



Karolinska ICU Planning

21th April 2023

Who I am?



Daniel Roth
Senior Business Advisor

Boeing Global Services

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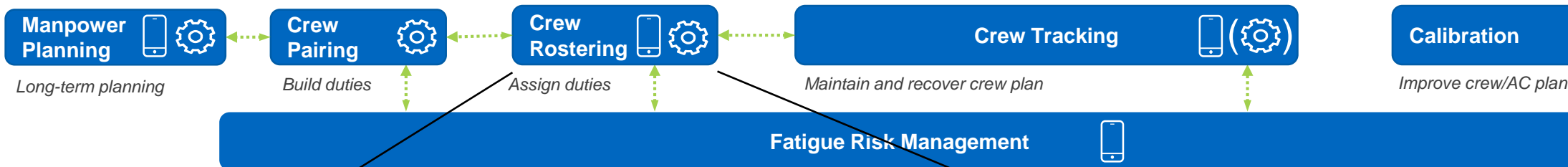
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Training & Professional Services



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qualified and competent aviation
personnel.

Airline Crew Scheduling



minimize $c^T x$

← Objective function

subject to $Ax = 1$

← Coverage constraints

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

- Each crew has 1 roster
- Each trip is assigned

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

Assignable to crew 1

$\begin{bmatrix} 1 \\ 0 \\ \vdots \\ 1 \\ 0 \\ 0 \\ \vdots \\ 1 \end{bmatrix}$ — Number of crew

$\begin{bmatrix} 1 \\ 0 \\ 0 \\ \vdots \\ 1 \end{bmatrix}$ — Number of trips

$A = [a_1 \ a_2 \ \dots \ a_n]$, where e.g. $a_j =$

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

Example: Roster 5

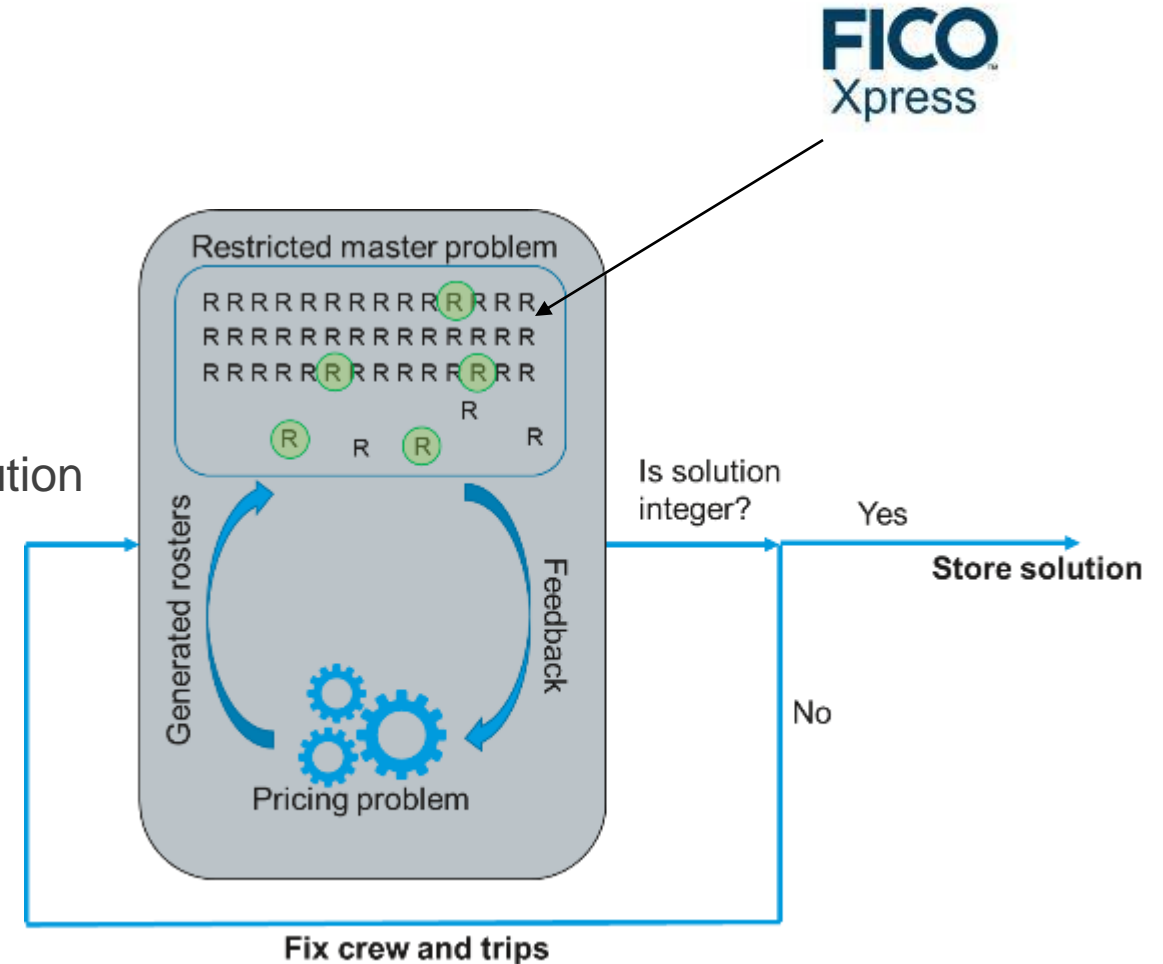
c_5 : Cost of roster 5

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



Small example: 2 crew, 4 trips, 4 rosters

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

Crew 1	<div>1</div>	1	0	0	$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$	<div>$x_1 + x_2$</div>	<div>1</div>	$\begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$
Trip 1	<div>0</div>	0	1	1		<div>$x_3 + x_4$</div>	<div>1</div>	
Trip 3	<div>1</div>	0	1	0		<div>$x_1 + x_3$</div>	<div>1</div>	
Trip 4	<div>0</div>	1	0	1		<div>$x_2 + x_4$</div>	<div>1</div>	
Trip 2	<div>1</div>	0	0	0		<div>x_1</div>	<div>1</div>	

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

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

How do we define the “best solution”?

Input from end-user (planner)

Solution preference



Fairness

Divide workload equally



Quality

Avoid working too many night shifts



Robustness

Include rest buffers



Bids

Crew's personal preference

Cost function

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

Rules

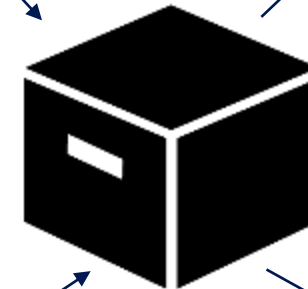


12 hours of rest after a trip
At most 80 working hours per month
...

User input is a black box for the optimizer

Q: Cost of roster R_{12345} ?

A: Cost of roster R_{12345} is 4500

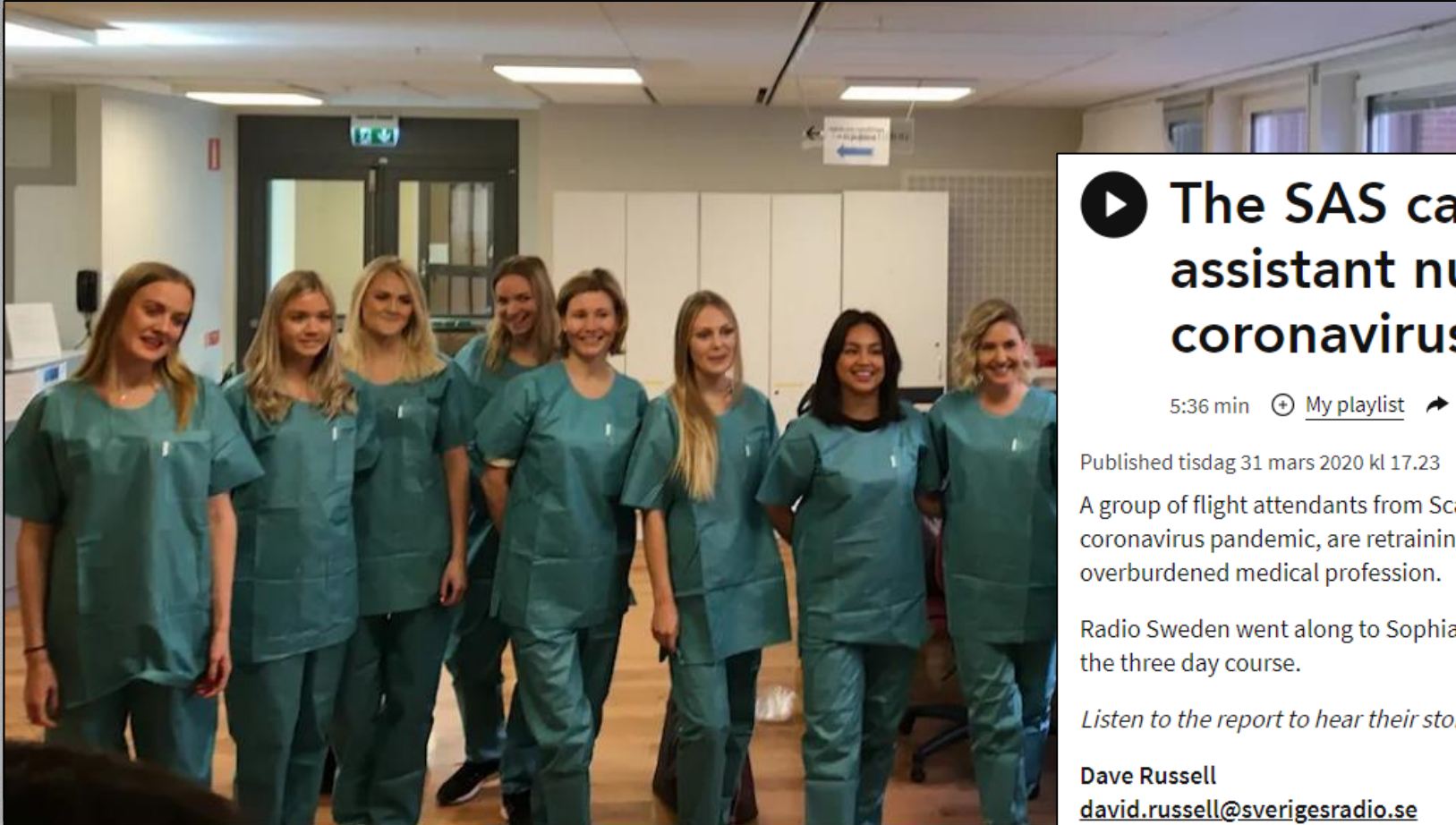


Q: Is roster R_{54321} legal?

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

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...

START PRESS WINNERS JURY CHALLENGES INSPIRATION PARTNER

Daily number of

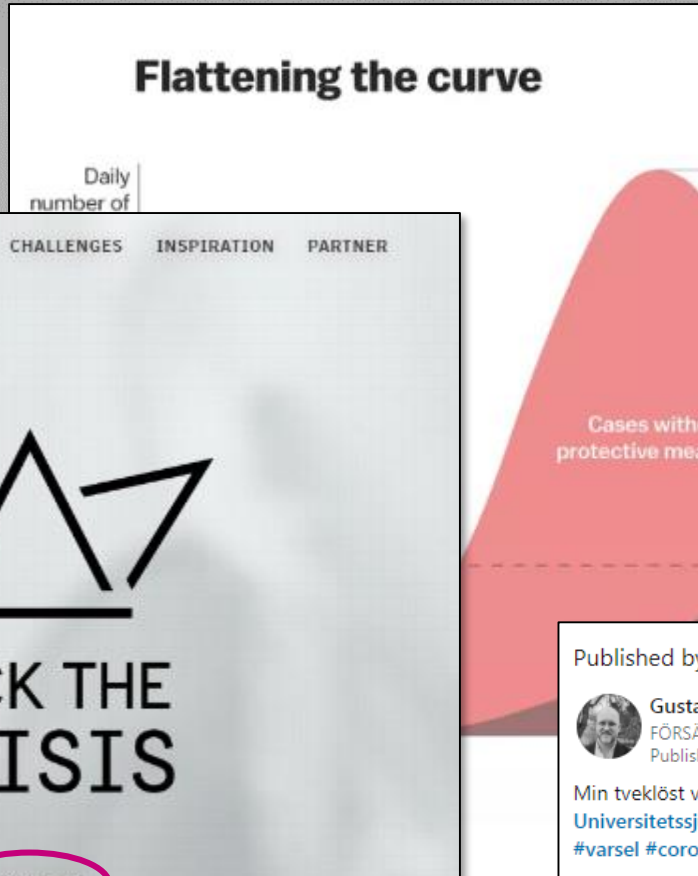
Flattening the curve

Cases with protective mea



HACK THE CRISIS

3 - 6 APRIL



DAGENS NYHETER. Nyheter Ekonomi Kultur Sthlm Gbg Sport Ledare DN Debatt

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

f t e 1

Läs senare

Published by

 Gustav Jannerland
FÖRSÄLJNING/HR/LEDARSKAP
Published • 3w

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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
-----	-----	--	-----	-----	-----	-----	-----	-----	-----	-----	-----

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 ..



Initial call				Crisis Agreement period starts				Current 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
	ID	From	To	Namn	Position	LARM	VL	NEURO	ECMO	PT	day/night/daynight	
1	CID_02001	2020-01-01	2022-01-01	Namn 1	ISSK				ECMO	PT	night	
2	CID_02002	2020-01-01	2022-01-01	Namn 2	ISSK	LARM		NEURO			daynight	
3	CID_02003	2020-01-01	2022-01-01	Namn 3	ISSK		VL				dag	

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



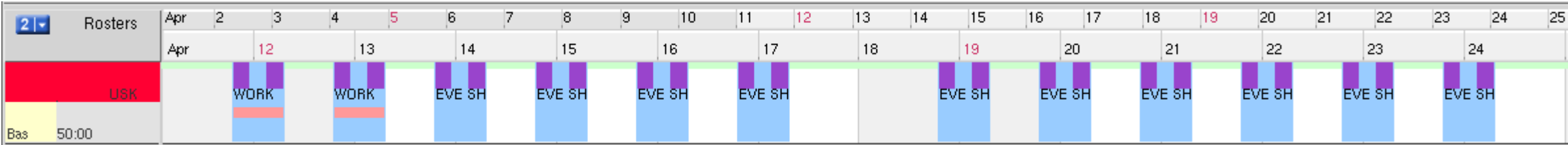
Anmärkning

Med måltidsuppehåll menas paus som räknas in i arbetstiden.

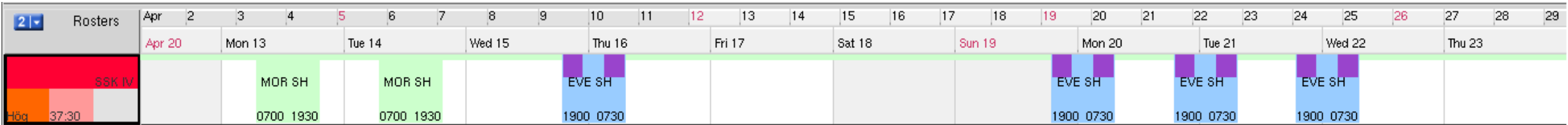
- e) Arbetsgivaren bör eftersträva att den sammanhängande dygnsvilan inte understiger ett genomsnitt av nio timmar under varje period av 24 timmar under beräkningsperioden.
- f) Arbetsgivaren bör eftersträva att den sammanhängande veckovilan inte understiger 24 timmar under varje period om sju dagar.
- 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

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TUE

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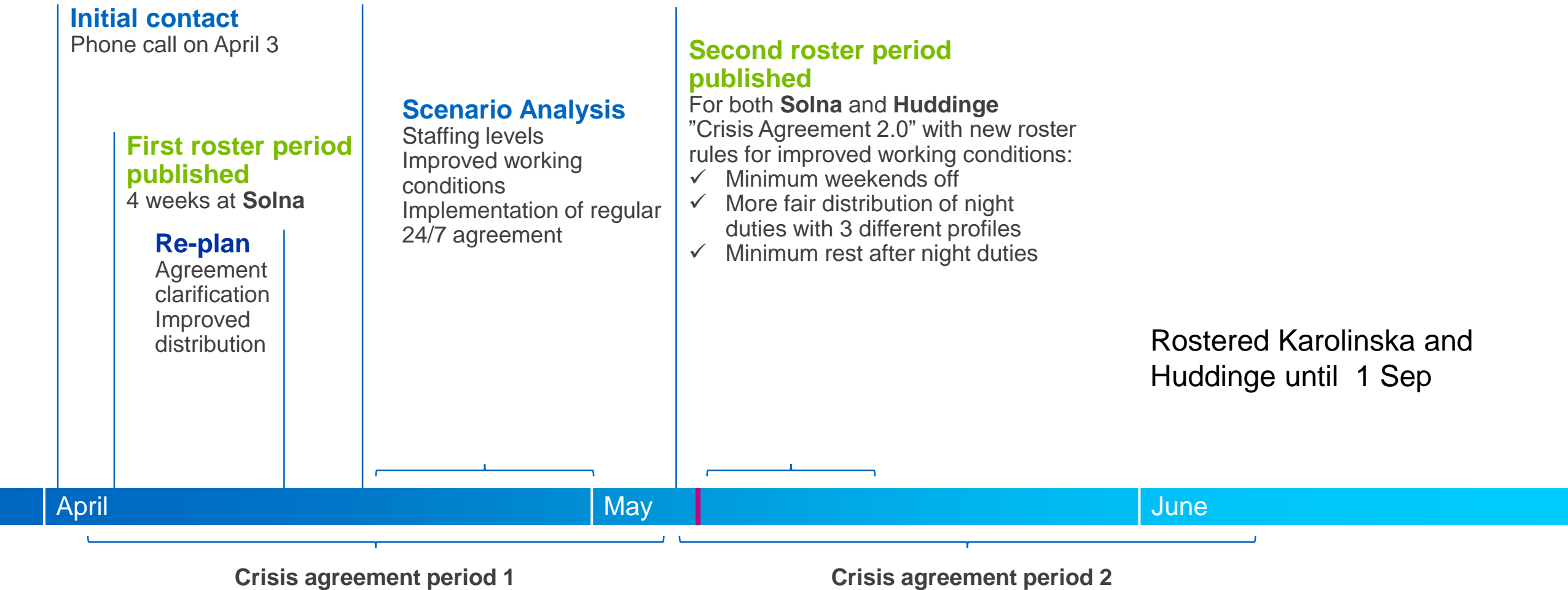
FRI

SAT

SUN

MON

What happened then?

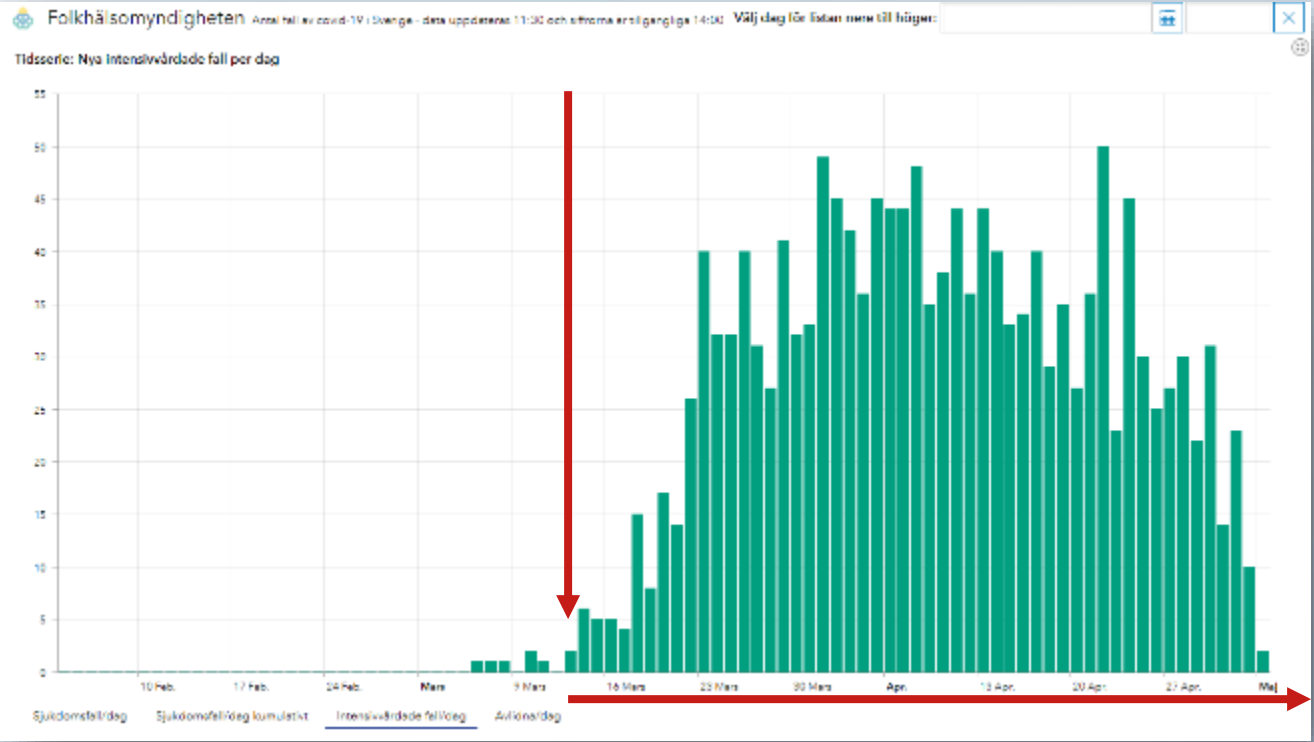


Supporting the real heroes...



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

/Lisa



Questions?



