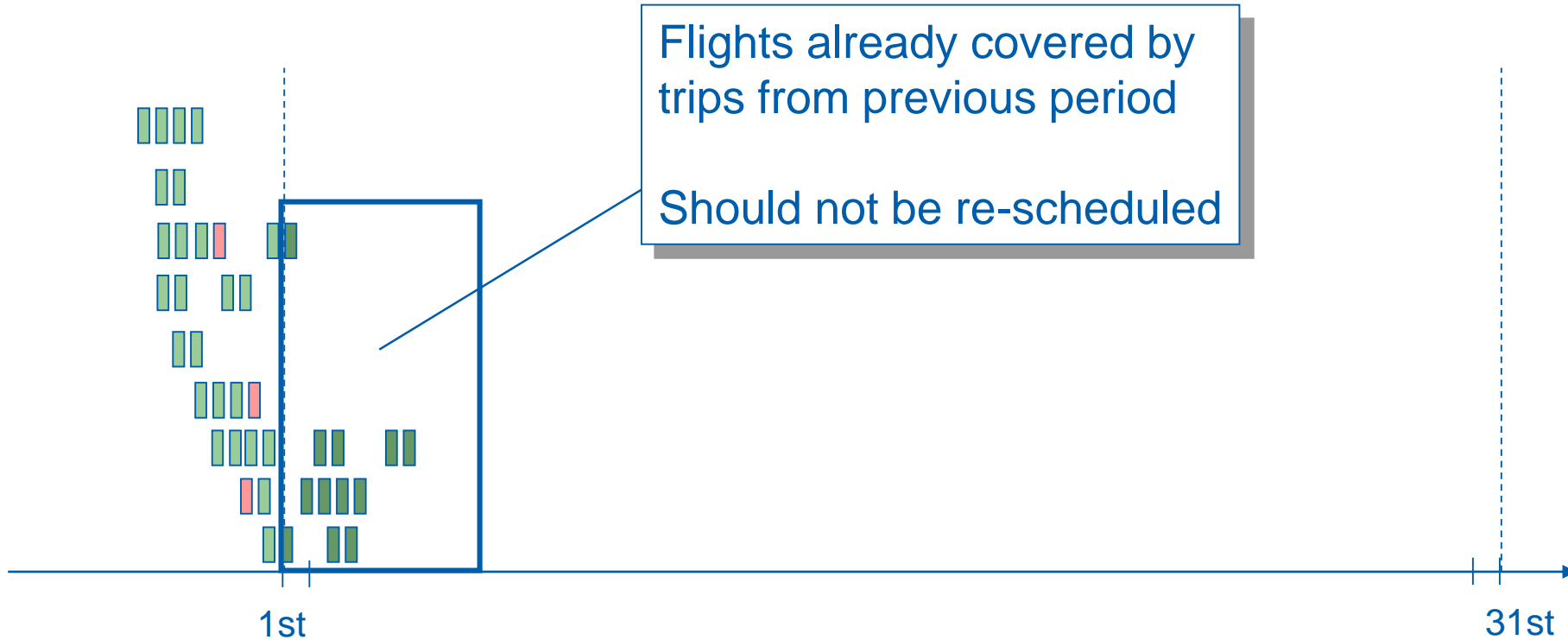
## Issues in brief:

- trips from previous planning period cover flights in the beginning of this planning period
- new legs outside the standard week
- legs only existing in the standard week
- legs changing departure/arrival time
- legs changing aircraft type



## Issues

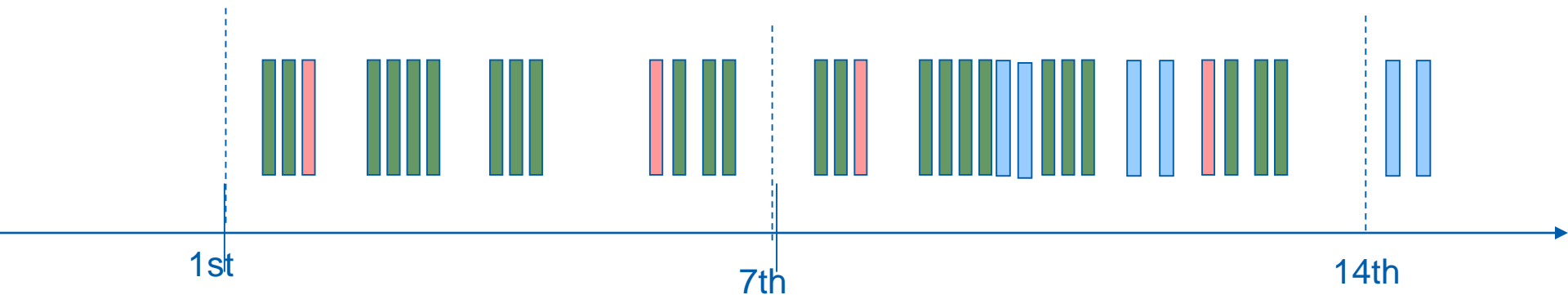
# Carry-in trips



## Issues

# New legs

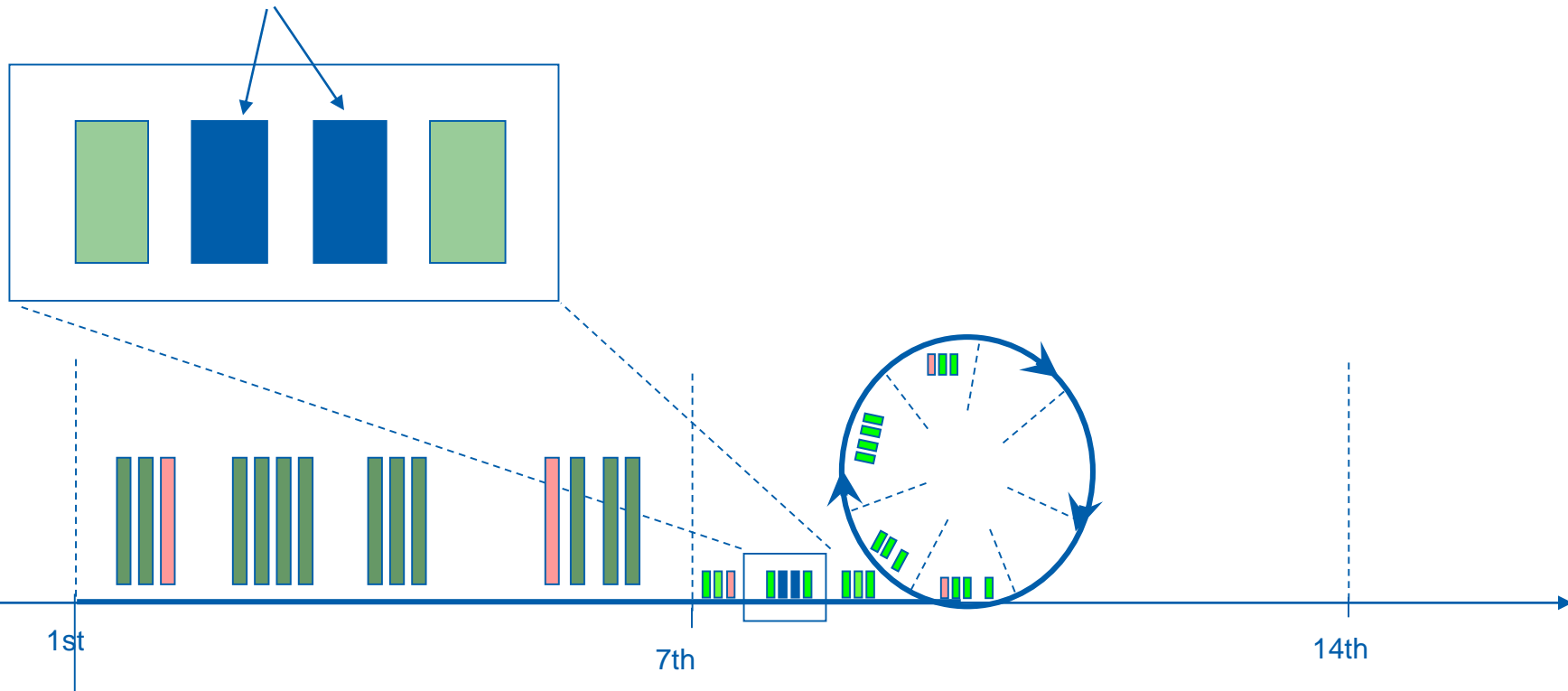
Legs you are supposed to plan that do not exist in the standard week must be **added** to the problem.



Issues

# Flights existing only in standard week

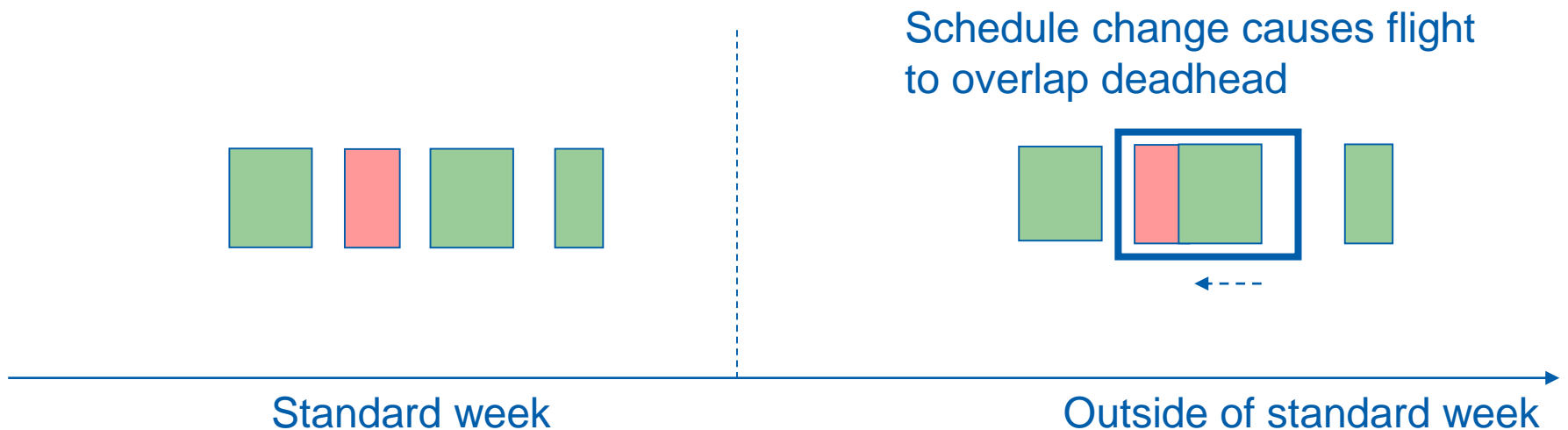
Not operating legs



## Issues

# Changes in departure/arrival time

Smaller changes in departure/arrival times **may** not cause any problems.  
Larger changes cause trips outside of the standard week to break.

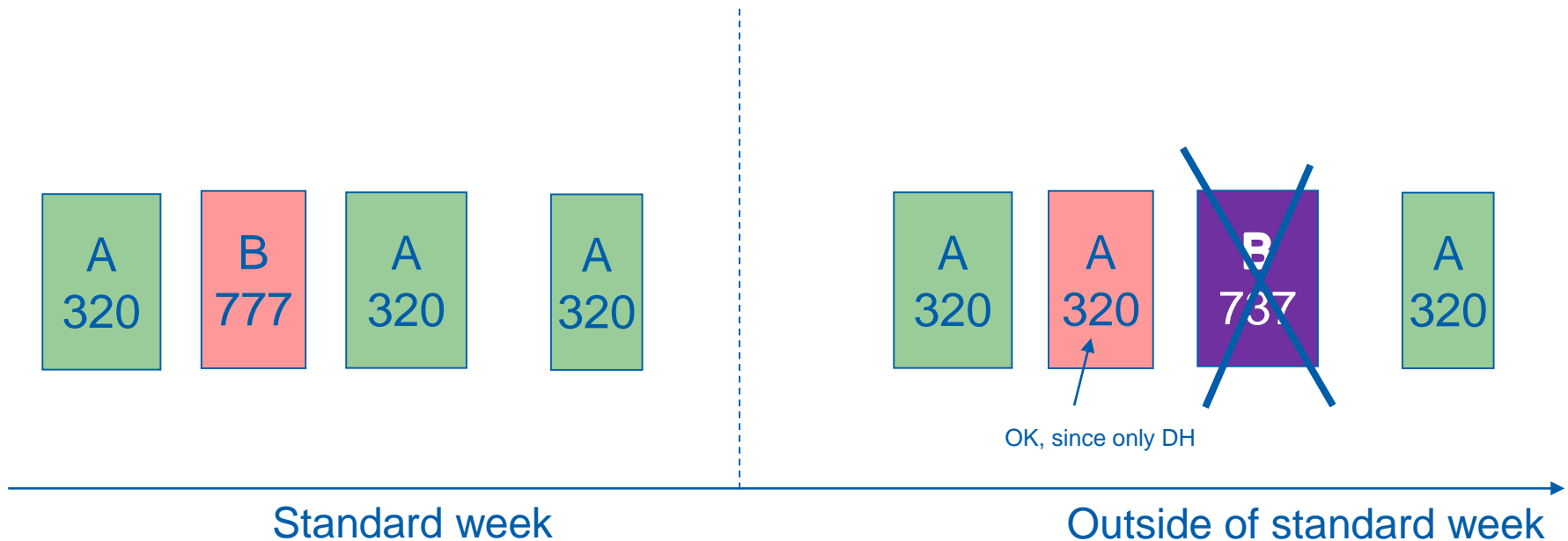


## Issues

# Change of aircraft type

Aircraft type changes cause trips to break if crew is not qualified.

Aircraft type changes



# Create a dated solution

---

## Main steps:

1. Create a dated local plan
2. Build rotations
3. Roll out the standard (weekly) solution
4. Add carry-in trips  
and new flights
5. Remove non-operating flights etc.
6. Repair the dated solution

Create a dated solution

## **Roll out to Dated**

Roll out the standard solution

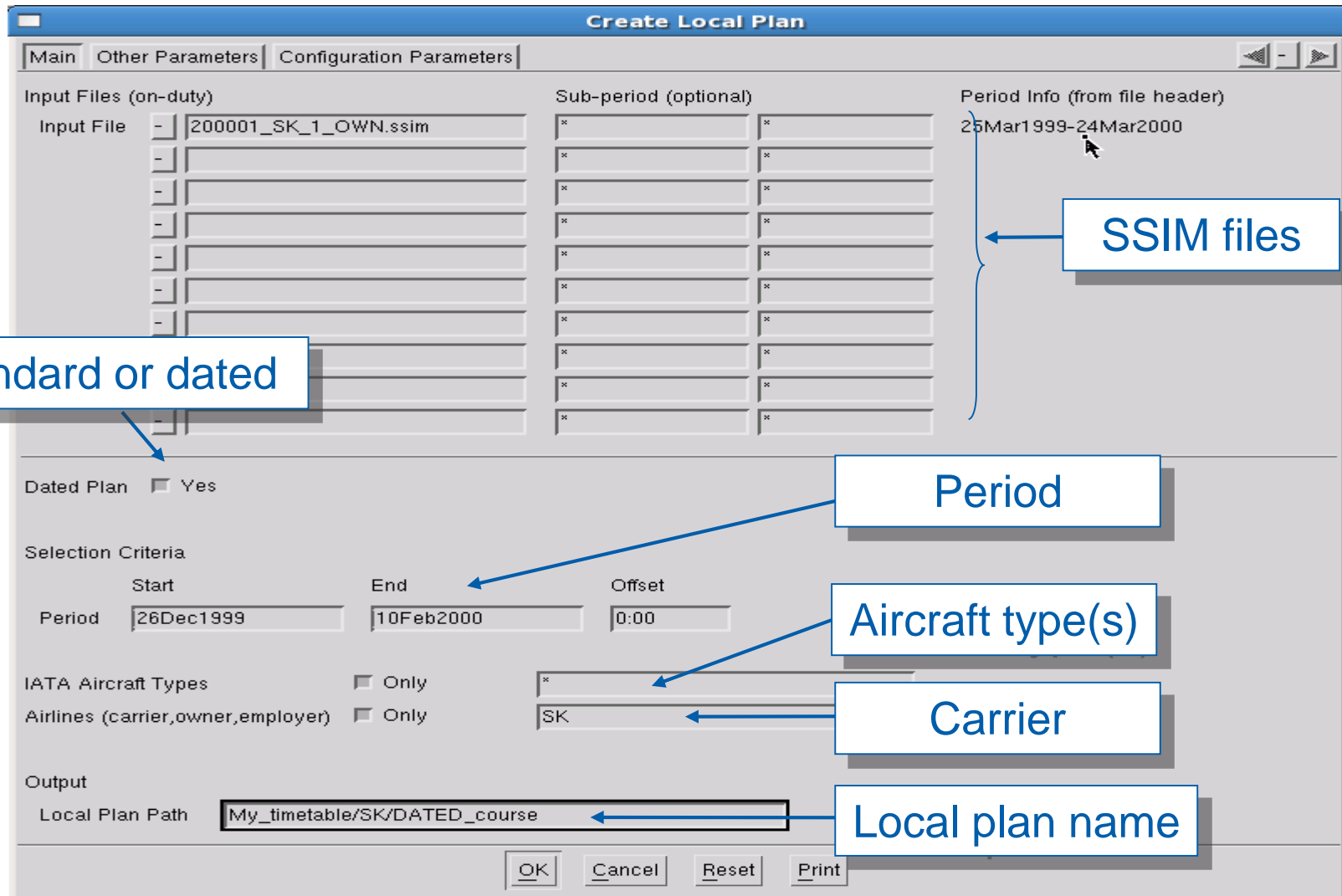
Open the standard (weekly) solution.



Roll out the standard solution to dated local plan.

Create a dated solution

## Create a dated local plan



The screenshot shows the 'Create Local Plan' dialog box with the following fields and annotations:

- Input Files (on-duty):** A table with columns 'Input File' and 'Sub-period (optional)'. The first row contains '200001\_SK\_1\_OWN.ssim'. A bracket on the right side of this table is labeled 'SSIM files'.
- Period Info (from file header):** A text field containing '25Mar1999-24Mar2000'. An arrow points from this field to a label 'Period'.
- Dated Plan:** A checkbox labeled 'Dated Plan' with 'Yes' selected.
- Selection Criteria:**
  - Start:** A text field containing '26Dec1999'.
  - End:** A text field containing '10Feb2000'.
  - Offset:** A text field containing '0:00'.
  - IATA Aircraft Types:** A checkbox labeled 'Only' with 'x' in the adjacent field.
  - Airlines (carrier,owner,employer):** A checkbox labeled 'Only' with 'SK' in the adjacent field. An arrow points from this field to a label 'Carrier'.
- Output:**
  - Local Plan Path:** A text field containing 'My\_timetable/SK/DATED\_course'. An arrow points from this field to a label 'Local plan name'.
- Buttons:** 'OK', 'Cancel', 'Reset', and 'Print' at the bottom.

Annotations include:

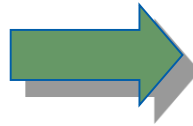
- 'Standard or dated' with an arrow pointing to the 'Dated Plan' checkbox.
- 'Period' with an arrow pointing to the 'Period Info' field.
- 'Aircraft type(s)' with an arrow pointing to the 'IATA Aircraft Types' field.
- 'Carrier' with an arrow pointing to the 'Airlines' field.
- 'Local plan name' with an arrow pointing to the 'Local Plan Path' field.



# Create a dated solution

## Build rotations

2 Rotations		Mon	Tue
1	735	OSD ARN	
1	736	TRD CPH	
1	736	CPH ARN	
1	736	WAW CPH	
1	735	KRS OSL	
1	735	OSL AES	



Planning Tools
 Admin

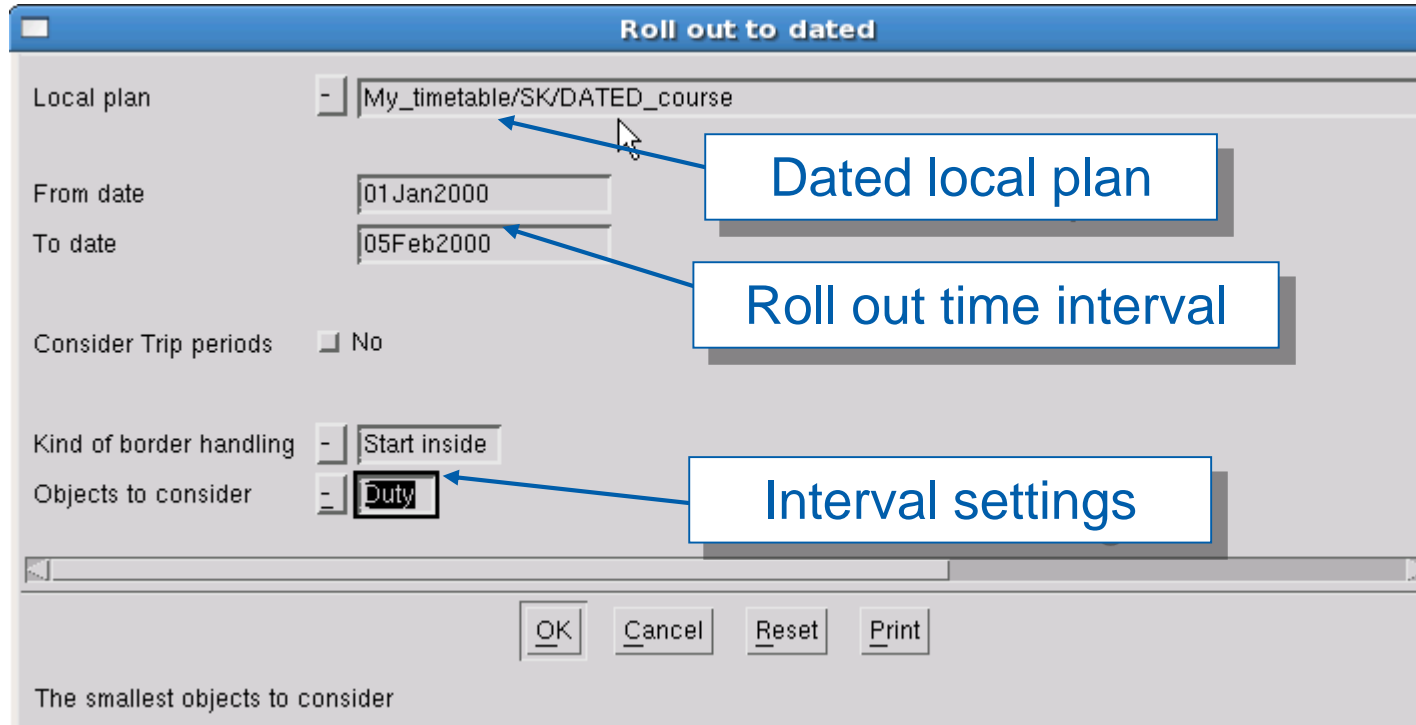
Plan Manager...  
 Scenario Analyzer...  
 Local Plan  
 Sub-plan  
 Rule Parameters...  
 External Table Manager...  
 TOR Table Manager...  
 Airport Manager...  
 Saved Reports Manager...  
 Generate Report...  
 Process Automation

Add Legs to Sub-plan...  
 Dissolve Rotations  
**Build Rotations**  
 Recalculate Crew Need  
 Merge...  
 Properties...  
 Set Planning Problem...

2 Rotations		Mon	Tue
1	735	OSD 1 OSD	
1	736	TRD 8 1 1 6 STR	
1	736	WAW 7 6 6 6 MUC	
1	736	CPH 1 15 15 1 7 WAW	
1	735	KRS	OSL
1	736	CDG 58 57 57 57 CDG	

Create a dated solution

# Roll out to dated



The screenshot shows a dialog box titled "Roll out to dated". It contains several input fields and checkboxes. Annotations with blue arrows point to specific fields:

- Dated local plan**: Points to the "Local plan" dropdown menu, which currently shows "My\_timetable/SK/DATED\_course".
- Roll out time interval**: Points to the "To date" field, which contains "05Feb2000".
- Interval settings**: Points to the "Objects to consider" dropdown menu, which currently shows "Duty".

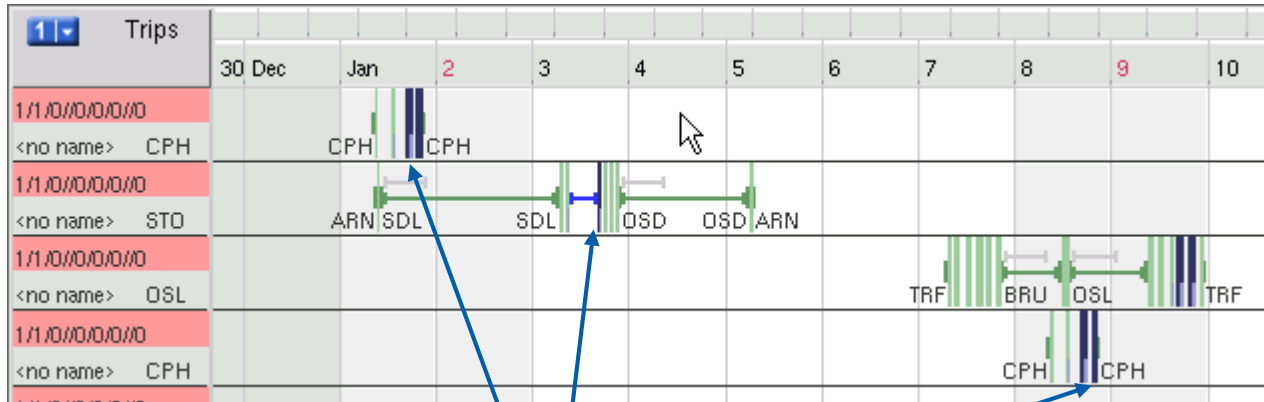
Other fields in the dialog include:

- From date**: "01Jan2000"
- To date**: "05Feb2000"
- Consider Trip periods**: A checkbox labeled "No" (which is unchecked).
- Kind of border handling**: A dropdown menu showing "Start inside".
- Objects to consider**: A dropdown menu showing "Duty".

At the bottom of the dialog, there are four buttons: "OK", "Cancel", "Reset", and "Print". Below the buttons, the text "The smallest objects to consider" is visible.

# Create a dated solution

## After roll-out



Not operating legs after roll-out

# Exercise 5.A

---

**Create a dated solution 5.1 to 5.4**

## **Purpose**

To learn all steps for creating a dated solution



# Exercise 5.A – summary

---


## Summary of exercise



Create a dated solution

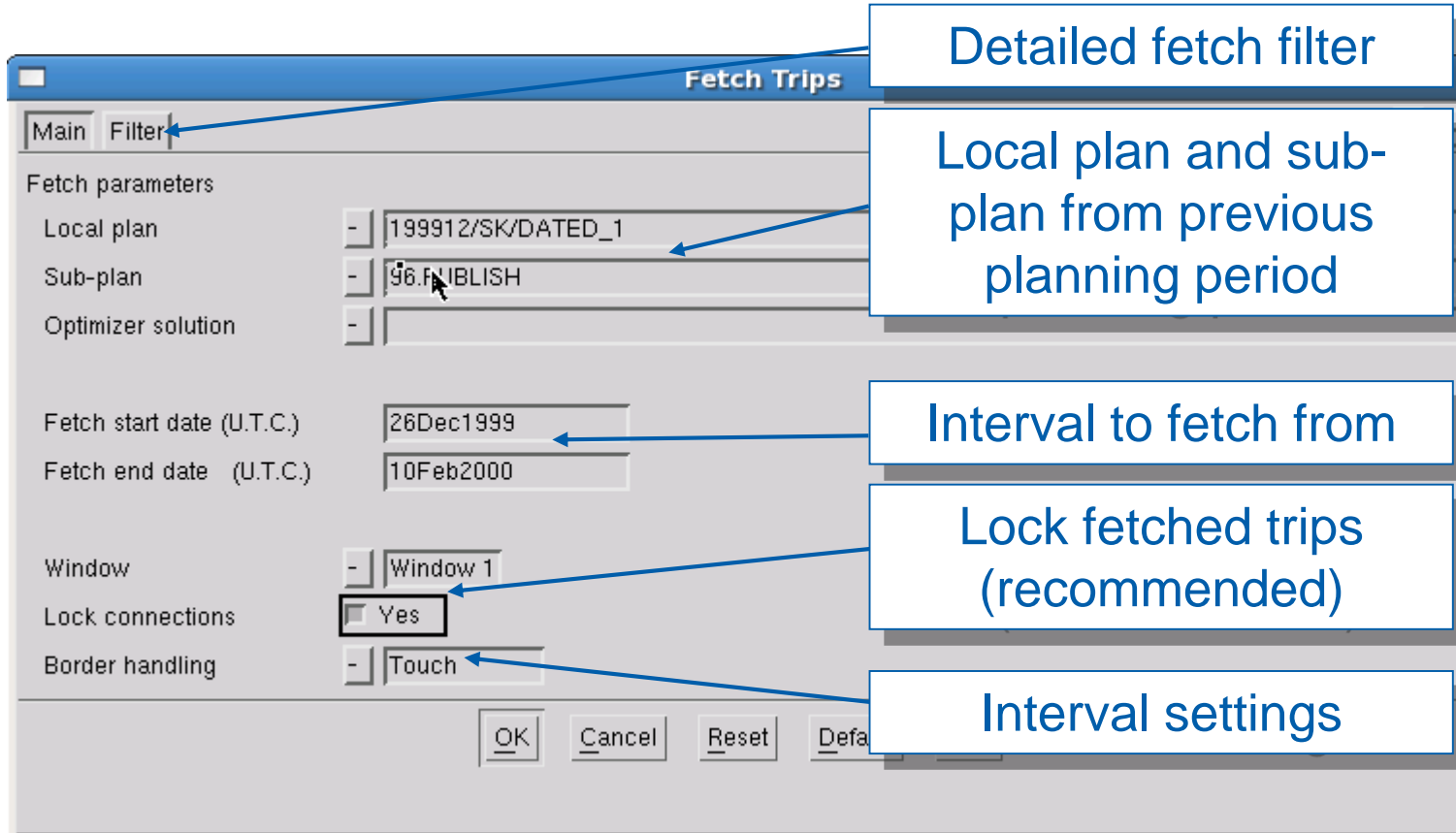
## Add carry-ins and new flights

Add carry-in trips and new flights

- 
- Add carry-in trips from previous planning period
  - Add legs not existing in the standard week

Create a dated solution

# Fetch carry-in trips



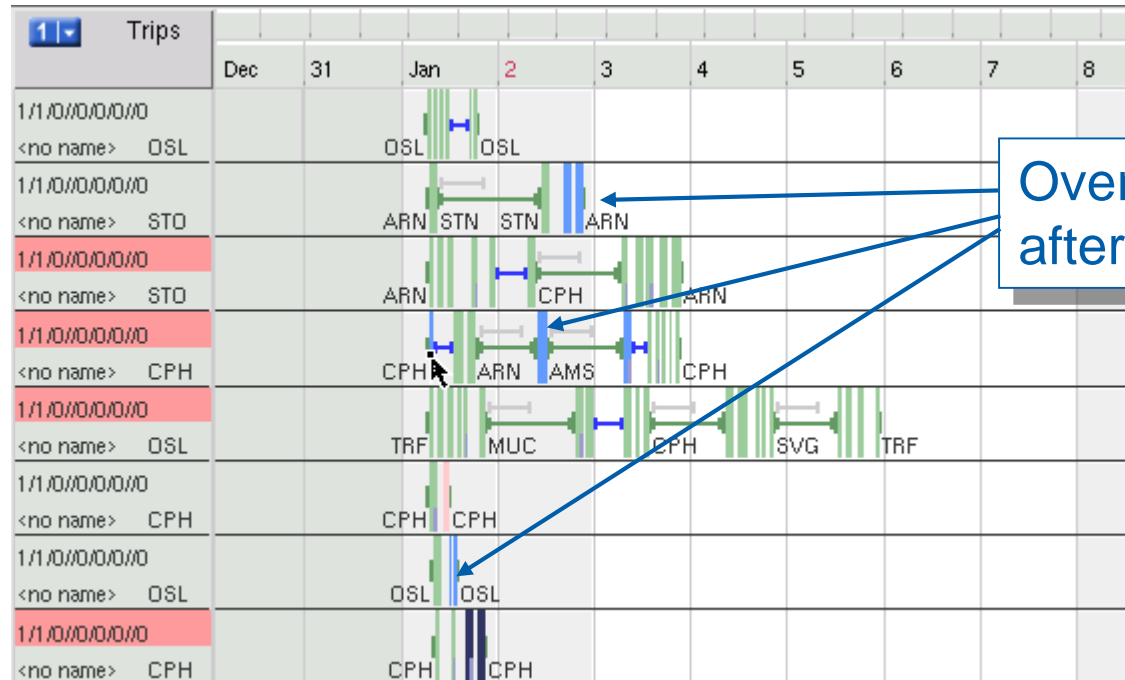
The screenshot shows the 'Fetch Trips' dialog box with the following fields and annotations:

- Fetch parameters:**
  - Local plan: 199912/SK/DATED\_1 (Annotated: Local plan and sub-plan from previous planning period)
  - Sub-plan: 96.PUBLISH (Annotated: Local plan and sub-plan from previous planning period)
  - Optimizer solution: (Empty)
- Fetch start date (U.T.C.):** 26Dec1999 (Annotated: Interval to fetch from)
- Fetch end date (U.T.C.):** 10Feb2000 (Annotated: Interval to fetch from)
- Window:** Window 1 (Annotated: Lock fetched trips (recommended))
- Lock connections:** ☒ Yes (Annotated: Lock fetched trips (recommended))
- Border handling:** Touch (Annotated: Interval settings)

Buttons at the bottom: OK, Cancel, Reset, Default.

Create a dated solution

## After adding carry-in trips



Overbooked legs  
after fetch



# Create a dated solution

## Add new leg

Filter legs in planning period

Add other filter criteria if needed

General

Time Base  LDOP

Leg Values

Flight

Airline Designator

Flight Number

Flight Suffix

Leg Number

Service Type

Traffic Days

Departure

Airport

City

Date

Time

Arrival

Airport

City

Date

Time

Touched

Airport

City

Date

Time

Aircraft

IATA Aircraft Type

Other Properties

Chain User Tags

Tags

Changes

Not Operating

Overbooked

Ground Duty

Block Time

Area

Booked Crew

CP

FO

FE

PU

AP

FA

EP

Remaining Crew Need

CP

FO

FE

PU

AP

FA

EP

Crew Need

CP

FO

FE

PU

AP

FA

EP

Total Crew Need

Flight Deck

Cabin

OK

Cancel

Reset

Default

Print

Copyright © 2016 Jeppesen. All rights reserved. Pairing I

145

Create a dated solution

## After adding new legs

Added legs should be converted to trips before starting the optimizer.

1 ▾	Legs	Dec	31	Jan	2	3	4	5	6	7	8	9
6	1/1/0//0/0/0//0			ARN BRU								
6	1/1/0//0/0/0//0			ARN SFT								
6	1/1/0//0/0/0//0			BRU ARN								
6	1/1/0//0/0/0//0			SDL ARN								
6	1/1/0//0/0/0//0			BRU OSL								
6	1/1/0//0/0/0//0			ARN OSD								
6	1/1/0//0/0/0//0			OSL AES								
6	1/1/0//0/0/0//0			OSD ARN								

Selected Legs

Number of legs found: 84

Cancel

Add to Sub-plan

New selection

# Exercise 5.B

---

## Create a dated solution 5.5 to 5.6

### Purpose

To learn all steps for creating a dated solution



# Exercise 5.B – summary

---






## Summary of exercise



Create a dated solution

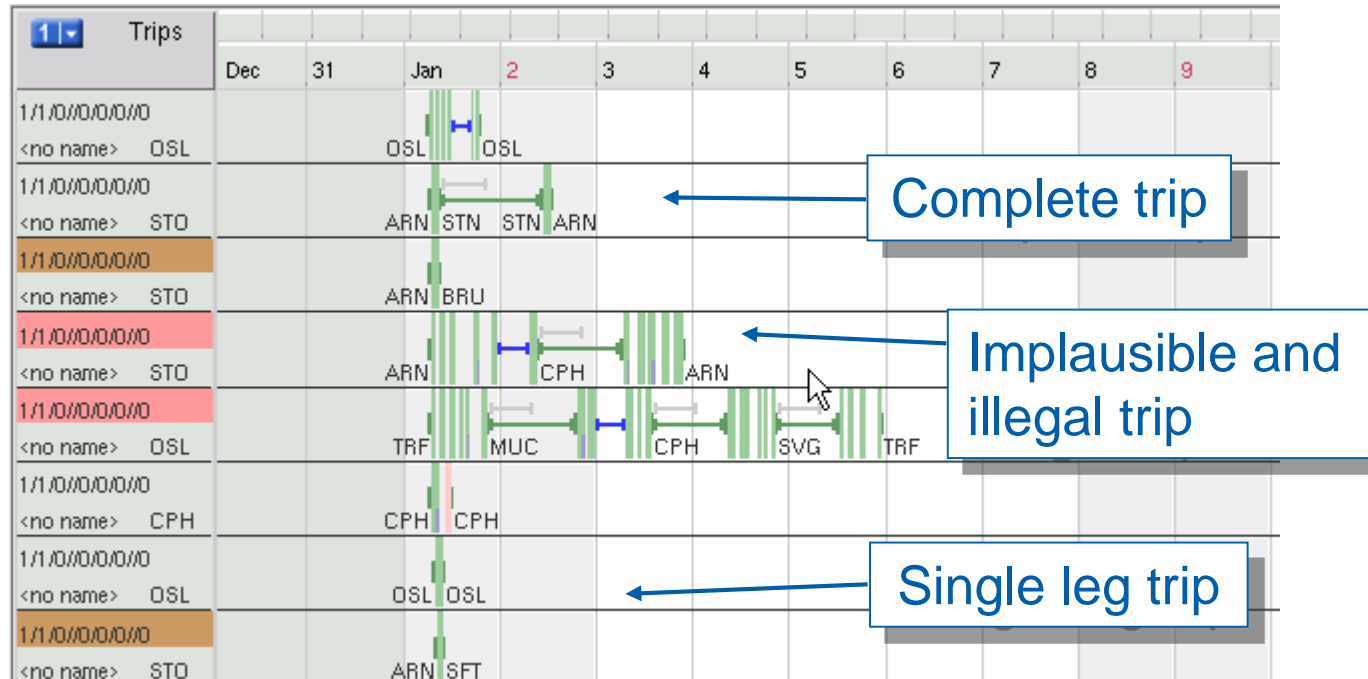
## Remove and repair

### Remove and repair

-  Not operating legs
-  Overbooked legs
-  Other fleet on-duty
-  Set parameters (from file and/or manually)
-  Start Crew Pairing Optimizer

Create a dated solution

# Show all trips and start the optimizer



# Exercise 5.C

---

**Create a dated solution 5.7 to 5.9**

## **Purpose**

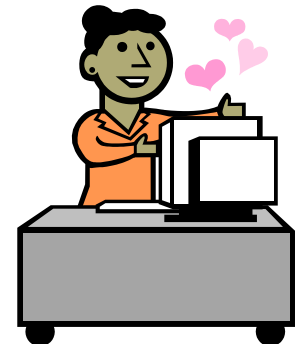
To learn all steps for creating a dated solution



# Exercise 5.C – summary

---

## Summary of exercise





# Variable crew need

---

So far we have only been solving flight deck problems with a crew need of 1 CP and 1 FO (1/1/0).

How are cabin problems solved, where the crew need differs between the different legs?

This typically arises in cross-qualification cabin crew problems.

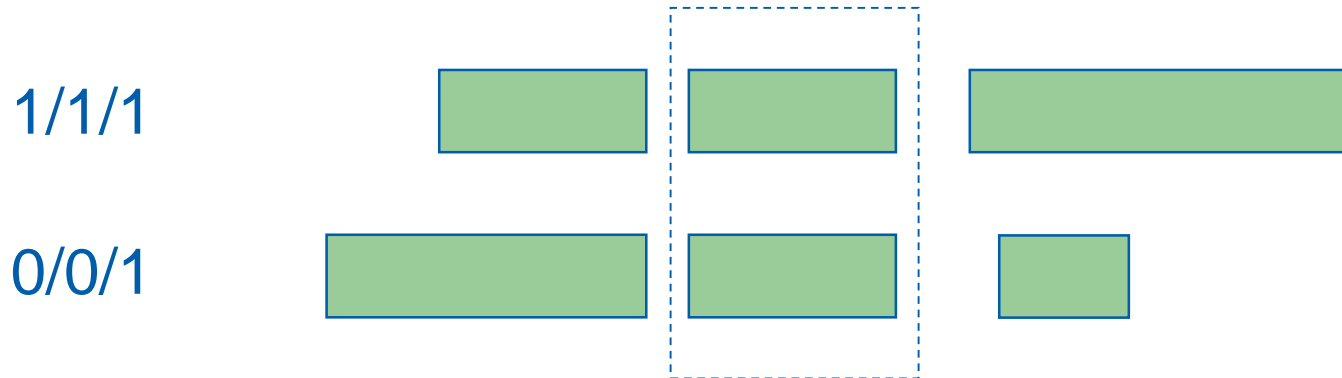
# Variable crew need

Legs have different crew need (e.g. 1/1/1, 1/1/2, 1/1/3)

1 ▾ Legs		Mon	Tue	Wed
1	1	M		
0/0/0//1/1/2//0		CCS PTY		
1	1			
0/0/0//1/1/2//0		MEX ZCL		
1	1			
0/0/0//1/1/2//0		MEX VSA		
1	1			
0/0/0//1/1/1//0		MEX SLW		
1	1			
0/0/0//1/1/1//0		MEX GDL		
1	1			
0/0/0//1/1/2//0		MEX MTT		
1	1			
0/0/0//1/1/3//0		GDL MEX		
1	1			
0/0/0//1/1/2//0		ZCL MEX		

# Variable crew need – crew change

Crew changes increase the sensitivity of the solution as a delay of one leg may have impact on several following legs.



# Variable crew need

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

1. Sub-problems with identical crew need are solved separately (minimise crew changes).
2. 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.
3. Different methods combining the above.

# Variable crew need

## A simple 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)

# Variable 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)

GOOD: No crew changes

BAD: Often expensive

# Variable crew need – example

## Jumper approach

A two step procedure:

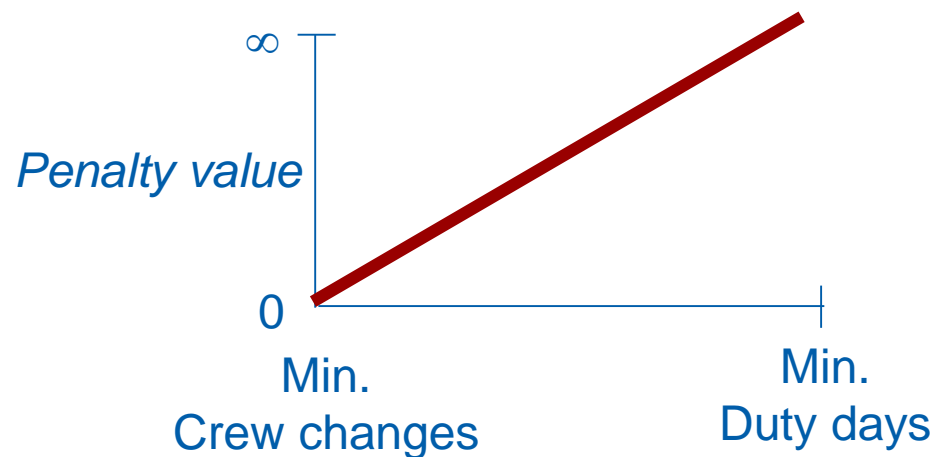
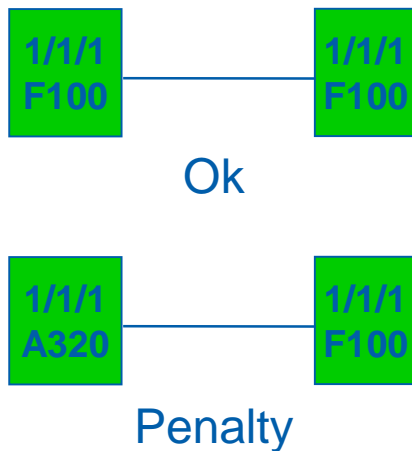
GOOD: Often cheapest  
BAD: Lots of crew changes

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 flight legs are included once. B757 flight legs are included twice.

# Variable crew need

## Penalty approach:

Penalizing connections between flights of non-identical crew need (in the basic solution of jumper approach) will give results somewhere in between:



There is not any “correct” approach - every airline must decide on its own strategy.

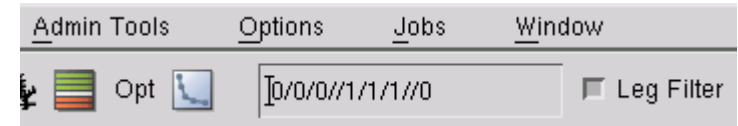


# Variable crew need – Jumpers

- Jumper pairings are usually not popular among crew - no one wants to fly “alone”.
- More jumper pairings can mean more instances of crew changes - and hereby less stable solutions. However, this can somewhat be controlled by forcing imitation between basic and jumper duties.
- Different strategies might be applied depending on flight hours in planning period, vacations, lack of resources etc.

# Variable crew need – Jumpers

When creating new trips from legs – either manually or using the optimizer – the crew complement of any new trip is given by the **assign value**.



# Variable crew need – Jumpers

Several copies of the same leg can be planned at the same time. Hereby, several planning steps can be combined in one.

1 ▾	Trips	Mon	Tue
0/0/0/0/0/1/0	<no name> MEX	MX LAX GDL	
0/0/0/0/0/2/0	<no name> MEX	MLM ZCL	
0/0/0/1/1/1/0	<no name> MEX	MLM ZCL	
0/0/0/0/0/2/0	<no name> MEX	MX 8 ORD MEX	
0/0/0/1/1/1/0	<no name> MEX	MX 8 ORD MEX	
0/0/0/1/1/1/0	<no name> MEX	MX 1 SFO GDL	
0/0/0/0/0/2/0	<no name> MEX	MX LAX MEX	
0/0/0/0/0/2/0	<no name> MEX	MX LAX GDL	

# Exercise 6

---

## Variable Crew Need

### Purpose

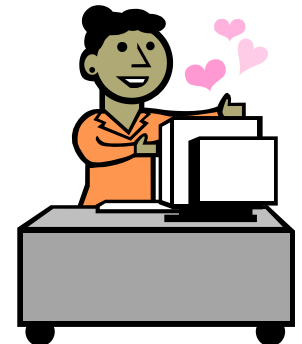
To see differences by solving a variable crew need solution according to different approaches



# Exercise 6 – summary

---

## Summary of exercise



# Regularity

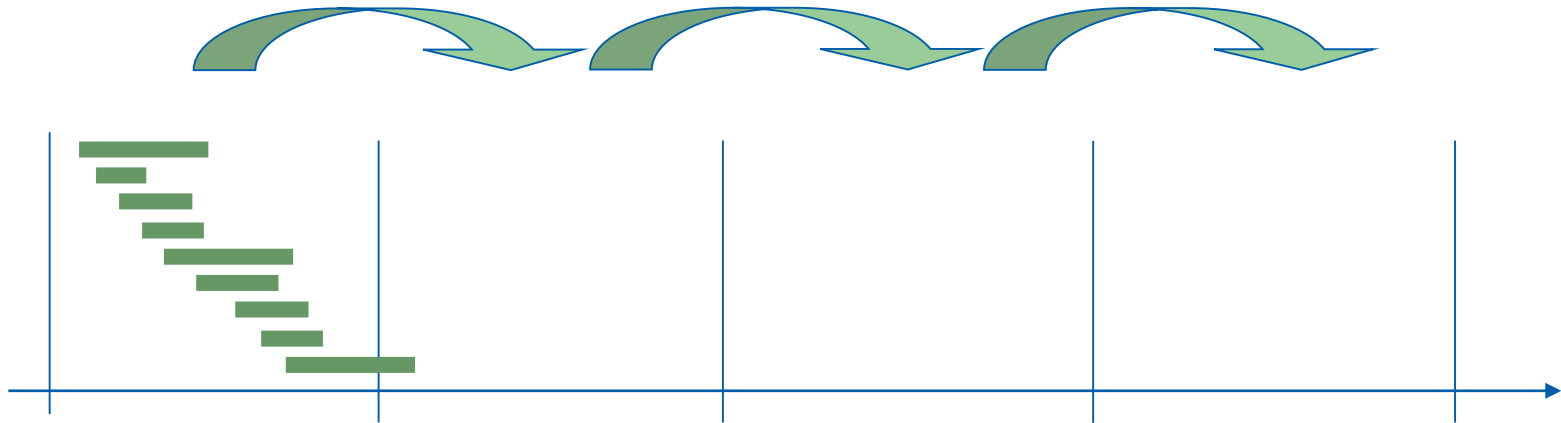
---

Designing trips that are more or less identical from one period to another (typically from week to week:

- Union requirement
- Eases maintenance (day of operation)

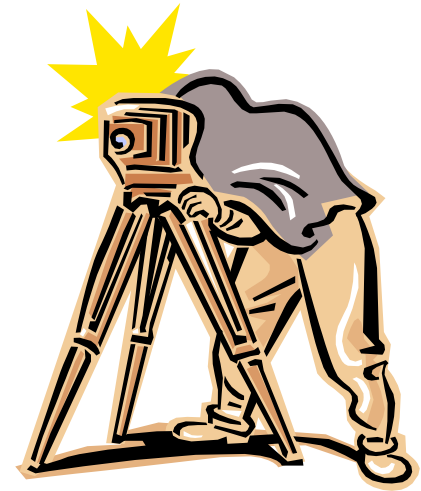
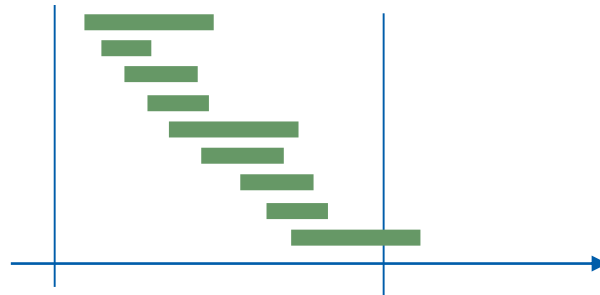
# Regularity

Pattern of the regular solution (daily or standard week solution) should be preserved in the dated solution.



# Regularity

When solving problems arising in dated mode, regularity must be actively supported by rule code (rules and penalties), preserving the structure of the standard week solution.

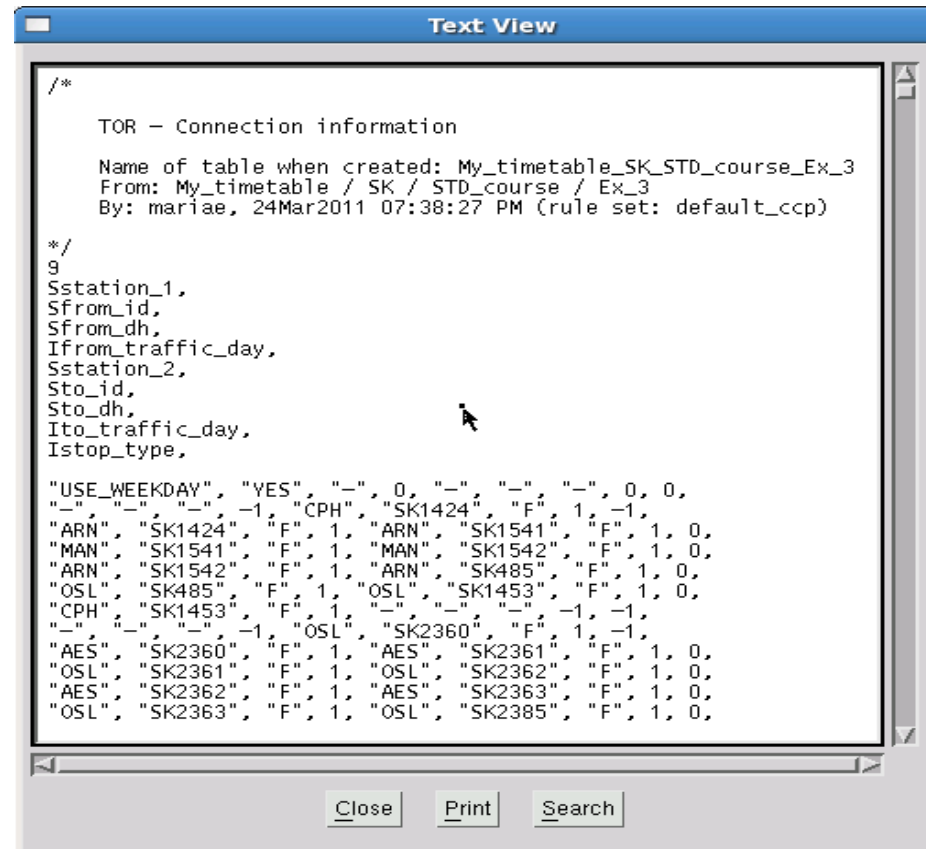




# Regularity

Functionality in the Regularity add-in  
(also called TOR,  
Table Of Regularity):

- takes a snapshot of a regular solution
- adds rules preventing anything but strict regularity
- adds penalties for deviations from strict regularity.



```

/*
TOR - Connection information

Name of table when created: My_timetable_SK_STD_course_Ex_3
From: My_timetable / SK / STD_course / Ex_3
By: mariae, 24Mar2011 07:38:27 PM (rule set: default_ccp)

*/
9
Sstation_1,
Sfrom_id,
Sfrom_dh,
Ifrom_traffic_day,
Sstation_2,
Sto_id,
Sto_dh,
Ito_traffic_day,
Istop_type,

"USE_WEEKDAY", "YES", "-", 0, "-", "-", "-", 0, 0,
"-", "-", "-", -1, "CPH", "SK1424", "F", 1, -1,
"ARN", "SK1424", "F", 1, "ARN", "SK1541", "F", 1, 0,
"MAN", "SK1541", "F", 1, "MAN", "SK1542", "F", 1, 0,
"ARN", "SK1542", "F", 1, "ARN", "SK485", "F", 1, 0,
"OSL", "SK485", "F", 1, "OSL", "SK1453", "F", 1, 0,
"CPH", "SK1453", "F", 1, "-", "-", "-", -1, -1,
"-", "-", "-", -1, "OSL", "SK2360", "F", 1, -1,
"AES", "SK2360", "F", 1, "AES", "SK2361", "F", 1, 0,
"OSL", "SK2361", "F", 1, "OSL", "SK2362", "F", 1, 0,
"AES", "SK2362", "F", 1, "AES", "SK2363", "F", 1, 0,
"OSL", "SK2363", "F", 1, "OSL", "SK2385", "F", 1, 0,

```

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# Activate TOR table

**Carmen Crew Pairing (pairing\_1\_system) My\_timetable/SK/DATED\_course/Ex\_5.7\_opt\_prepared default\_1**

File Edit Planning Tools Admin Tools Options Jobs Window Help

Plan Manager... Scenario Analyzer... Opt 1/1/0//0/0/0/0 Leg Filter Rotation Filter Trip Filter 19:44

Trips

- 1/1/0//0/0/0/0
- <no name> OSL
- 1/1/0//0/0/0/0
- <no name> OSL
- 1/1/0//0/0/0/0
- <no name> STO
- 1/1/0//0/0/0/0
- <no name> STO
- 1/1/0//0/0/0/0
- <no name> CPH
- 1/1/0//0/0/0/0
- <no name> STO
- 1/1/0//0/0/0/0
- <no name> STO

Local Plan Sub-plan Rule Parameters... External Table Manager... TOR Table Manager... Airport Manager... Saved Reports Manager... Generate Report... Process Automation

OSL

OSL ARN

CPH WAW

BRU ARN

SDL ARN

908 rows

SK 668 \* STR - CPH J 7:00 - 8:40 LEG: Local: 8:00 - 9:40 DUTY: Block 1:40 Duty 3:10 Rest - Need: 1/1/7 User tags: ..... TRIP: Block 15:50 Duty 32:05 Duty Days 5

Manipulate and open local plans and sub-plans

**TOR Table Manager**

Files/My\_timetable\_SK\_STD\_course\_Ex\_3

Directory File

Files My\_timetable\_SK\_STD\_course\_Ex\_3

Close View Text View Delete Print Info **Activate for Current Sub-plan**

# Exercise 7

---

## Extra exercise – Imitation

### Purpose

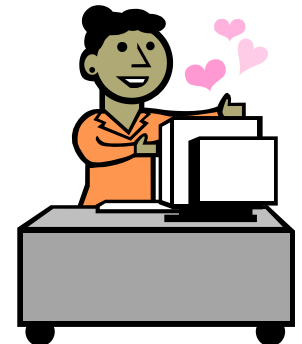
To get a picture on how imitation effects the solution.



# Exercise 7 – summary

---

## Summary of exercise



# Summary

- Four modules
- Windows and menus
- Manual planning functions
- Planning concepts
- Rules: legal, union and quality
- Standard week solution
- Influence the solution by penalties
- Dated solution
- Variable crew need
- Imitation



# Summary

## Planning process

- ↪ Create standard local plan
- ↪ Build rotations
- ↪ Load rules and parameters
- ↪ Create sub-plan by adding legs
- ↪ Run Crew Pairing Optimizer
- ↪ Verify solution
  
- ↪ Create dated local plan
- ↪ Build rotations
- ↪ Roll out standard solution to dated
- ↪ Load rules and parameters
- ↪ Add carry-in trips
- ↪ Remove NOPs, overbooked etc.
- ↪ Add new legs
- ↪ Run Crew Pairing Optimizer
- ↪ Verify solution



# Exercise 8

---

## Entire Process Steps

**Purpose**  
Repetition

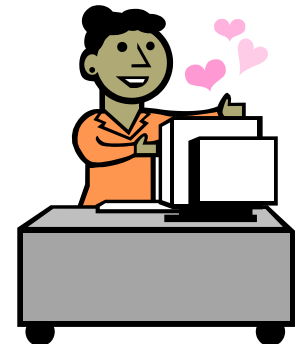




# Exercise 8 – summary

---

## Summary of exercise



# 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)

Are the exercise definitions too vague (too real-life), would you like them to be more exact and straight forward?

Would you like to have even more info on slides (for self studying) or would you be stressed about the time constraint?

# The end

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