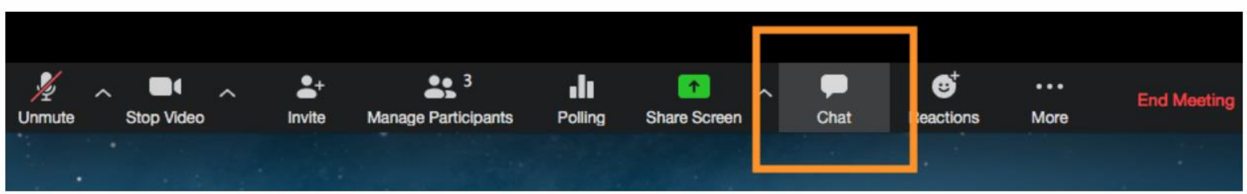
SMARTVISION Europe

Model Building for Optimisation and Efficiency

Robert Cordina **John McConnell**

FAQ's

- Is this session being recorded? Yes
- Can I get a copy of the slides? Yes, we'll email links to download materials after the session has ended.
- Can we arrange a re-run for colleagues? Yes, just ask us.
- How can I ask questions? All lines are muted so please use the chat panel – if we run out of time we will follow up with you.



A bit about SmartVision

We are vendor agnostic

We do Statistics/Data Science/Machine Learning/Optimisation/AI

We have some strategic partnerships …

Our expertise spans commercial platforms and open source

We work across all sectors, all industries and many geographies

Our people have a long history in the domain

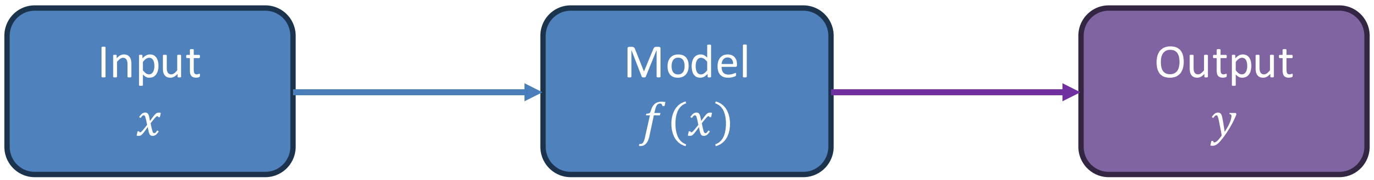
More about our offerings at the end of this presentation

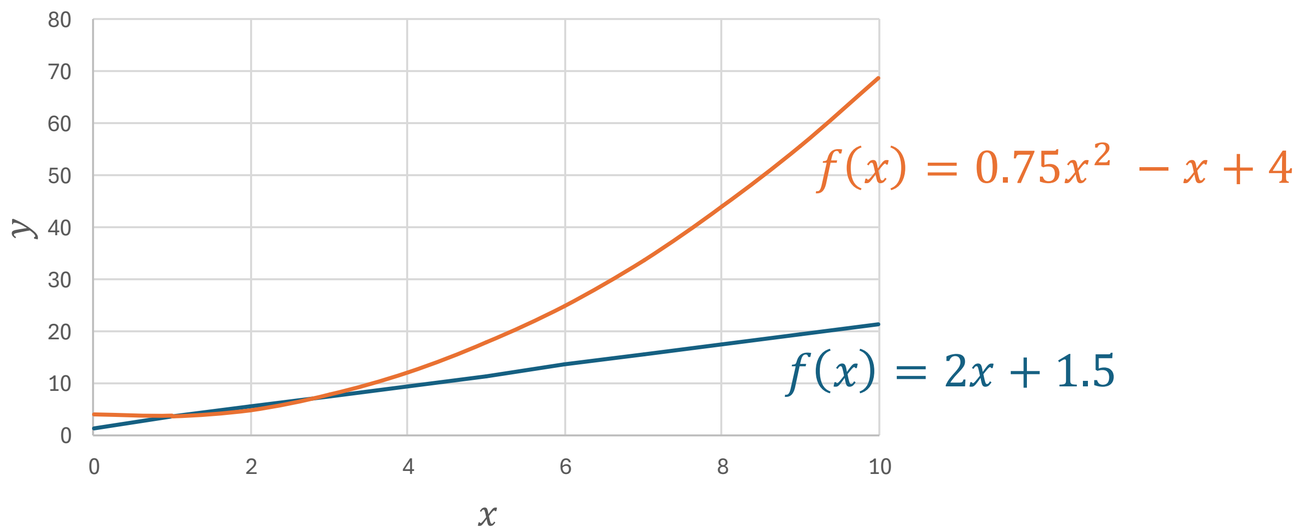
Agenda

- What is optimisation, and what types of optimisation can be done?
- Example demonstrations
- Accessing optimisations easily

Background on Optimisation

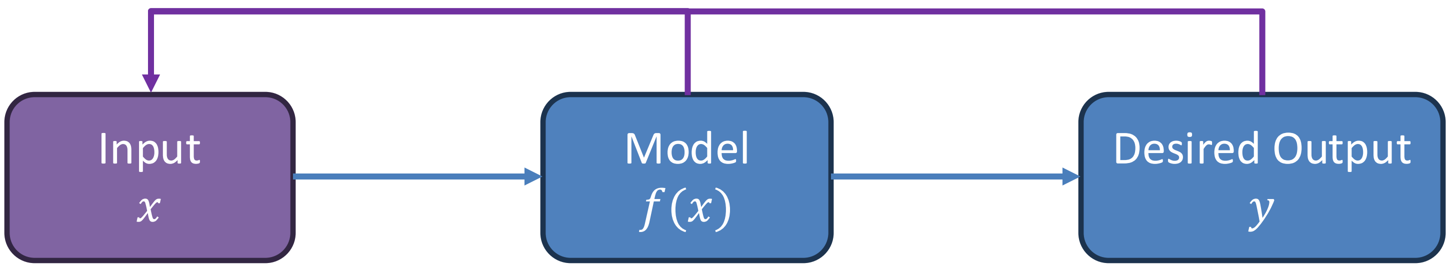
Prediction

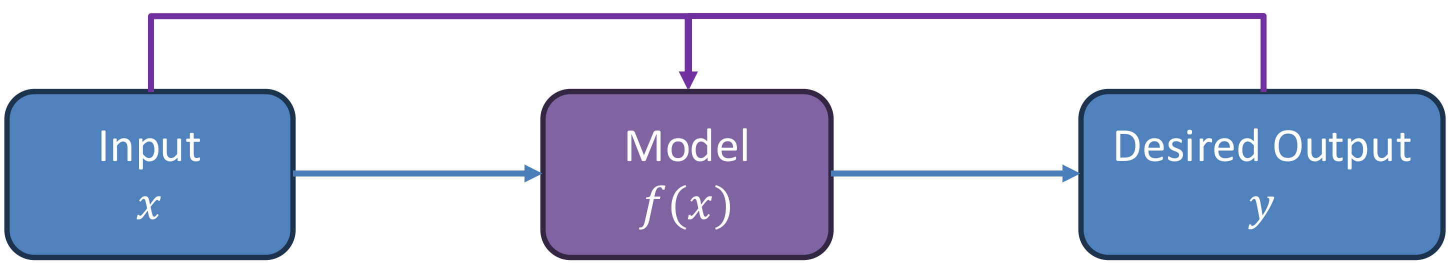




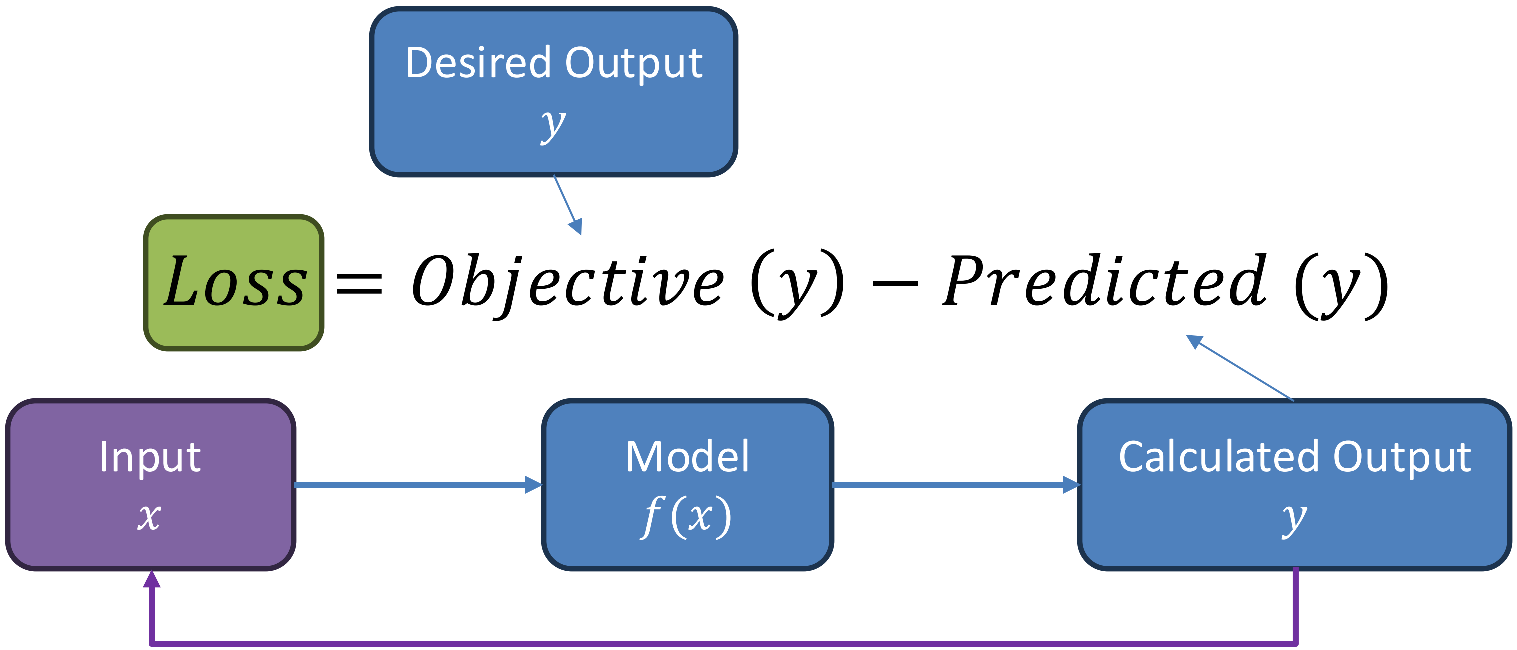
Background on Optimisation

Optimisation

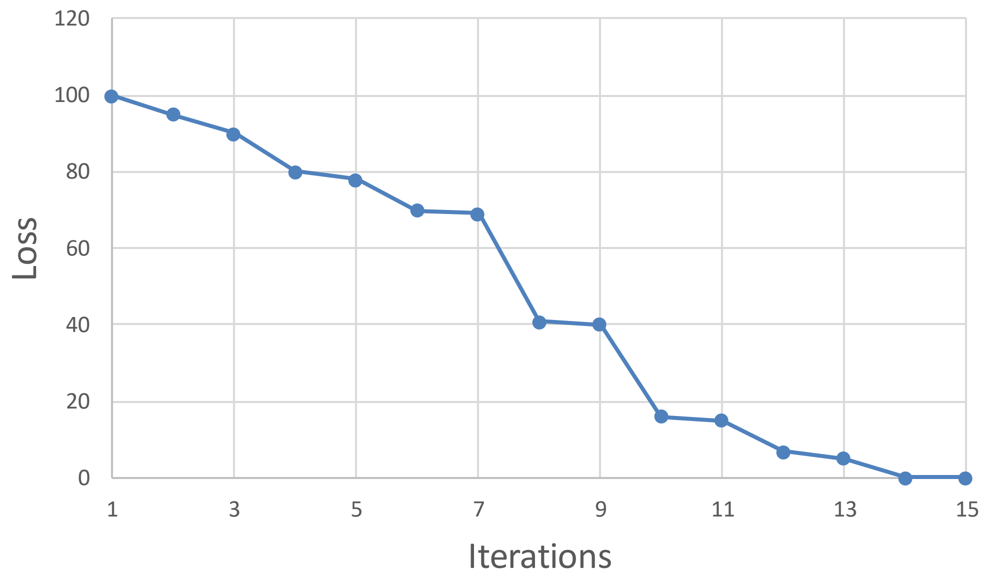


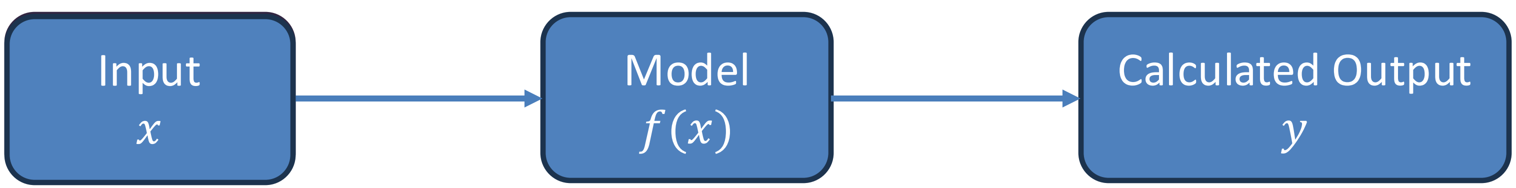


Background on Optimisation



Background on Optimisation





Types of Optimisation

Type	Example
Single-objective	Matching a single value or Cost (minimising) or Profit (maximising)
Multi-objective	Matching multiple values or Cost + Time (minimising) or Profit (maximising) + People (minimising)

Model Type	Example
Linear	$y = mx + c$ $y = Aa + Bb + C$
Non-linear	$y = ab + (ab)^2$ Neural network

Model Type	Example
Linear	$y + z = Aa + Bb + C$
Non-linear	$Cost\ + Time\ = \frac{d^2y}{dt^2}x^2$

Increasing Complexity

I'd like to find the right balance between cost and time for my sorting process.

Conflicting Objectives

more people = less time = more cost

or

less people = less cost = more time

Fast conclusion, or cheapest outcome?

Constraints

I can't employ more than *x* people

Project must be ready in *y* days

Overall cost can't surpass £*z*

I can employ more people, but they must cost less per person

Example 1 – Complex Rostering

Required Staff

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Morning	9	12	8	10	13	10	14
Afternoon	11	13	10	11	9	11	7
Night	8	7	5	15	7	8	6
Day	2	4	18	7	10	5	17

- Each shift requires different minimum resourcing, depending on the day
- Each staff member must work a minimum of 36 hours per week, and they cannot work on more than 5 days per week

Example 1 – Complex Rostering

- No one can work the Night shift immediately followed by a Morning shift

- Staff requirements (vacation leave etc.)
  - Emily Johnston can't work the Night shift on Monday
  - Emily Johnston can't work the Morning shift on Thursday
  - Don Harper can't work the Day shift on Tuesday
  - Mario Ryan can't work the Day shift on Wednesday

- Staff preferences
  - Don Harper prefers Morning and Day shifts
  - Chris Campbell prefers Afternoon shifts

Example 1 – Complex Rostering

- Not a trivial problem – imagine doing this kind of rostering optimisation every week
- Use of specialised algorithms would help speed things up immensely
  - enter all the rules, such as those specified above
  - click Run
  - get results back in seconds, although they may not always be successful results, depending on the rules that are specified

Example 1 – Complex Rostering

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Rostered Staff

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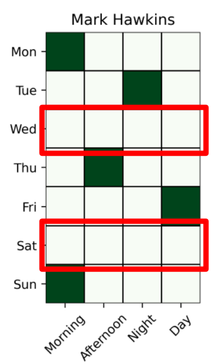

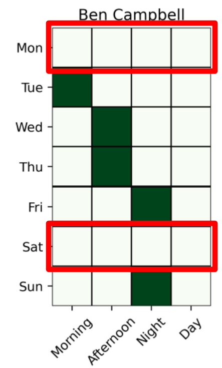

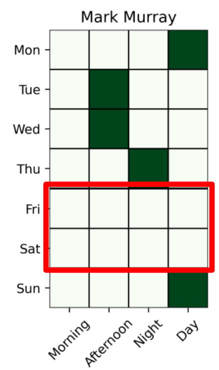

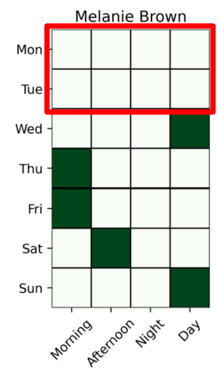

Staff Hours

Emily Johnston	38	Timothy Chapman	36
Don Harper	38	Simon Harris	38
Mark Hawkins	38	Andy Farrell	40
Martha Ellis	38	Doug Douglas	36
Ben Campbell	40	Alexandra Dougla	38
Stephanie Richards	38	Jane Cole	36
John Evans	36	Vicoria Mysers	36
Sarah Brooks	36	Louise Owens	40
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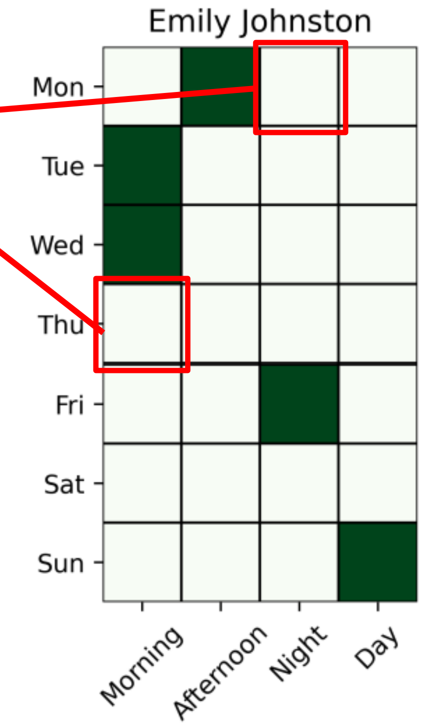

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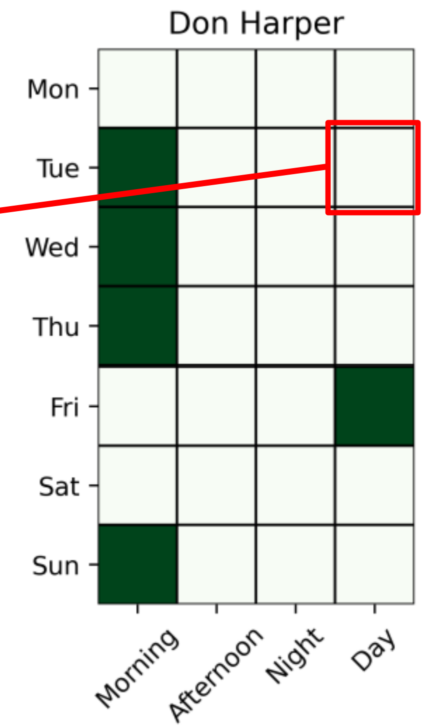

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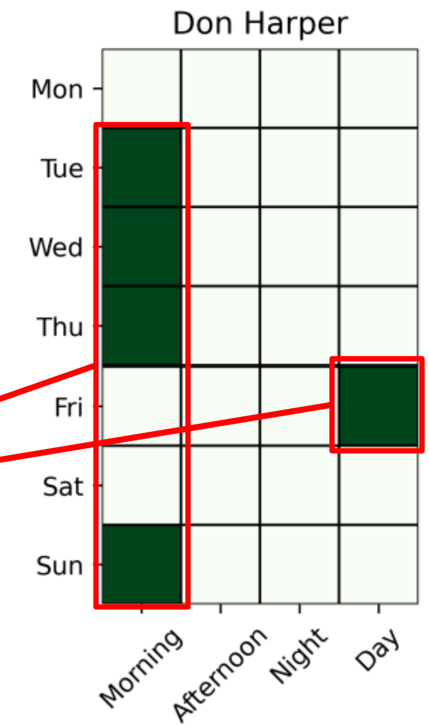

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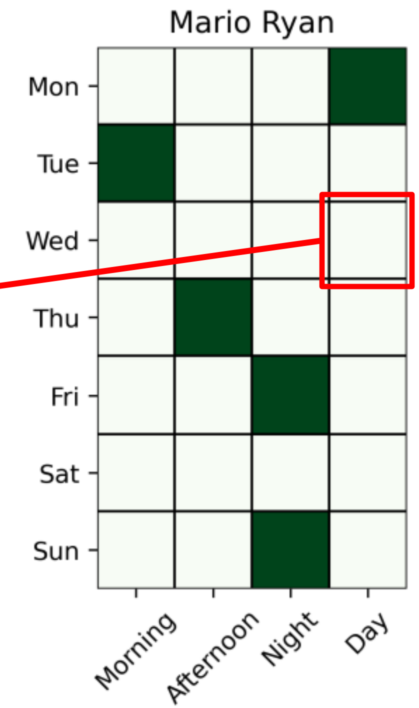

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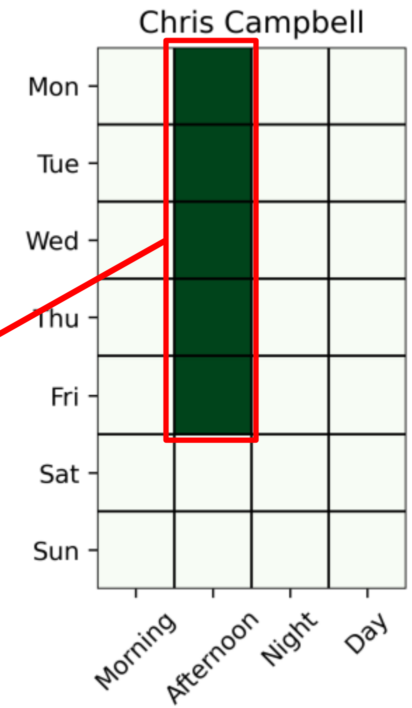

Example 1 – Complex Rostering

What if Chris Campbell doesn't mind working other shifts now?

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Old Rules

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New Rules

Rostered Staff

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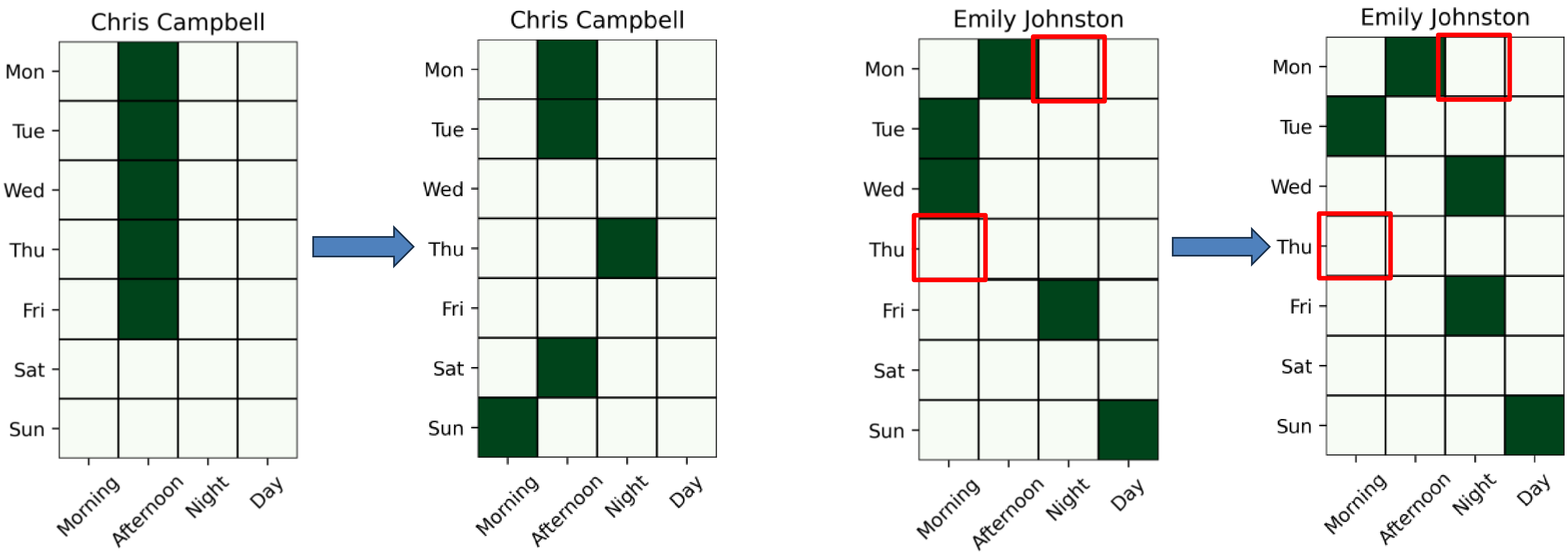

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Example 1 – Complex Rostering

- Imagine extending this to hundreds of employees, with multiple rules related to different people – it would be pretty much impossible to do manually
- All of this rostering optimisation was done in Python using a specialised package called pyworkforce - there other solutions out there that we could leverage too e.g. from AWS
- It could even be set up through a custom interface, where all the rules are entered simply, and every staff member gets an email with their weekly roster automatically

- This approach can also be extended to scheduling of services too

Example 1 – Complex Rostering

$$Loss = \sum_{i=1}^{n} \begin{cases} Constraint\ i\ met = 0 \\ Constraint\ i\ not\ met = 1 \end{cases}$$

Example 2 – Optimising for Time and Price

- Imagine you work in a manufacturing environment, and you need to formulate a product by combining a number of ingredients
- But it gets interesting… you need to combine three ingredients, one each from three groups of ingredients, each with their own associated price, time to process and stock constraint, and the blend has to have a combined weight of 225 +/- 1 kg
- How would you go about optimising the perfect blend?

Example 2 – Optimising for Time and Price

Group	Ingredient	Price (£/kg)	Time (min/kg)	Stock (kg)
1	A	1.23	0.45	
	B	0.75	1.81	
2	C	2.26	0.62	
	D	5.21	1.54	102
	E	0.34	1.55	123
3	F	3.33	1.23	155
	G	4.20	0.95	110
	H	5.99	0.66	107

No obvious choice.

E = low price, high time
C = high price, low time

Example 2 – Optimising for Time and Price

The problem means making the following decisions:

1. balancing price and time

   What we are minimising – the optimisation

2. making sure that the batch size is correct

   A constraint

3. ensuring that only one ingredient from each ingredient group is used in any batch

Think of it as having 16 variables →
- each ingredient is being used or not (1 or 0) = 8 variables
- the quantity of each ingredient used in the optimisation = 8 variables

With 3 more constraints
- sum of A+B being used = 1
- sum of C+D+E being used = 1
- sum of F+G+H being used = 1

Example 2 – Optimising for Time and Price

- There obviously are a vast number of possible combinations this problem could take – remember it's not only time and price, but also which ingredient is used from each of three groups, and the total batch size must be 225 kg
- We therefore need to run an optimisation, minimising the time and price, while keeping within the constraints → we need a loss function

A loss function is a calculation that calculates how much the formulation will "cost" us

The lower the price and time, the smaller the loss (or "cost" to us)

$$Loss = (Price * Price_{weight}) + (Time * Time_{weight})$$

We can bias the loss towards Price or Time by setting a weighting

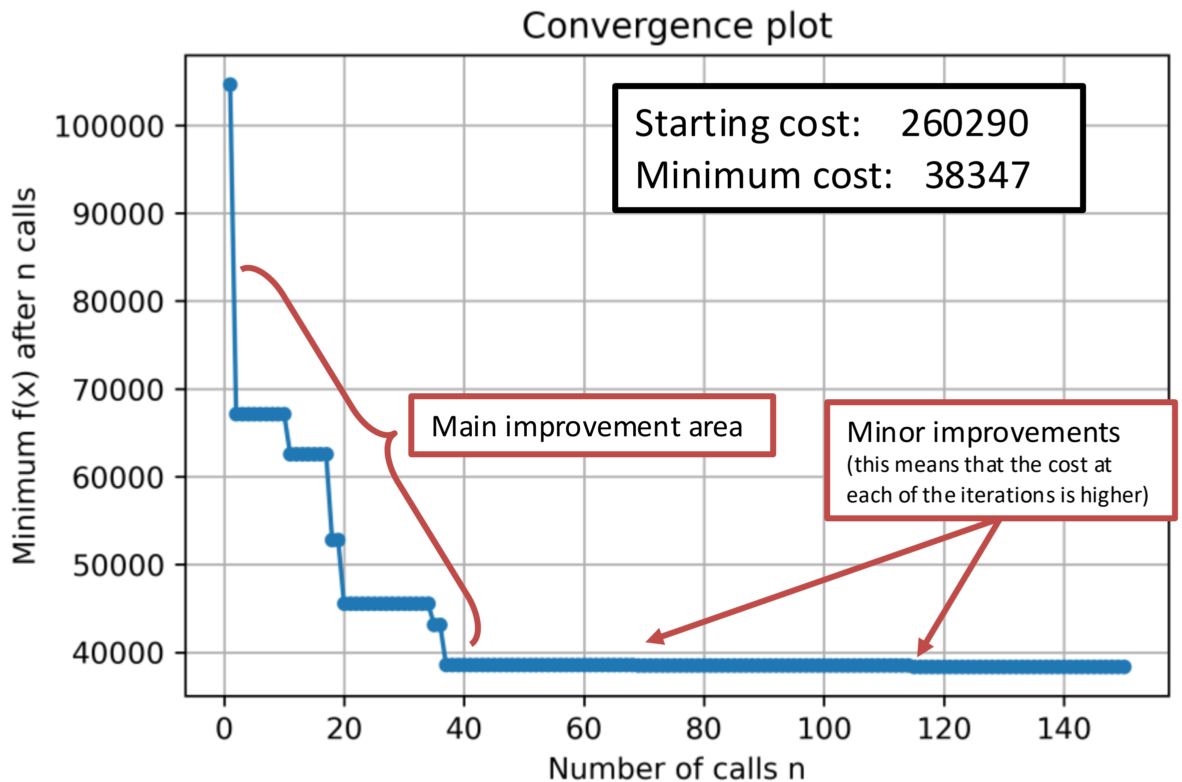
Example 2 – Optimising for Time and Price

- We ran this optimisation using a Bayesian Optimisation approach, as follows:
  - 10 initial random points, within the specific constraints
  - Ran the optimisation for a further 140 points
    - Each optimisation step evaluates 500 different samples, and selects the next one based on which of the samples will fill in the 16-dimensional variable space best
  - At the end of the optimisation, we selected the best 20 options out of the total of 150 points

- Why this approach…?

Example 2 – Optimising for Time and Price

The “cost” is going down as more optimisation iterations are carried out, but not always



Example 2.1 – Optimising for Time and Price

- What if we had to make 3 consecutive batches, all with the same constraints and same ingredients… this is now a 48 (16 * 3) variable problem!
- With added complexity that individual ingredient stocks are limited!

- The optimisation would either simply take too long to be feasible, or else it would fail as there are too many constraints.

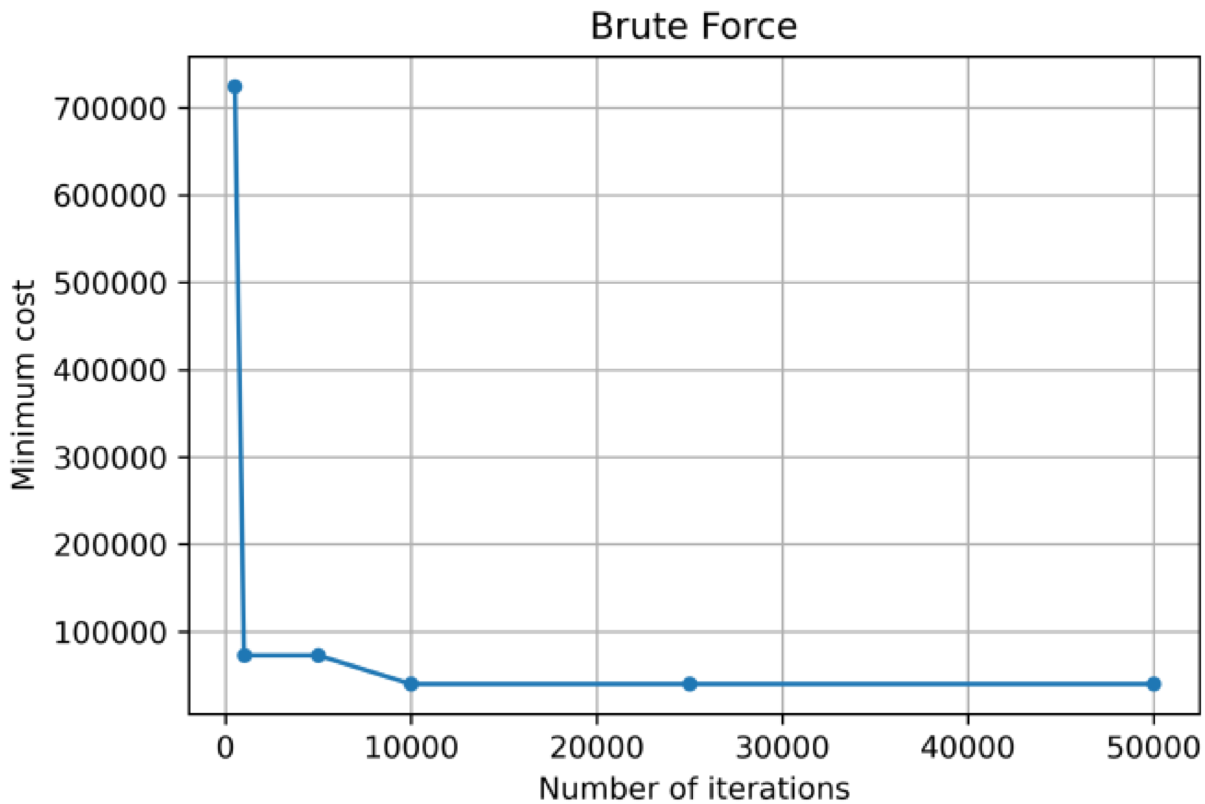
- For this we took more of a brute force approach, where we generated thousands of different samples – this means that we leave finding the best options down to mere chance – so, statistically, the more samples we run the more likely we are to find the best options

Example 2.1 – Optimising for Time and Price

500 Iterations (Cost = 790473)				
Ingredient	1	2	3	Stock
A	164.9			164.9 (175)
B		125.7	62.0	187.7 (200)
C	56.6	33.6		90.2 (105)
D				0 (102)
E			92.3	92.3 (123)
F		65.7	70.8	136.5 (155)
G				0 (110)
H	3.5			3.5 (107)
Sum	*225*	*225*	*225*	

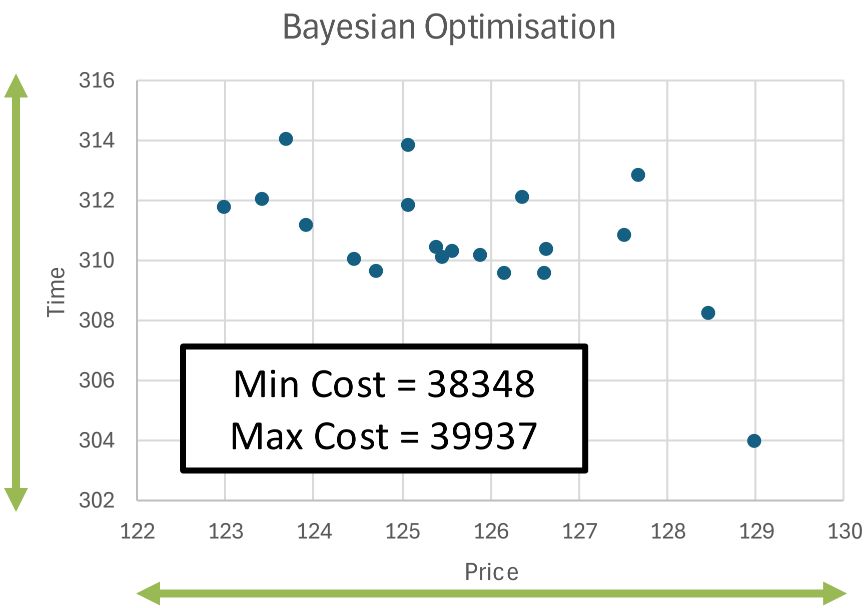
50,000 Iterations (Cost = 724460)				
Ingredient	1	2	3	Stock
A		170.7		170.7 (175)
B	122.4		71.4	193.8 (200)
C	55.1	47.8		102.9 (105)
D				0 (102)
E			121.2	121.2 (123)
F				0 (155)
G	47.4	6.5	32.5	86.4 (110)
H				0 (107)
Sum	*225*	*225*	*225*	

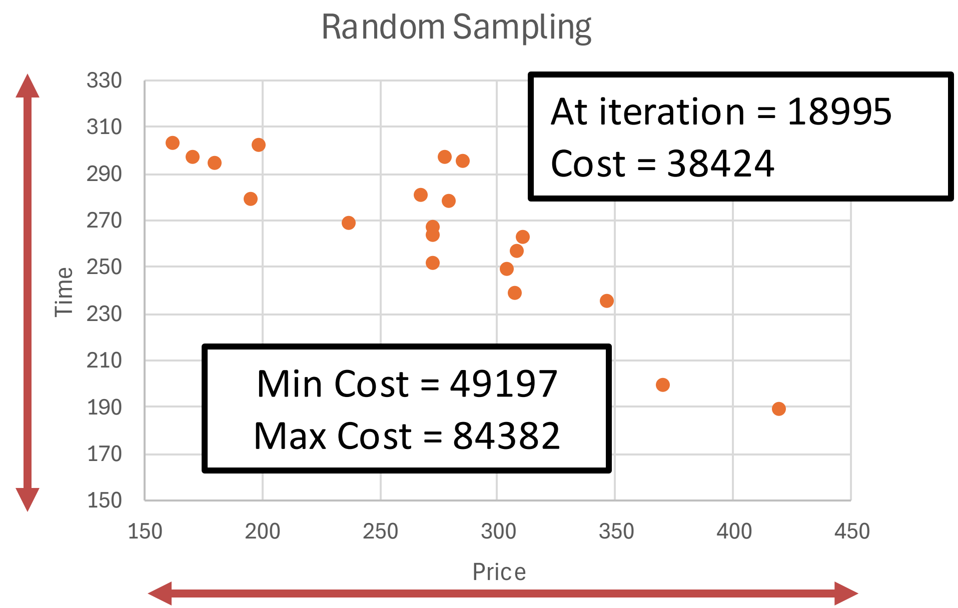
Example 2.1 – Optimising for Time and Price



Comparing Approaches

150 iterations in both cases





A selection of Use Cases

Manufacturing & Operations

- **Process Optimization**: Tuning parameters for performance/safety
- Product formulation: Optimization: Balancing efficacy and cost
- **Quality Control**: Minimizing defects via optimal settings
- **Resource Allocation**: Assigning machines, labor, and materials efficiently

Supply Chain & Logistics

- **Transportation Planning & Routing**: Cost-effective shipping routes
- **Inventory Optimization**: Balancing holding costs vs. stock-outs
- **Production Scheduling**: Minimizing setup times and cost

Healthcare & Medical Applications

- **Radiation Therapy Planning**: Maximizing tumor targeting, minimizing harm
- **Staff Scheduling**: Meeting demand with workforce constraints
- **Hospital Resource Allocation**: OR schedules, bed capacities, supplies

A selection of Use Cases

Public Policy & Government Planning

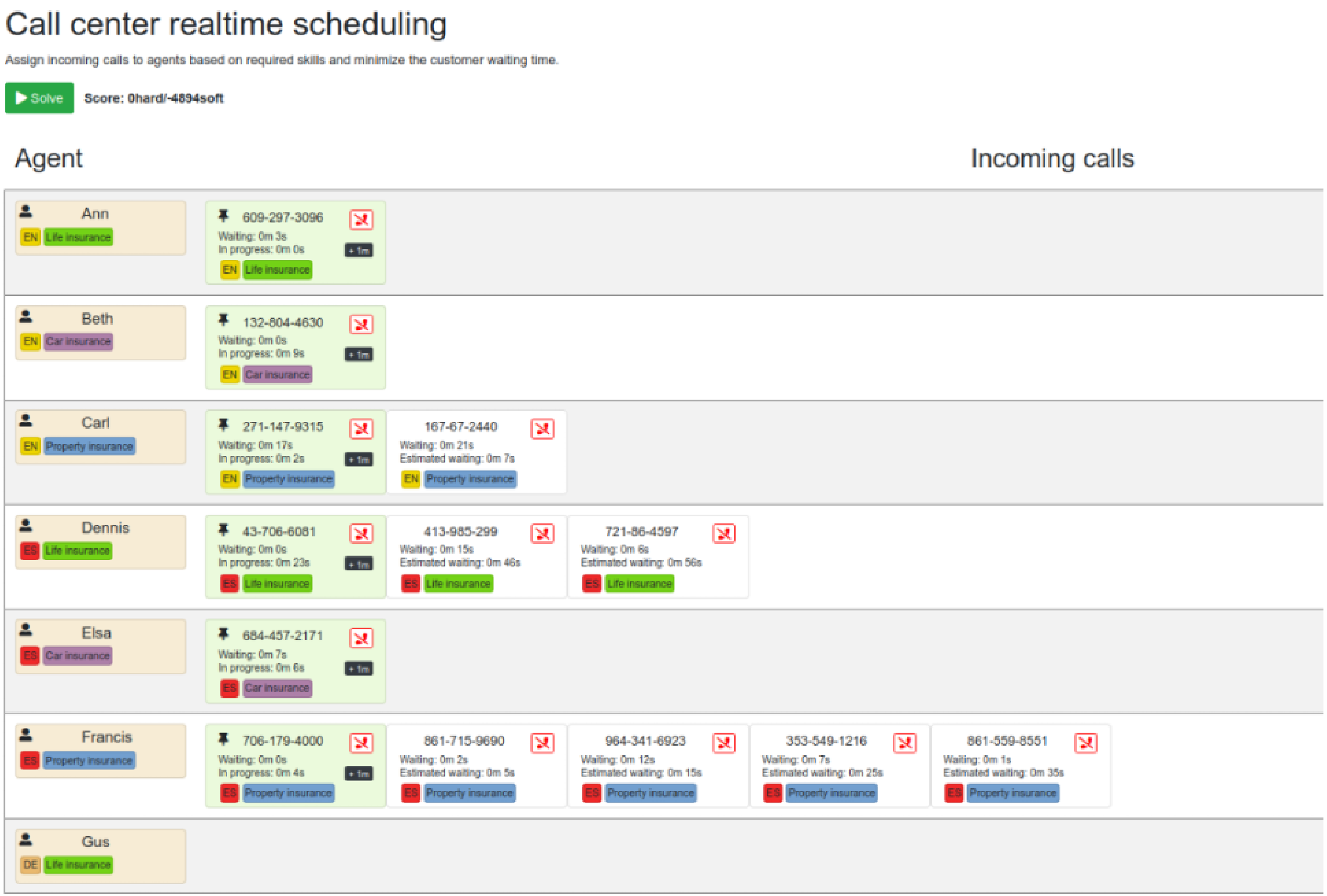
- **Disaster Response & Evacuation**: Minimizing evacuation times/costs
- **Urban Development & Zoning**: Balancing economic
- and environmental goals
- **Resource Distribution**: Equitable allocation of public goods

Pharmaceutical & Biotechnology

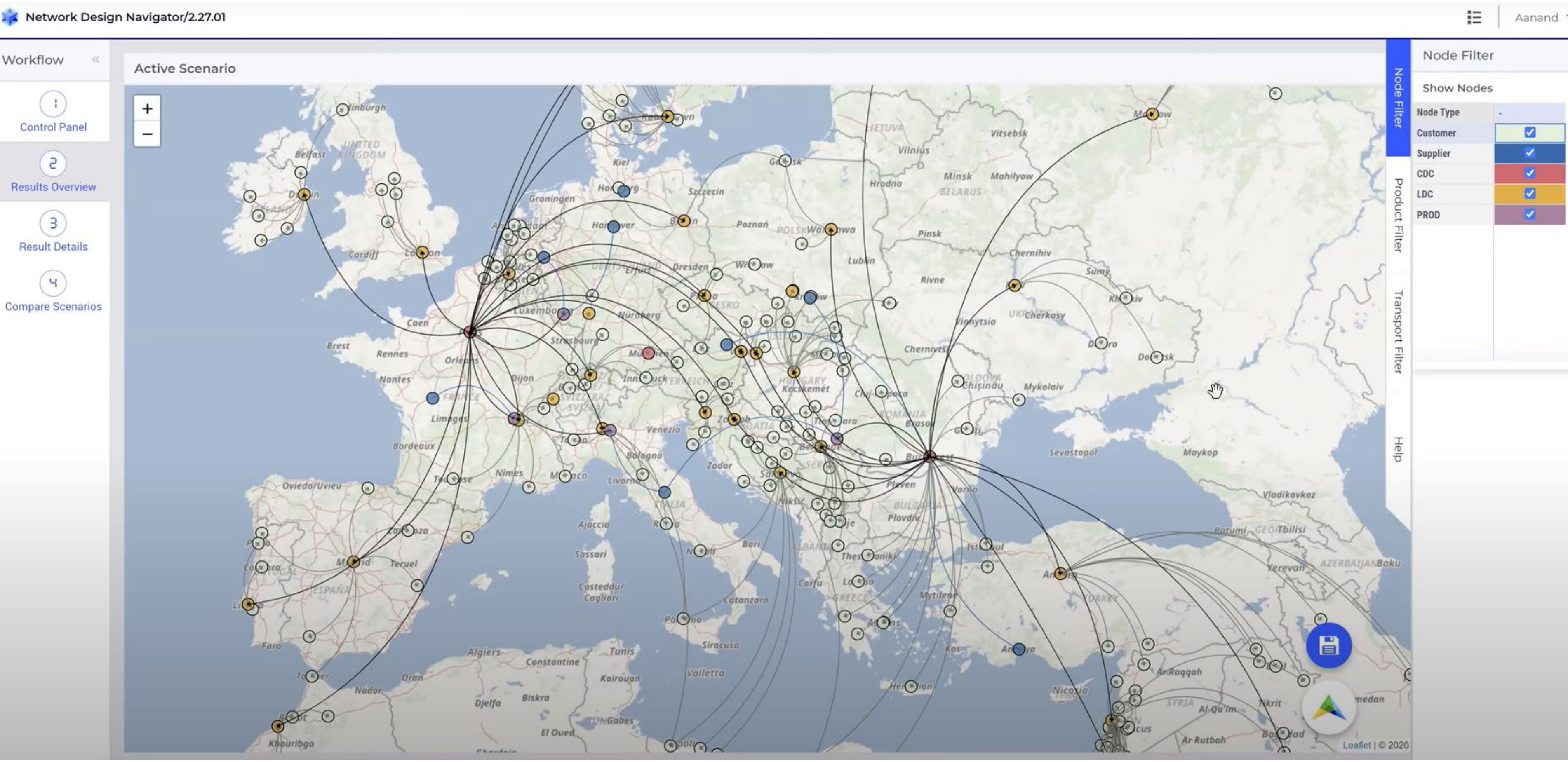
- **Drug Formulation** Optimization: Balancing efficacy and cost
- **Clinical Trial Optimization**: Designing cost-effective, robust studies
- **Pharma Supply Chain**: Managing temperature-sensitive distribution

Transportation & Mobility Services

- **Airline Scheduling & Crew Pairing**: Reducing operational costs
- **Ride-Sharing & Fleet Management**: Real-time driver/passenger matching
- **Urban Traffic Flow Optimization**: Managing congestion via signal timing



https://docs.optaplanner.org/9.44.0.Final/optaplanner-docs/html_single/index.html#releaseNotes-8.7.0.Final



The AIMMS "Network Designer" is a map-based UI that lets us construct our supply chain network visually and optimize connections and flows based on that topography

Source: https://www.aimms.com/stories/extended-demo-aimms-network-design/

Smart Vision Service/Product Offerings

- **CONSULTING SERVICES**

  Providing expert guidance and strategic advice to help organizations achieve their analytical goals

- **IMPLEMENTATION SERVICES**

  Seamless integration and deployment of software, systems, and technologies to ensure successful adoption and utilization.

- **TRAINING, SUPPORT & ENABLEMENT**

  Comprehensive training programs and ongoing support to empower clients and ensure they maximize the value of our services. Enabling our customers to become self sufficient through collaborative projects

- **SOFTWARE LICENSING AND SUPPORT**

- **MANAGED SERVICES**

  Outsourced data, analytics and business process management solutions that optimize operations, reduce costs, and enhance efficiency.

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