Who I am?

Daniel Roth
Senior Business Advisor
Boeing Global Services
24/7 World-class Customer Support anytime, anywhere

Supply Chain
Delivering the one part you need, precisely when you need it.

Engineering, Modifications & Maintenance
Optimizing fleet performance and maintenance operations to OEM Standards.

Digital Solutions & Analytics
Providing data-driven solutions to complete today's mission

Training & Professional Services
Helping meet global demand for qualified and competent aviation personnel.
Airline Crew Scheduling

Manpower Planning
- Long-term planning

Crew Pairing
- Build duties

Crew Rostering
- Assign duties

Crew Tracking
- Maintain and recover crew plan

Calibration
- Improve crew/AC plan

Fatigue Risk Management

Objective function
\[
\text{minimize } c^T x \\
\text{subject to } Ax = 1 \\
x \in \{0,1\}^n
\]

Coverage constraints
- Each crew has 1 roster
- Each trip is assigned

Example: Roster 5
- \( c_k \): Cost of roster 5
- \( x_k \): 1 if roster 5 is assigned, else 0
- \( a_k \): Crew assignable and trips on roster 5
Solving the problem

- Rostering problem:
  - Largest real problem in test suite: 20,000 crew

- Impossible to generate all possible rosters
  - Use a column generation framework to generate a solution

- Pricing problem
  - Very important part of solving the problem
  - Consists of generating rosters for crew
  - Solve for one crew member at a time
Small example: 2 crew, 4 trips, 4 rosters

Roster 1: | 1 | 3 | 4 | trips 1, 3 and 4 assigned, | cost 20 |
Roster 2: | 2 | 4 | | trips 2 and 4 assigned, | cost 10 |
Roster 3: | Preassignment | trip 1 assigned, | cost 15 |
Roster 4: | Preassignment | trip 2 assigned, | cost 10 |

Optimization

\[ \min c^T x = \min c_1 x_1 + c_2 x_2 + c_3 x_3 + c_4 x_4 = \min 20 x_1 + 10 x_2 + 15 x_3 + 10 x_4 \]

subject to \( A x = \)

Optimal solution:

\[ x_1 = 1, x_2 = 0, x_3 = 0, x_4 = 1 \]

Assign Roster 1 (to crew 1) and Roster 4 (to crew 2)

Total cost: 30
How do we define the “best solution”?

**Input from end-user (planner)**

**Solution preference**

- **Fairness**: Divide workload equally
- **Robustness**: Include rest buffers
- **Quality**: Avoid working too many night shifts
- **Bids**: Crew’s personal preference

**Rules**

- 12 hours of rest after a trip
- At most 80 working hours per month
  …

**Cost function**

\[ C_1 \times Fairness + C_2 \times Robustness + C_3 \times Quality + C_4 \times Bids + \ldots \]

**User input is a black box for the optimizer**

- Q: Cost of roster \( R_{12345} \)?
  A: Cost of roster \( R_{12345} \) is 4500

- Q: Is roster \( R_{54321} \) legal?
  A: Roster \( R_{54321} \) is illegal

Solution preferences and rules (and therefore the black box) are unique for each airline
The optimizer must handle any black box
Covid-19 spreads over the world

30 SAS cabin crew started a 3 day course on Monday at Sophiahemmet University to learn to become nursing assistants. 270 more will follow. Credit: Dave Russell/Radio Sweden

Source: https://sverigesradio.se/artikel/7442564
A Friday in April, 2020…
Friday Afternoon 3rd

- Around noon, Jeppesen received a call from the ICU management at Karolinska
- We decided to have a meeting on the following Monday…
- …but started to build a system over the weekend with the little knowledge that we had
Weekend

- Numerous phone calls and text messages with Karolinska management
- Next week’s rosters created (6-12)
- Crisis agreement from Wednesday
Monday morning

- ICU staff, no problem
- "Others" are problematic
- Need to publish by Wednesday evening for the coming week
- 10:00 Decision made
  "Let the Boeing guys fix the scheduling issue for all nurses, so that we can focus on intensive care"
- Swiftly needed to put a contract in place between Boeing and Karolinska

... but our system isn't built for nurse scheduling..
Iterative process – Data feeds

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- **Day/night**: night/daynight/daynight/night
Iterative process - Constraints

• Work “items” are 12 hour long shifts (not flights)
  • 07:00-19:30
  • 19:00-07:30
  • No ”need”, just as many as possible

• Competences per shift
  • At least 6 VL
  • HIGH
  • MEDIUM
  • BASIC

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• Even amount of work **over time**
  • Heads, and competences
Even distribution - over time

- Shifts are not flights
  - Flights have a certain "need"
  - 1 Captain, 1 First Officer etc

We want "as many as possible"

- We don’t want to have 30 nurses one shift, and 22 the next
  - Can be solved with "many shifts", per shift, which have an increasing unassigned cost

```plaintext
export %unassigned_trip_cost% =
  %trip_cost_multiply% * %unassigned_factor%;

%trip_cost_multiply% =
  %max_multiplier% - %trip_cost_multiply_prio%;

%max_multiplier% = 10;

table cost_multiply_prio_table =
  trip.%name%  -> int %trip_cost_multiply_prio%;
  "1"   -> 1;
  "2"   -> 2;
  "3"   -> 3;
  "4"   -> 4;
  "5"   -> 5;
  "6"   -> 6;
  "7"   -> 7;
  "8"   -> 8;
  "9"   -> 9;
  -   -> %max_multiplier%;
end

%unassigned_factor% =
  parameter 10
  remark "Factor unassigned work";
```
Tuesday - Wednesday

• A lot of updates to the data, over and over again as the hospital needed to re-prioritize a lot of care to send nurses to ICU.

• Also, new requirements coming in all the time. Certain people have certain work needs e.g. “only works days”

• The patterns are not workable
Iterative process – Rules

- Ordinary working rules does not apply
- Try to achieve 9 hours of rest per 24 hours
- Try to achieve 24 hours of rest per week
- The regular work hours for full-time employees should on average be 48 hours per week
Iterative process – Rules

• What would a legal pattern look like?
  
  • Agreed on a 3 ON, 3 OFF (at most)
    • Stay away from single nights
Wednesday evening

• Solution looks good!
• Human readable schedule report implemented and…
  … printed! (~300 nurses)

• Roster inspection
  • Is "day" == "dag"
  • Is "tre nätter" == "three_nights" ?

• Publication postponed to Thursday
Thursday ...

- Rosters published to ICU nurses

- "Other nurses" rosters published on Friday

- The rosters were photo-graphed and sent by MMS to ~300 nurses
What happened then?

**Initial contact**
Phone call on April 3

**First roster period published**
4 weeks at Solna

**Scenario Analysis**
- Staffing levels
- Improved working conditions
- Implementation of regular 24/7 agreement

**Second roster period published**
For both Solna and Huddinge
"Crisis Agreement 2.0" with new roster rules for improved working conditions:
- Minimum weekends off
- More fair distribution of night duties with 3 different profiles
- Minimum rest after night duties

**Re-plan**
Agreement clarification
Improved distribution

Rostered Karolinska and Huddinge until 1 Sep
Supporting the real heroes...

Tack för att ni finns och för all hjälp ni har gett oss! Tillsammans räddar vi liv!!

/Lisa