

A faint, light gray world map is visible in the background of the slide. A horizontal bar with a blue-to-white gradient is positioned above the title.

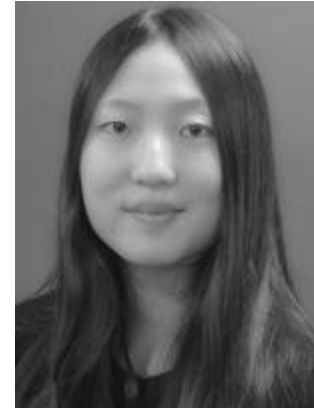
Optimization in the aviation industry

November 2, 2020

- **Introduction**
 - Jeppesen/Boeing
 - The aviation business
 - Our products
- **The rostering problem**
 - Modeling
 - Challenges
 - Solution
- **Work opportunities**

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- Attended Engineering Mathematics at Chalmers 2013-2018
- Master's in Engineering Mathematics and Computational Science
- Optimization Expert at Jeppesen for ~2 years



Who we are

Global Services

- Previously Jeppesen
- Started as a Volvo project, then became Carmen Systems, then acquired by Boeing...
- ~400 people work in our Gothenburg office, ~30 different nationalities
- Focus on airline planning problems for crew and fleet

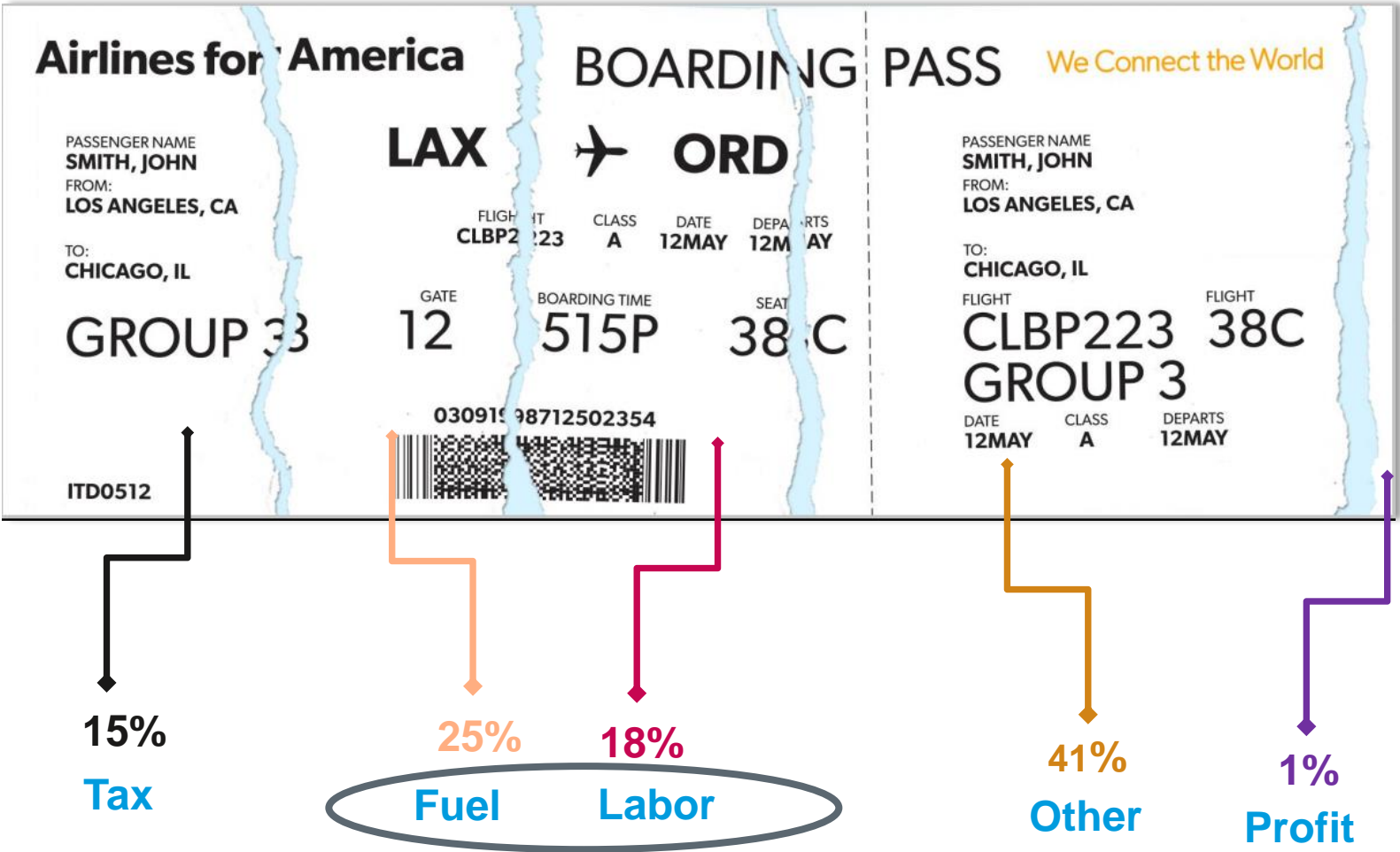


Our customers

Global Services

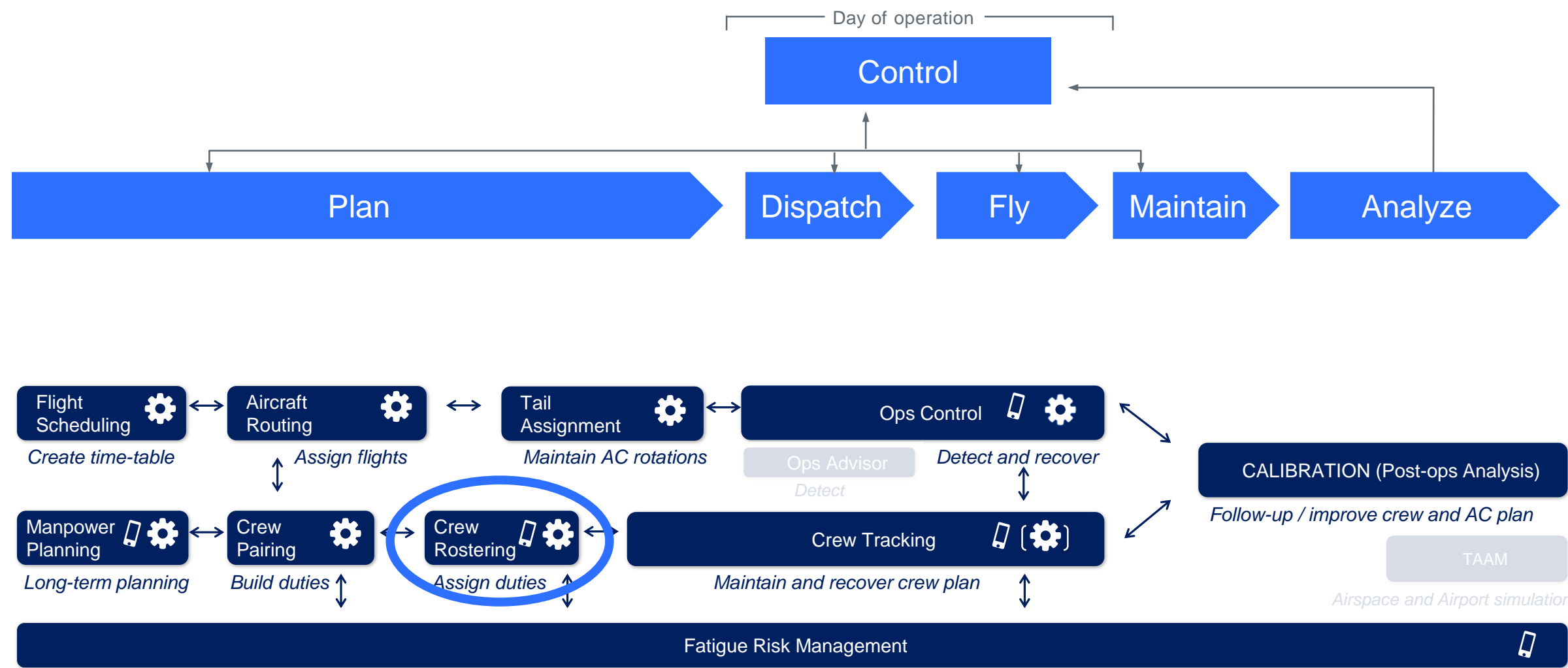


Why use our products?



Our products

Global Services

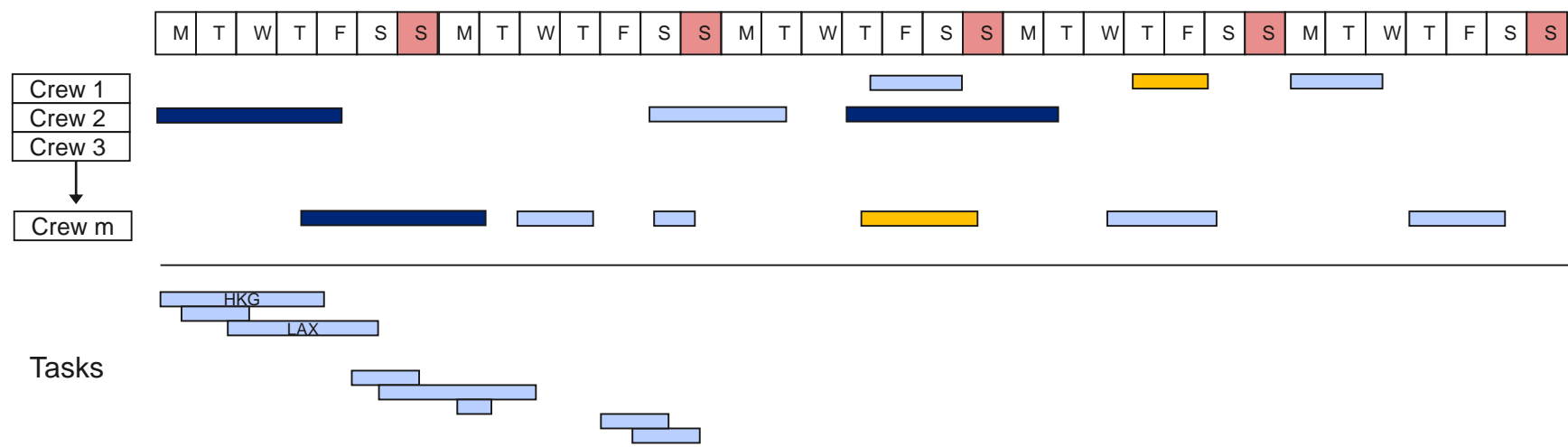


The rostering problem

(roster = personal monthly schedule)

Aim:

Assign all tasks to crew, such that global cost is minimized and legal/contractual rules are respected.



What is optimization?

Global Services

In general

Minimize

objective function

Subject to

Constraints

Example: Volume of a soda can

Objective: Use as little material as possible

Minimize area

Subject to volume = V



$$\begin{aligned} \text{minimize } & 2\pi r^2 + 2\pi rh \\ \text{subject to: } & \pi r^2 h = V \\ & r \geq 0, h \geq 0 \end{aligned}$$

The rostering optimization problem

Global Services

Objective: Minimize cost, make sure that all trips are assigned to crew and legal/contractual rules are satisfied

Min "cost"

Subject to

all crew assigned to exactly one roster

all trips assigned to crew

all rules satisfied

minimize $\mathbf{c}^T \mathbf{x}$

subject to $A\mathbf{x} = \mathbf{1}$

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

← Objective function

← Coverage constraints

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

$\left[\begin{array}{c} 1 \\ 0 \\ \vdots \\ 1 \\ 0 \\ 0 \\ \vdots \\ 1 \end{array} \right]$

Number of crew

Number of trips

$A = [\mathbf{a}_1 \quad \mathbf{a}_2 \quad \dots \quad \mathbf{a}_n]$, where e.g. $\mathbf{a}_j =$

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

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>	<div>Preassignment</div>		trip 1 assigned,	cost 15	} Crew 2
Roster 4:	<div>2</div>	<div>Preassignment</div>		trip 2 assigned,	cost 10	

Optimization

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

$$\text{subject to } Ax = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} x_1 + x_2 \\ x_3 + x_4 \\ x_1 + x_3 \\ x_2 + x_4 \\ x_1 \\ x_1 + x_2 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}$$

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

Combinatorial explosion

Global Services

Small problem: 10 crew, 50 trips

Possible rosters for 1 crew:

$$C(50, 5) \approx 2\,000\,000$$

Possible solutions:

$$C(\text{\#possible rosters}, 10) \approx 10^{60}$$

Largest test case: 22 000 crew, 190 000 trips

→ $\sim 10^{500\,000}$ possible solutions!

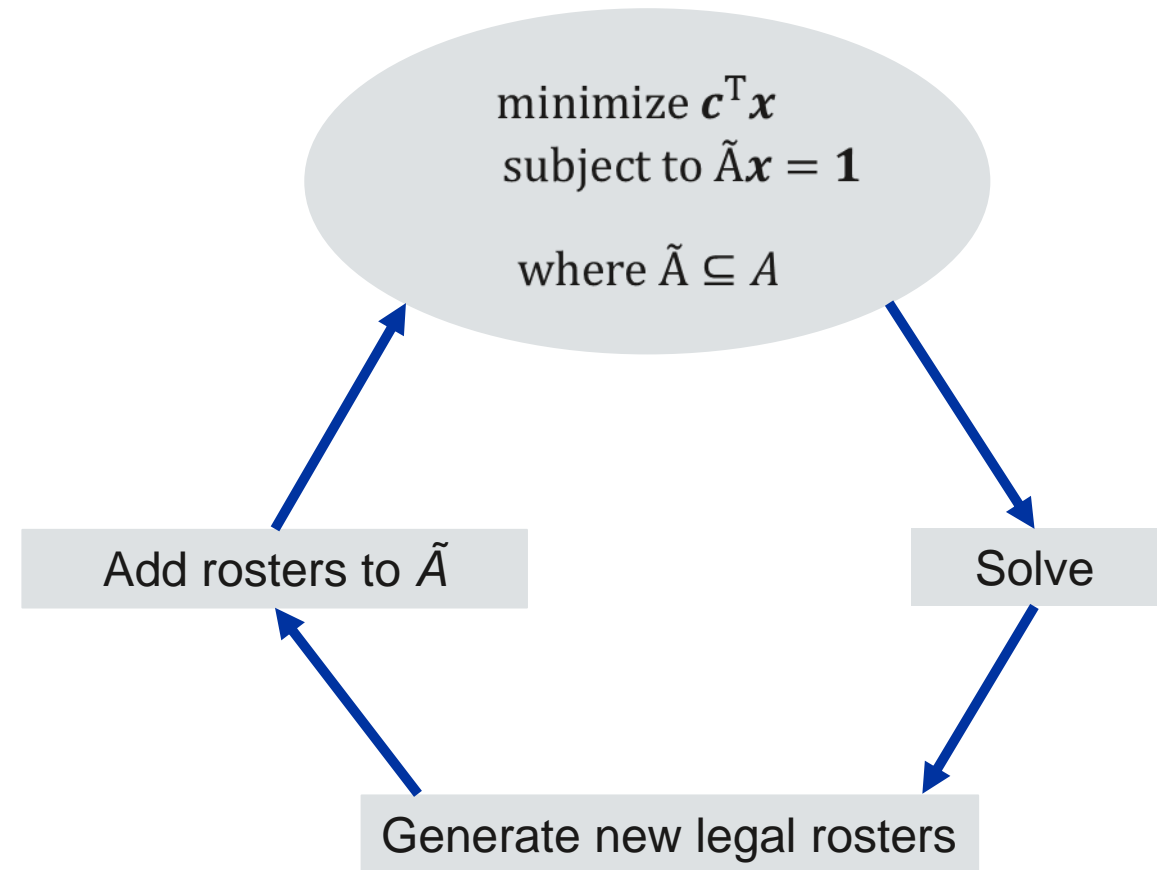
(Assuming any assignment is legal)



$\sim 10^{18}$ grains of sand on earth!

Column Generation

1. Set up smaller problem
2. Solve smaller problem
3. Try to generate new columns (rosters)
4. Repeat steps 2 and 3 until no more rosters can be generated



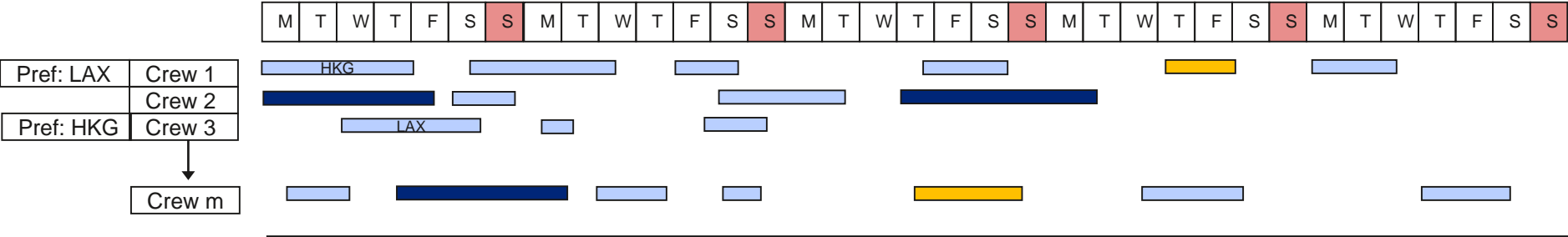
- Use column generation framework to solve the problem
- Rely on heuristics to generate solution within reasonable time



"We cannot solve these problems optimally within reasonable time... But as long as we are the best in the world at it, it doesn't matter"

What is the best solution?

- Cheapest solution = Best solution?

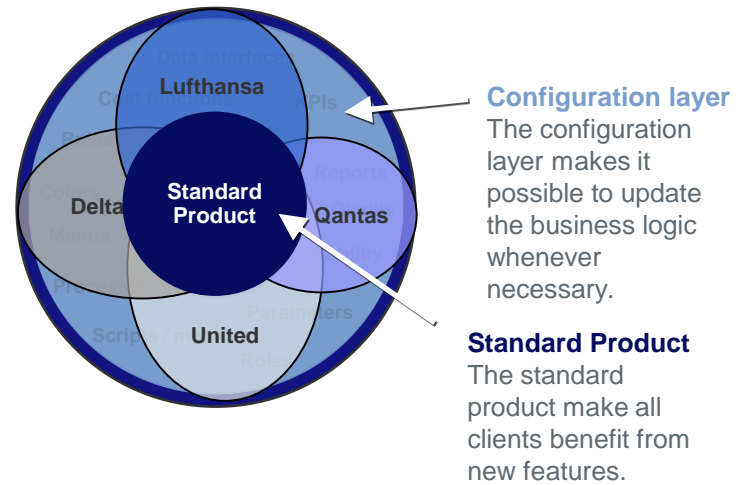


Other aspects:

- Satisfaction
- Fairness
- Robustness

The Avocado Model

Global Services



Optimization Expert

Tasks:

- Research, Design, Development and maintenance of algorithms, models and systems

Background:

- Math, Computer Science, Physics, ...

Skills/Strengths:

- Algorithms and optimization
- Programming (C++)
- Problem solving

Systems Analyst

Tasks:

- Customer system configuration and installation
- Optimization modeling

Background:

- Math, Computer Science, Physics, Industrial Engineering,...

Skills/Strengths:

- Communicative
- Programming
- Problem solving

Business Consultant

Tasks:

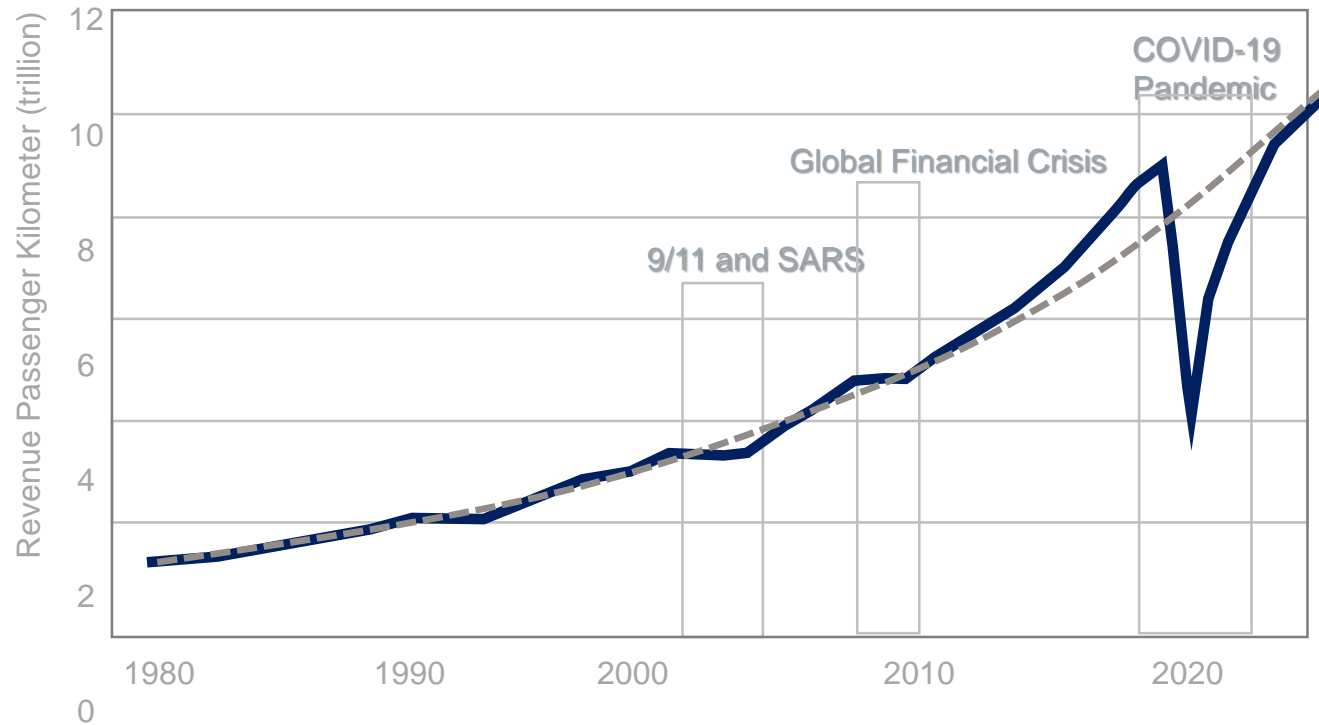
- Optimization modeling
- Tech-sales support, Consulting

Background:

- Math, Computer Science, Physics, Industrial Engineering

Skills/Strengths:

- Communicative
- Programming
- Problem solving



Provide support to Karolinska University Hospital

- Create schedules for hospital staff using our Crew Rostering product

Focus on supporting our customers

- Offer business consulting services
- Quickly adapt to changes
- Different modeling

- Why do we want to solve this problem?
- Right problem
- Right(?) solution
- Efficient solution





