



Karolinska ICU Planning

September 2024

Who I am?



Daniel Roth
Senior Business Advisor

The Boeing Company



COMMERCIAL AIRPLANES

A complete family of the world's most versatile commercial airplanes



DEFENSE, SPACE & SECURITY

The world's leader in delivering decisive mission advantage to its global customers through cutting-edge capabilities



GLOBAL SERVICES

A dedicated services business focused on keeping the world's fleet flying safely, sustainably and efficiently



Protect, connect and explore our world and beyond

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.

A history of innovation and business development

Project **CARM**

Start at



is founded



Acquires Carmen

1987



1994

2000

2006

2012



Lufthansa

Service
Center



forms

Digital Aviation Solutions
Integration of Jeppesen

Jeppesen Sweden Office – Jeppesen Systems AB



- ~ 340 employees
- ~ 100 contractors
- ~ 50 nationalities
- Most employees with MSc/BSc or PhD

Clients

- Global airlines
- Commercial market
 - Passenger
 - Cargo
- 20+ aircraft, ~1000 crew members
- Fleet agnostic



Crew & Network Operations customers



Crew & Network Operations



Flight Scheduling

Aircraft Routing

Tail Assignment

Ops Control

Fleet Insight

FlightChat



Manpower Planning

Crew Pairing

Crew Rostering

Crew Tracking

Calibration

Fatigue Risk Management

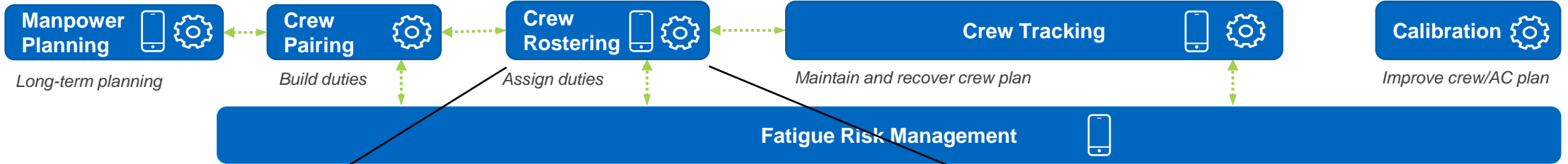


Turn Manager

With optimization

With web/mobile module

Airline Crew Scheduling



$$\begin{aligned} &\text{minimize } c^T x && \text{Objective function} \\ &\text{subject to } Ax = 1 && \text{Coverage constraints} \\ & && x \in \{0,1\}^n && \begin{aligned} &- \text{Each crew has 1 roster} \\ &- \text{Each trip is assigned} \end{aligned} \end{aligned}$$

where $x_i = \begin{cases} 1 & \text{if roster } i \text{ is assigned} \\ 0 & \text{else} \end{cases}$ for $i = 1, 2, \dots, n$

$A = [a_1 \ a_2 \ \dots \ a_n]$, where e.g. $a_j = \begin{bmatrix} 1 \\ 0 \\ \vdots \\ 1 \\ 0 \\ 0 \\ \vdots \\ 1 \end{bmatrix}$

Assignable to crew 1 \rightarrow (points to the first row of the vector a_j)

Number of crew (points to the first three elements of the vector a_j)

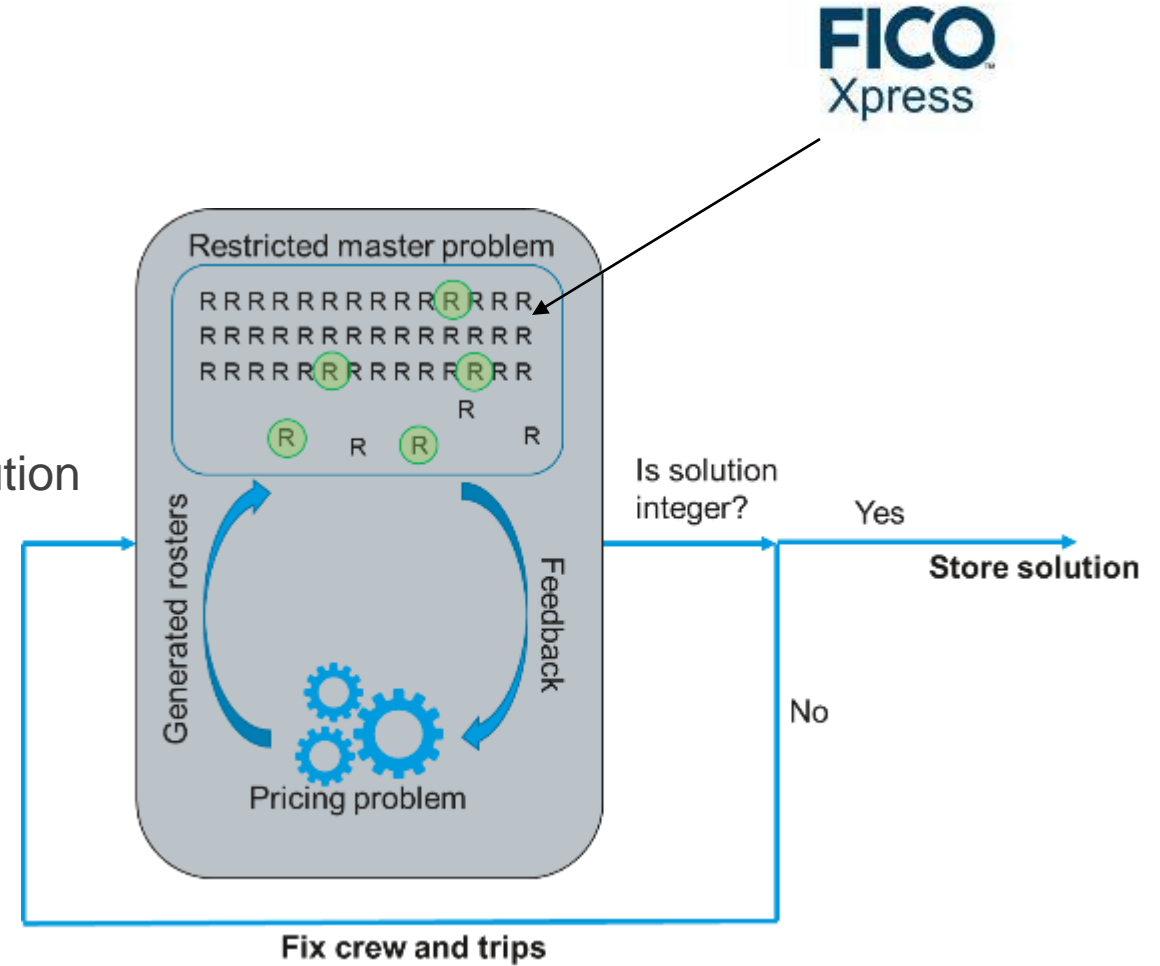
Number of trips (points to the last three elements of the vector a_j)

$j \in \{1, 2, \dots, n\}$

Example: Roster 5
 c_5 : Cost of roster 5
 x_5 : 1 if roster 5 is assigned, else 0
 a_5 : 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



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

Cost function

$$\begin{aligned} &C_1 \times \textit{Fairness} \\ &+ C_2 \times \textit{Robustness} \\ &+ C_3 \times \textit{Quality} \\ &+ C_4 \times \textit{Bids} \\ &+ \dots \end{aligned}$$

Rules

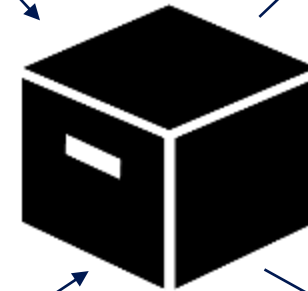


12 hours of rest after a trip
At most 80 working hours per month
...

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

Small example: 2 crew, 4 trips, 4 rosters

Roster 1:	1 3 4	trips 1, 3 and 4 assigned,	cost 20	} Crew 1
Roster 2:	2 4	trips 2 and 4 assigned,	cost 10	
Roster 3:	1 Preassignment	trip 1 assigned,	cost 15	} Crew 2
Roster 4:	2 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 $Ax =$

Crew 1	1	1	0	0	$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$	$=$	$x_1 + x_2$	1
Trip 1	0	0	1	1			$x_3 + x_4$	1
Trip 3	1	0	1	0			$x_1 + x_3$	1
Trip 4	1	0	0	0			$x_2 + x_4$	1
	1	1	0	0	x_1	1		
	1	1	0	0	$x_1 + x_2$	1		

$$x \in \{0,1\}^n$$

Crew 1 should get either roster 1 or 2

Trip 1 should be part of roster 1 or 3

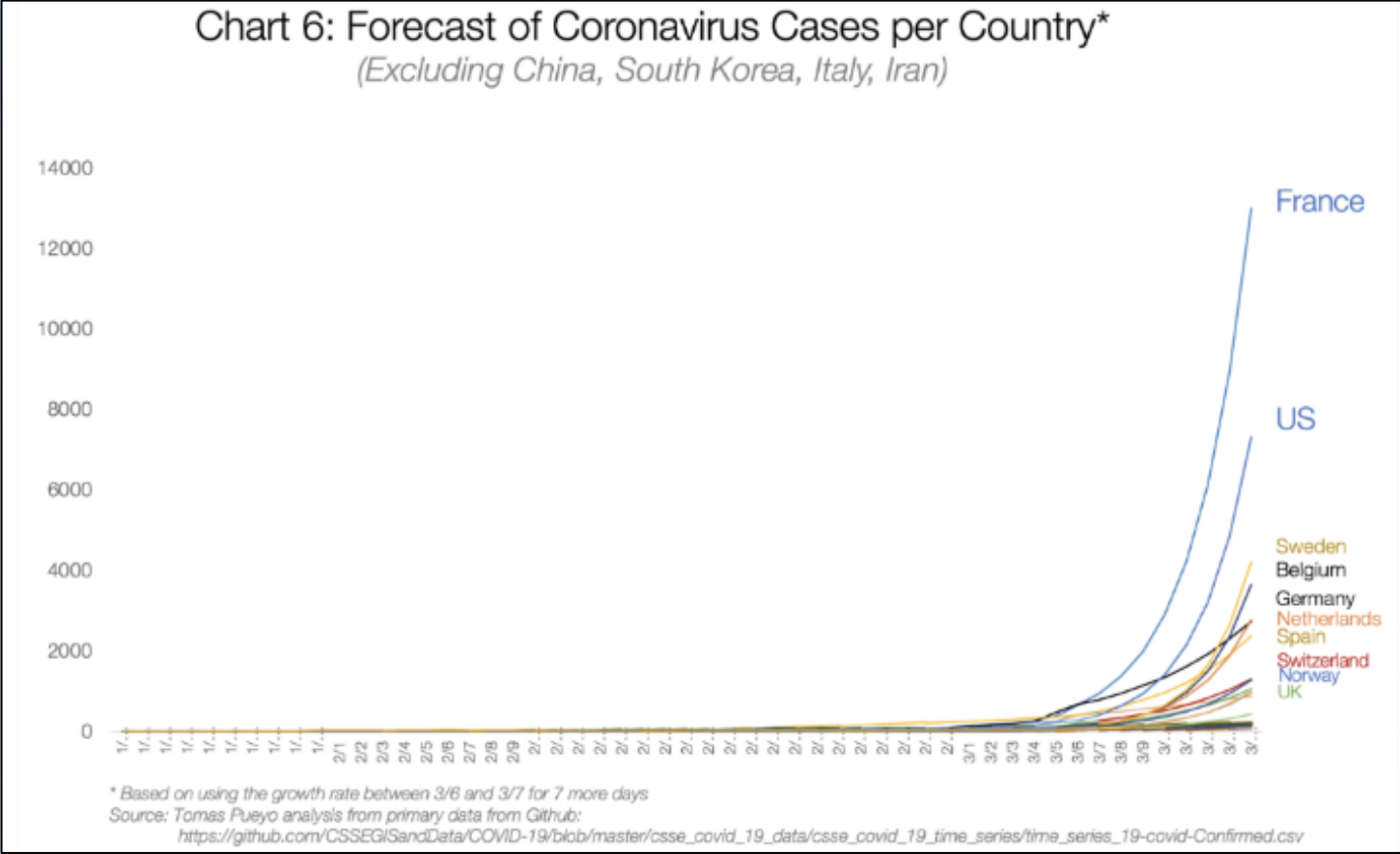
Optimal solution:

$$x_1 = 1, x_2 = 0, x_3 = 0, x_4 = 1$$

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

Total cost: 30

Covid-19 spreads over the world



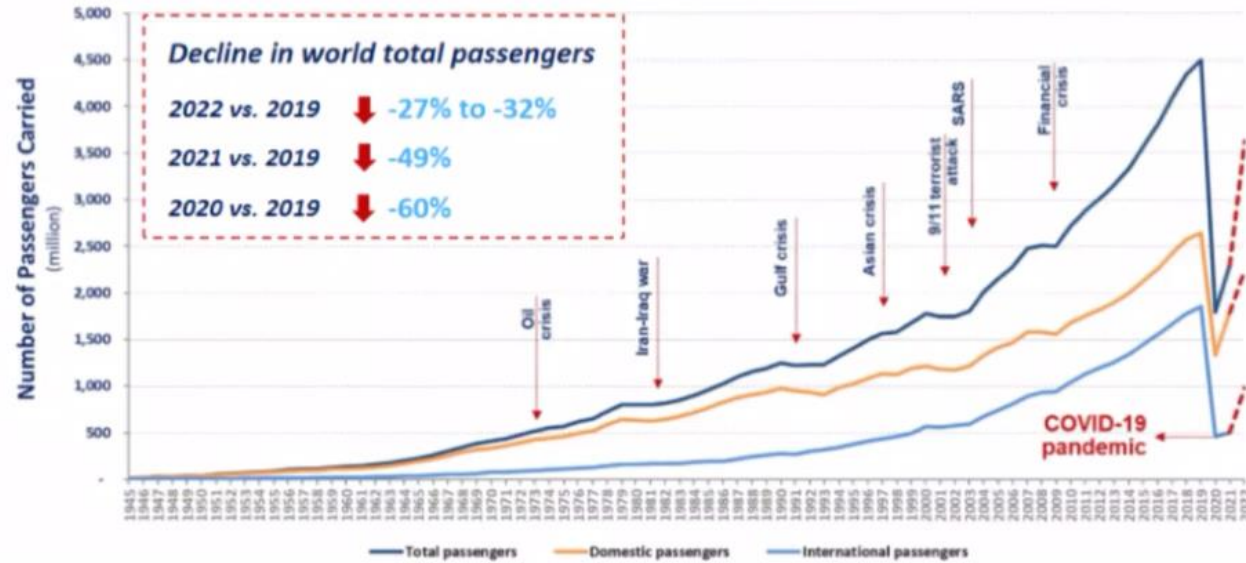
Covid-19 spreads over the world



ICAO UNITING AVIATION

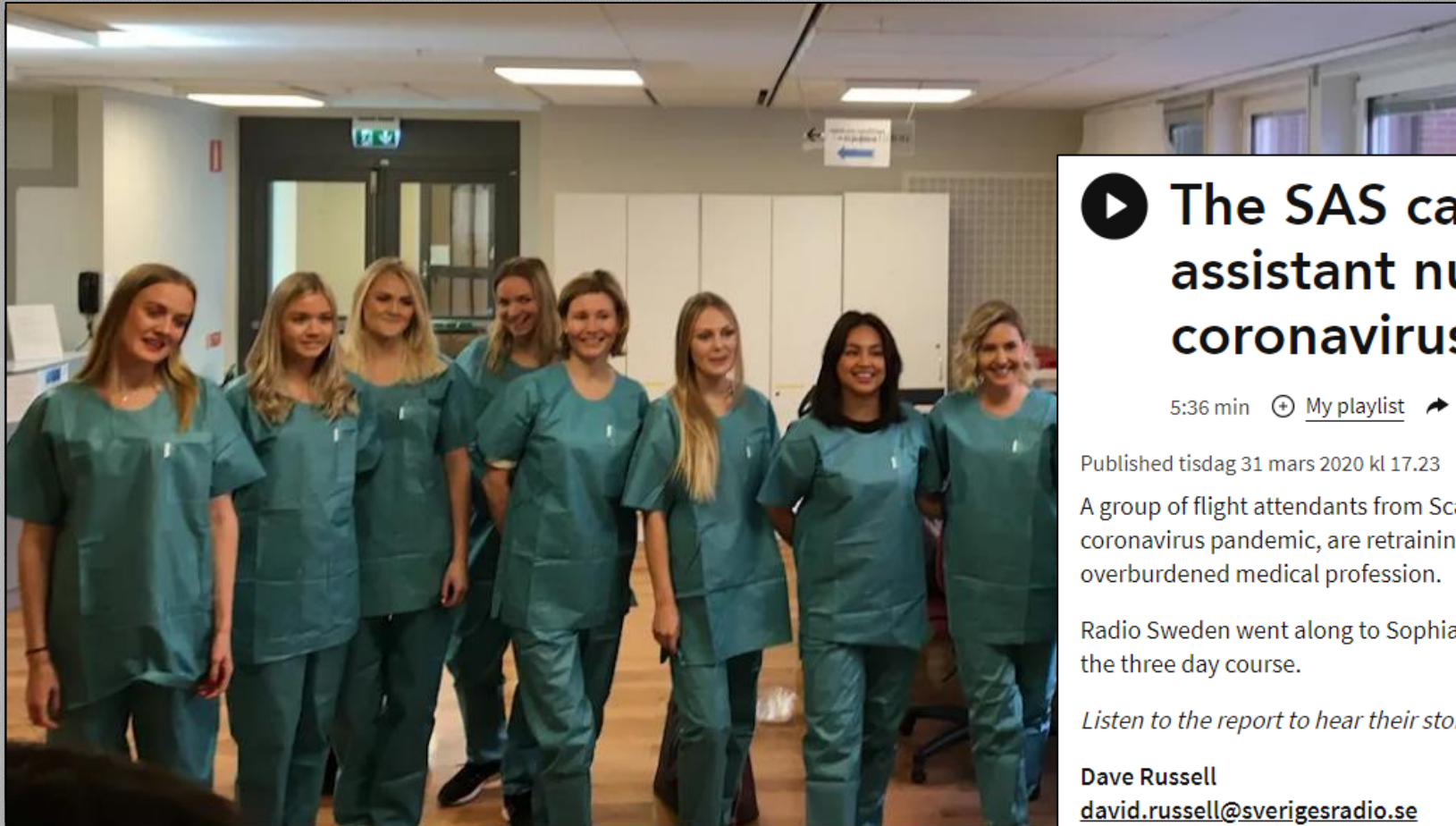
World passenger traffic collapses with unprecedented decline in history

**World passenger traffic evolution
1945 – 2022**



Source: ICAO Air Transport Reporting Form A and A-S plus ICAO estimates.

Covid-19 spreads over the world



▶ The SAS cabin crew retraining as assistant nurses to help during coronavirus pandemic

5:36 min [My playlist](#) [Share](#)

Published tisdag 31 mars 2020 kl 17.23

A group of flight attendants from Scandinavian Airlines SAS who have been laid off due to the coronavirus pandemic, are retraining as assistant nurses to help relieve the load on the overburdened medical profession.

Radio Sweden went along to Sophiahemmet University to meet some of the flight attendants taking the three day course.

Listen to the report to hear their story.

Dave Russell
david.russell@sverigesradio.se

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...

Flattening the curve

Daily
number of

Cases with
protective mea

START PRESS WINNERS JURY CHALLENGES INSPIRATION PARTNER



HACK THE CRISIS

3 - 6 APRIL

STHLM

Crisis agreement activated for health care personnel

PUBLICERAD 2020-04-03

Arbetsgivarorganisationen Sobona och Sveriges Kommuner och Regioner (SKR) aktiverar krislägesavtalet för intensivvården i Stockholm - för första gången någonsin.

Orsaken är den omfattande påverkan på personalförsörjningen.

TT
Text



Läs senare



Published by



Gustav Jannerland
FÖRSÄLJNING/HR/LEDARSKAP
Published • 3w

1 article

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Min tveklöst vackraste deal någonsin kom under den svåraste veckan på länge. Stor kram till Karolinska Universitetssjukhuset och Jeppesen Systems AB! #coronakrisen #nätverk #jeppesensystems #intensivvård #hjältar #varsel #corona #covid19

Like Comment Share

656 · 99 Comments

Friday Afternoon 3rd





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

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3 	4	5
6 	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	May 1	2	3
4	5	6	7	8	9	10

Initial call

Weekend

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

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3 	4 	5 
6 	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	May 1	2	3
4	5	6	7	8	9	10

Initial call

Crisis Agreement period starts

Planned rosters end here

FRI	SAT	SUN	MON	TUE	WED	THU	FRI	SAT	SUN	MON
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

Iterative process – Data feeds

	A	B	C	D	E	F	G	H	I	J	K	L
1	ID	From	To	Namn	Position	LARM	VL	NEURO	ECMO	PT	day/night/daynight	
2	CID_02001	2020-01-01	2022-01-01	Namn 1	ISSK				ECMO	PT	night	
3	CID_02002	2020-01-01	2022-01-01	Namn 2	ISSK	LARM		NEURO			daynight	
4	CID_02003	2020-01-01	2022-01-01	Namn 3	ISSK		VL				dag	

	A	B	C	D
1	ID	From	To	Code
2	CID_02001	2020-04-08 19:00	2020-04-09 07:30	WORK
3	CID_02001	2020-04-09 19:00	2020-04-10 07:30	WORK
4	CID_02001	2020-04-10 19:00	2020-04-11 07:30	WORK
5	CID_02002	2020-04-07 07:00	2020-04-07 19:30	WORK
6	CID_02002	2020-04-08 07:00	2020-04-08 19:30	WORK
7				
8				



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

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

Number of people per shift																	
Date	10N	11N	12N	13D	13N	14D	14N	15D	15N	16D	16N	17D	17N	18D	18N	19D	19N
SSK	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
USK	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
ECMO	7	8	6	5	8	7	8	7	9	4	4	9	7	7	6	8	7
LARM	1	1	2	3	4	1	1	3	3	4	3	2	2	1	3	3	3
VL	6	8	6	9	7	8	9	8	9	7	6	6	6	6	6	7	9

Even distribution - over time

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

```
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";
```

FRI

SAT

SUN

MON

TUE

WED

THU

FRI

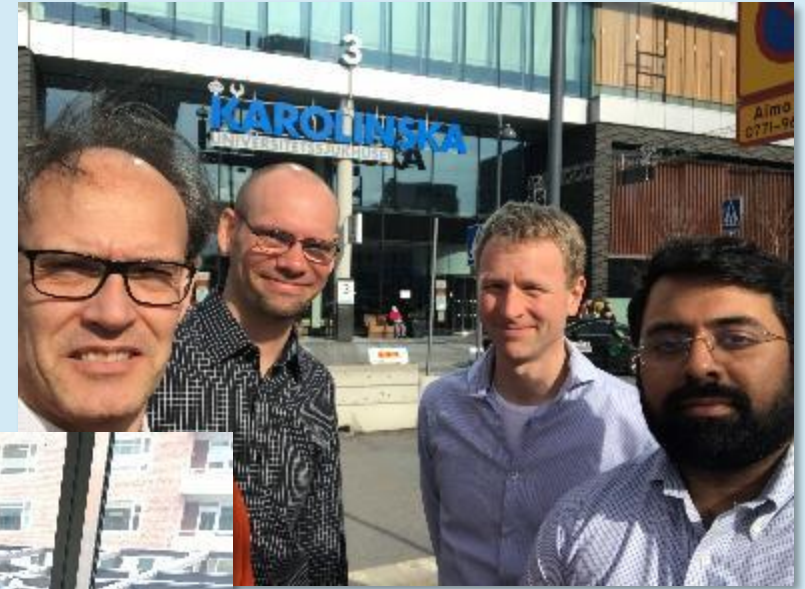
SAT

SUN

MON

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



Initial call

Crisis Agreement period starts

Current rosters end here

FRI

SAT

SUN

MON

TUE

WED

THU

FRI

SAT

SUN

MON

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

§ 3 Arbetstid

- a) Arbetstidslagen (ATL) gäller inte.
- b) Den ordinarie arbetstiden för heltidsanställd ska vara i genomsnitt 48 timmar per vecka.
- c) En beräkningsperiod kan omfatta högst fyra veckor.
- d) Rast kan bytas mot måltidsuppehåll.



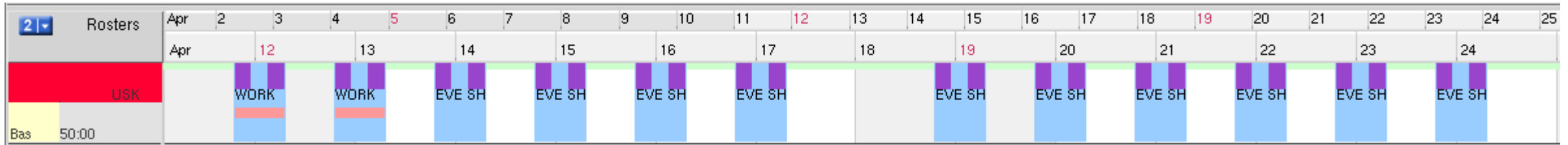
Anmärkning

Med måltidsuppehåll menas paus som räknas in i arbetstiden.

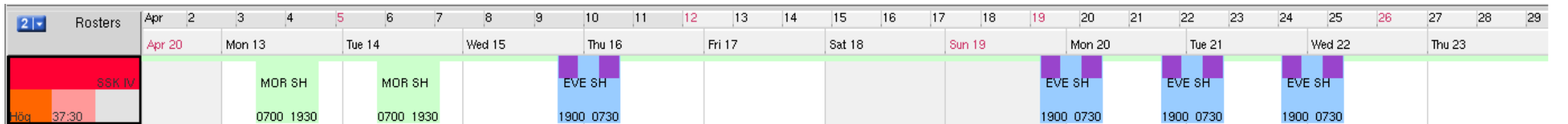
- e) Arbetsgivaren bör eftersträva att den sammanhängande dygnsvilan inte understiger ett genomsnitt av nio timmar under varje period av 24 timmar under beräkningsperioden.
- f) Arbetsgivaren bör eftersträva att den sammanhängande veckovilan inte understiger 24 timmar under varje period om sju dagar.
- g) I omedelbar anslutning till det sista arbetspasset som utförs på detta avtal ska arbetstagare tillförsäkras 24 timmars vila.

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



Initial call

Crisis Agreement
period starts

Current rosters
end here

FRI

SAT

SUN

MON

TUE

WED

THU

FRI

SAT

SUN

MON

Thursday ...

- Rosters published to ICU nurses
- "Other nurses" rosters published on Friday
- The rosters were photo-graphed and sent by MMS to ~300 nurses



Initial call

Crisis Agreement
period starts

First rosters published
ICA nurses at **Solna**

Rosters published
Other nurses

Current rosters
end here

FRI

SAT

SUN

MON

TUE

WED

THU

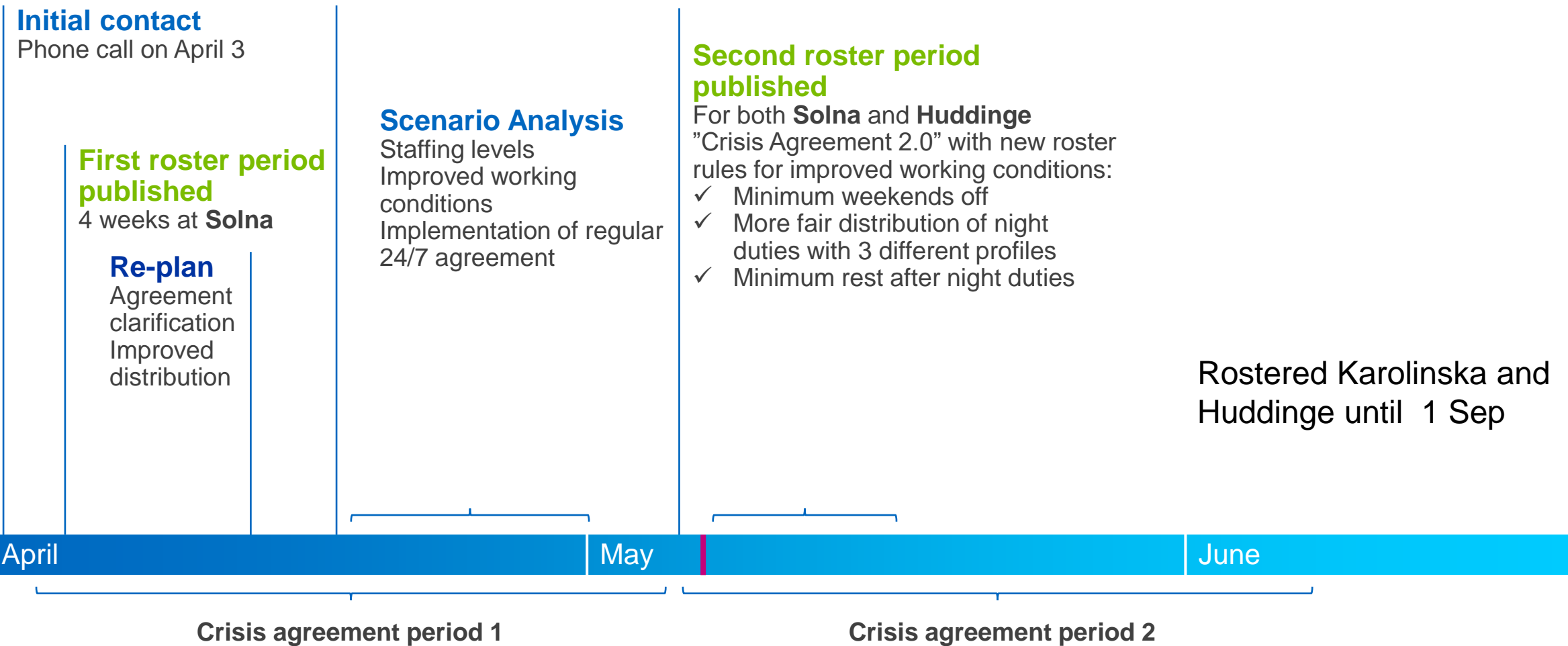
FRI

SAT

SUN

MON

What happened then?

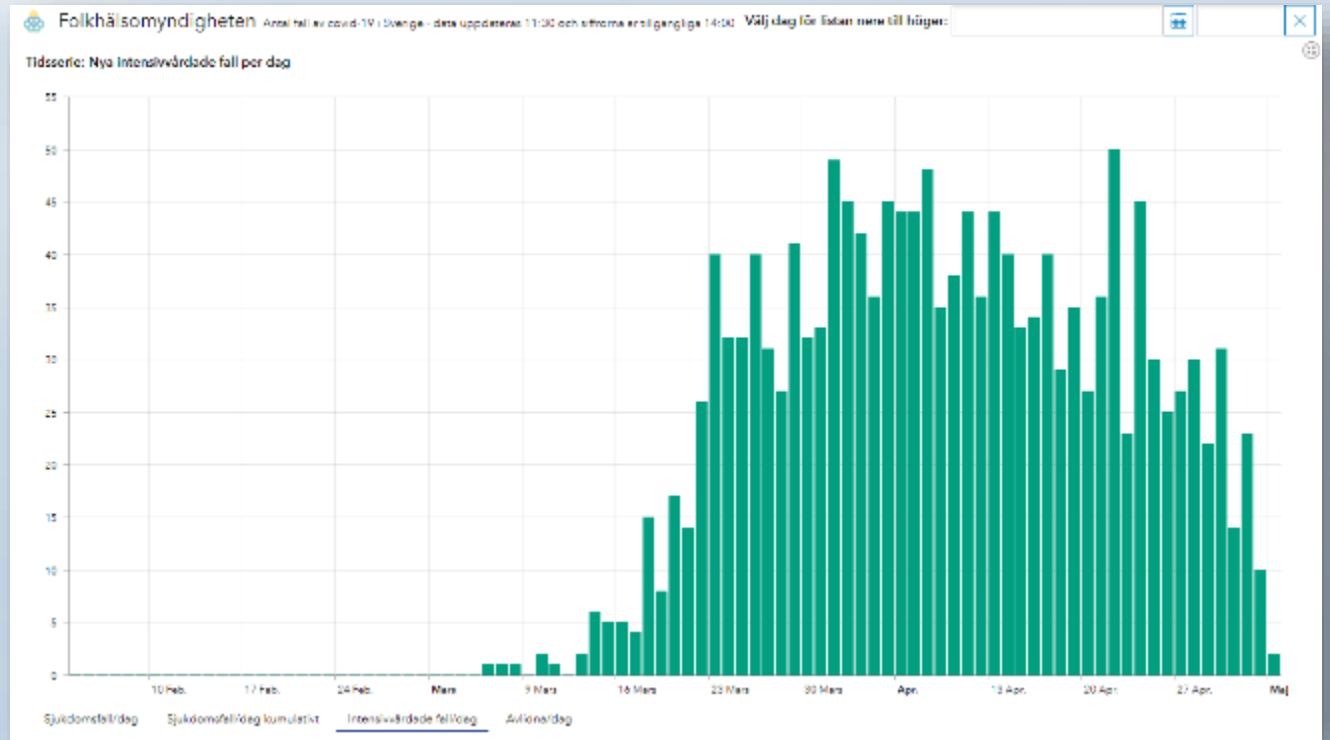


Supporting the real heroes...



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

/Lisa



Questions?



