Applying Mathematical Optimization to Trading

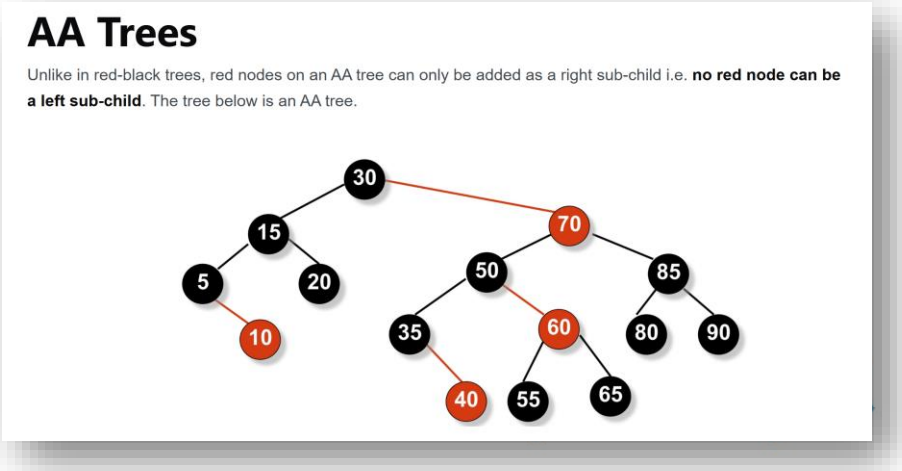
Arne Andersson

Retired from

Uppsala University / Coupa Software

Background

- Late 1990s: academic research on algorithms, optimization and electronic markets (AA-trees, World's fastest sorting algorithm, etc …)
- June 2000: Trade Extensions was founded, based on research on markets for electric power
- April 2017: Coupa Software acquires Trade Extensions



Cold winter morning.
Factories are starting up.
Water heaters are running.

Electricity Prices in Uppsala (SE3) 2025-02-18

NORD POOL
A EURONEXT COMPANY

Auctions | UK Auctions | Intraday | Power system data | Reports | Map | Settings | Subscribe | Log in

Day-ahead

- Prices
- System price & turnover
- Volumes
- Capacities
- Flows
- Scheduled physical flows
- Flow-based constraints
- Aggregated Bidding Curves

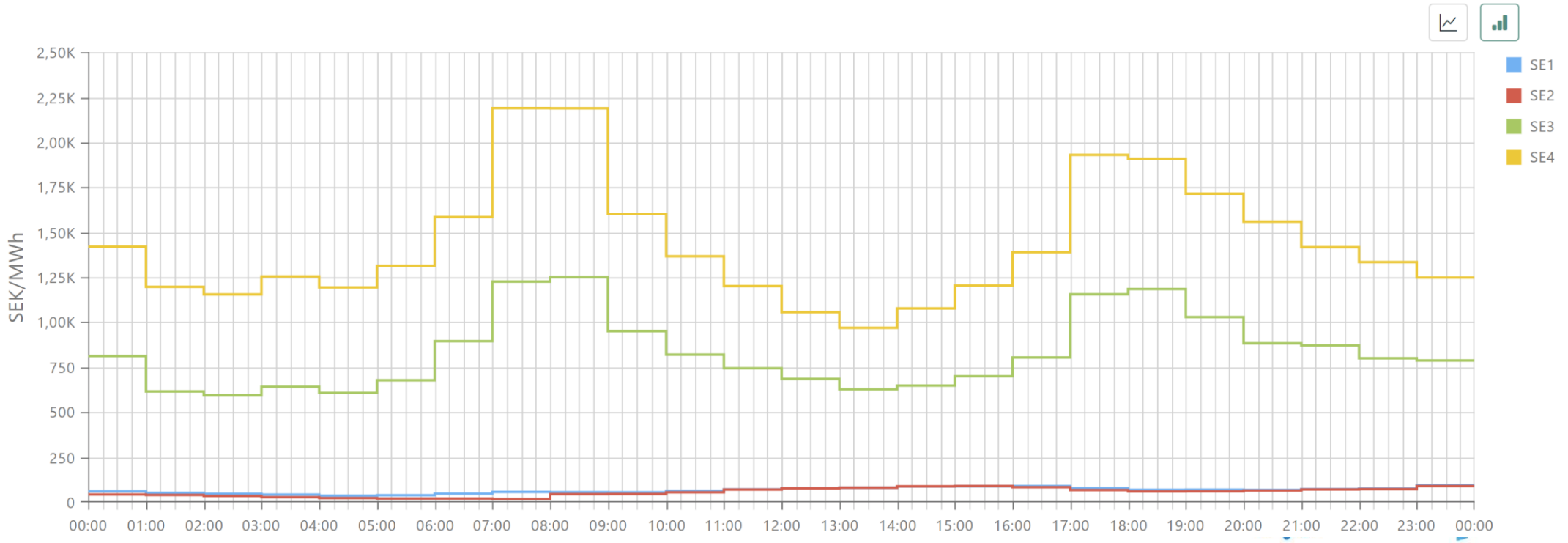
Prices

18.02.2025 | Time interval: Delivery Period | Currency: SEK | Filters | Hide Graph

Areas

Baltic | EE | LT | LV | CWE | AT | BE | FR | GER | NL | PL

Nordic | DK1 | DK2 | FI | NO1 | NO2 | NO3 | NO4 | NO5 | SE1 | SE2 | SE3 | SE4 | Romania | TEL | System | SYS



SVENSKA KRAFTNÄT

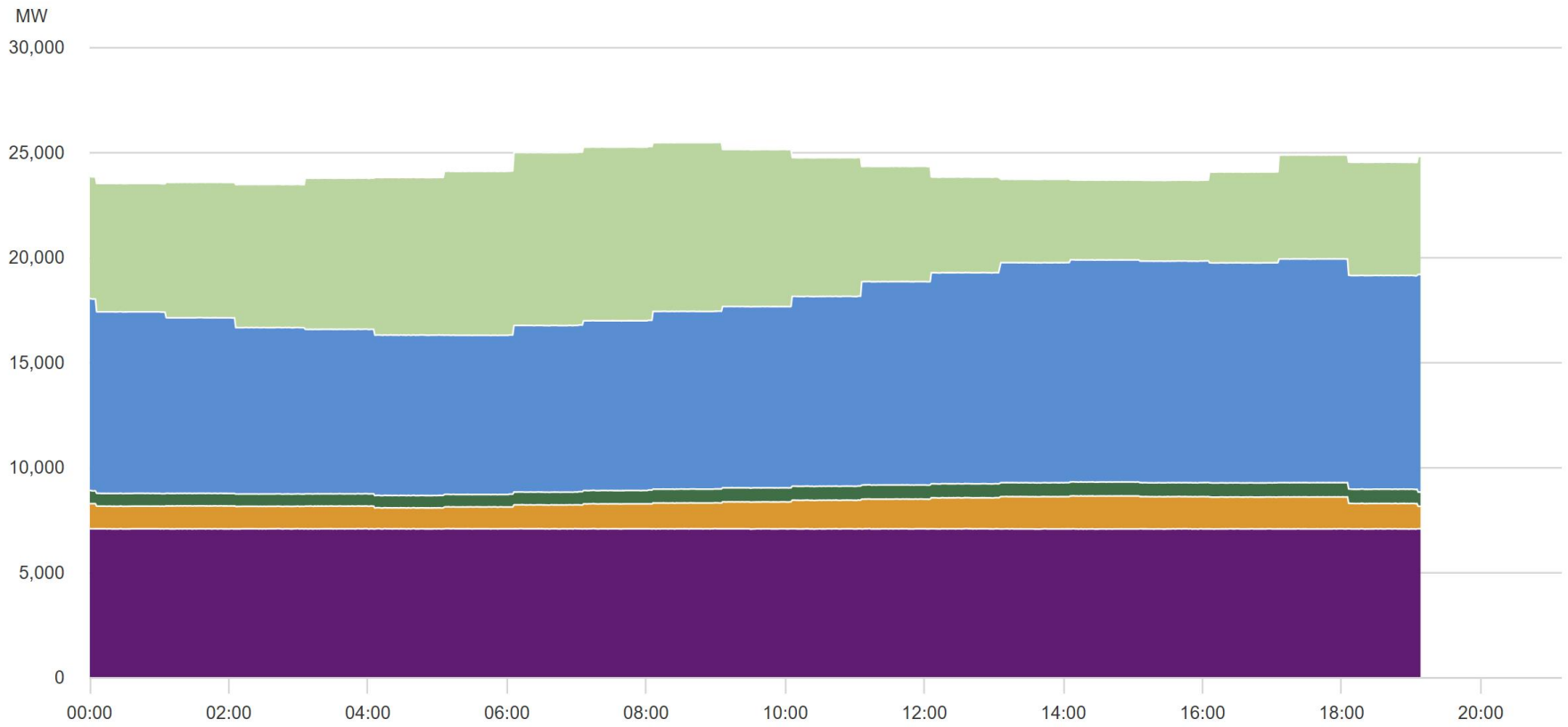
Search Menu

Date

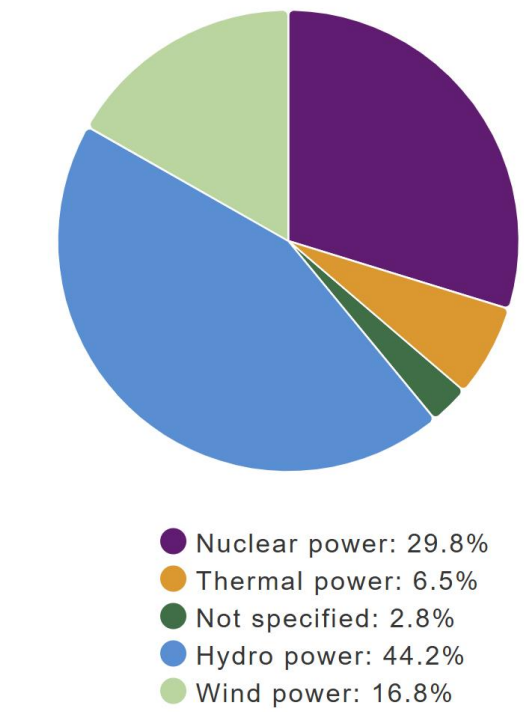
2025-02-18

Sweden | Denmark | Norway | Finland | Estonia | Latvia | Lithuania | Total

Graph Table



Power distribution at 19:08



Complex Market

Combinatorial bidding

Optimization

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What we do

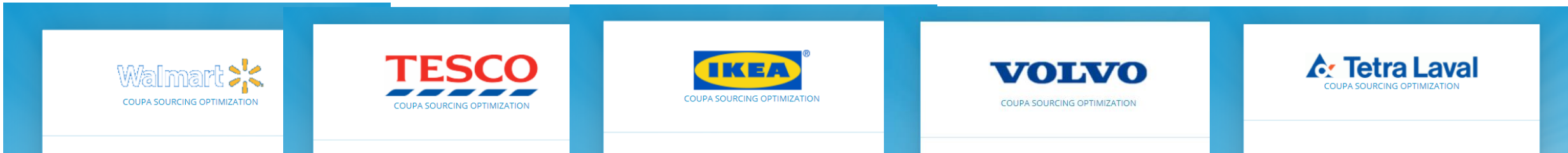
- Large-scale and complex negotiations between companies
- Optimization-based resource allocation.
- Handling lots of data, millions of bids, and advanced constraints

- ”I give you a better price if I get A, B, and C together”
- ”I want at most three suppliers in France”

Some facts

- A few billion USD sourced weekly.
- Several Fortune 10 clients. Majority of clients are large multi-national companies. Plus consultancy firms.
- Frequently projects at several 100 million USD.
- Largest sourcing project was around 8 billion USD.

- What we compute has large real-world consequences. Fantastic and scary.



The Optimization Problem

Minimize
- Cost

Given
- Items
- Bids
- Supplier constraints
- Buyer constraints

Solution
- A set of allocated bids.

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Negotiations add complexity to optimization


AZ İNCİ


IKEA®
$39.99/3pcs
ALVINE KVIST full/queen duvet cover set
Includes full/queen duvet cover and two queen pillowcases. 100% cotton. Imported.
White/gray 201.596.35 Available in other sizes.
Prices vary.
Where the everyday begins
THE PRICES IN THIS CATALOG CAN ONLY GET LOWER UNTIL JUNE 2015, NEVER HIGHER.
IKEA

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©Rolf Nystrom/www.rolfsbild.se


VOITH


MAERSK LINE


IKEA
Öppettider
mån - fre 10.00 - 20.00
lör - sön 10.00 - 18.00


Manetan

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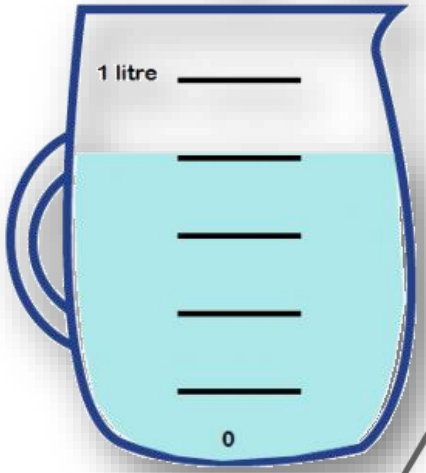

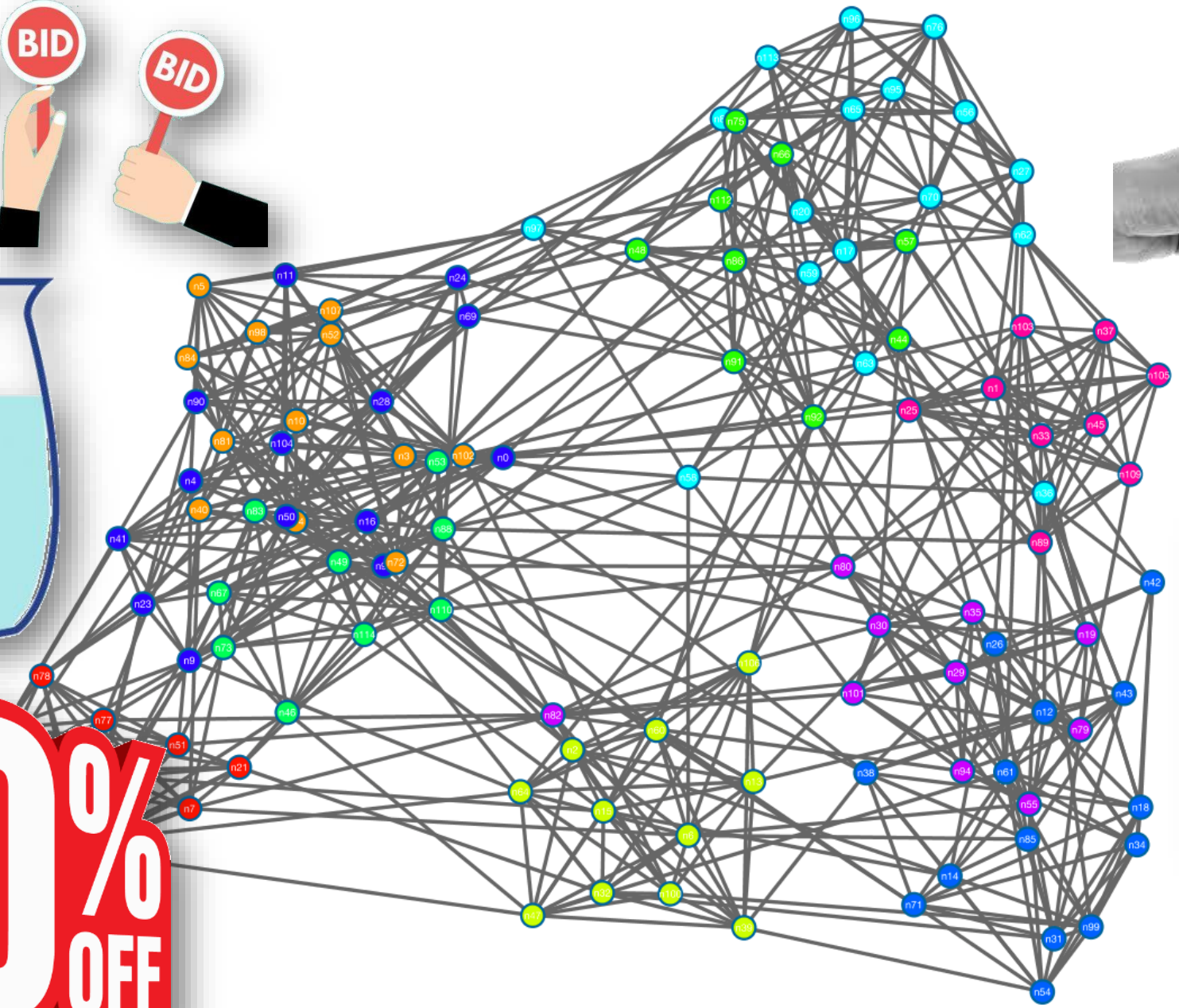

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Financial Development Index
Global investment percentage
Services
Ecology
Industry
Medicine
Science
Other
Key indicators
Financial assets by major type
0.4
0.2
0
-0.2
-0.4
2
1
0
-1
-2
-2
-1
0
1
2

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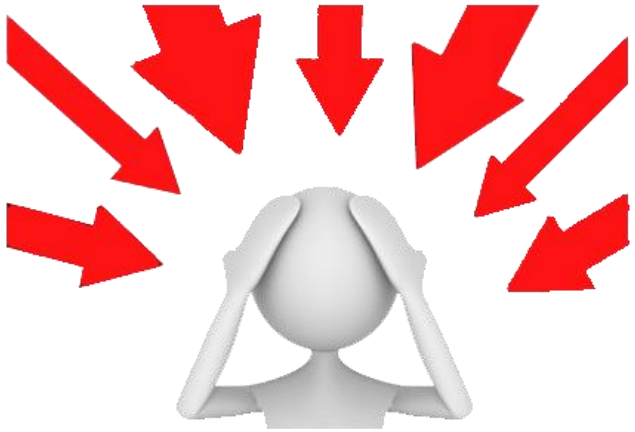
Buyer



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The mathematical world

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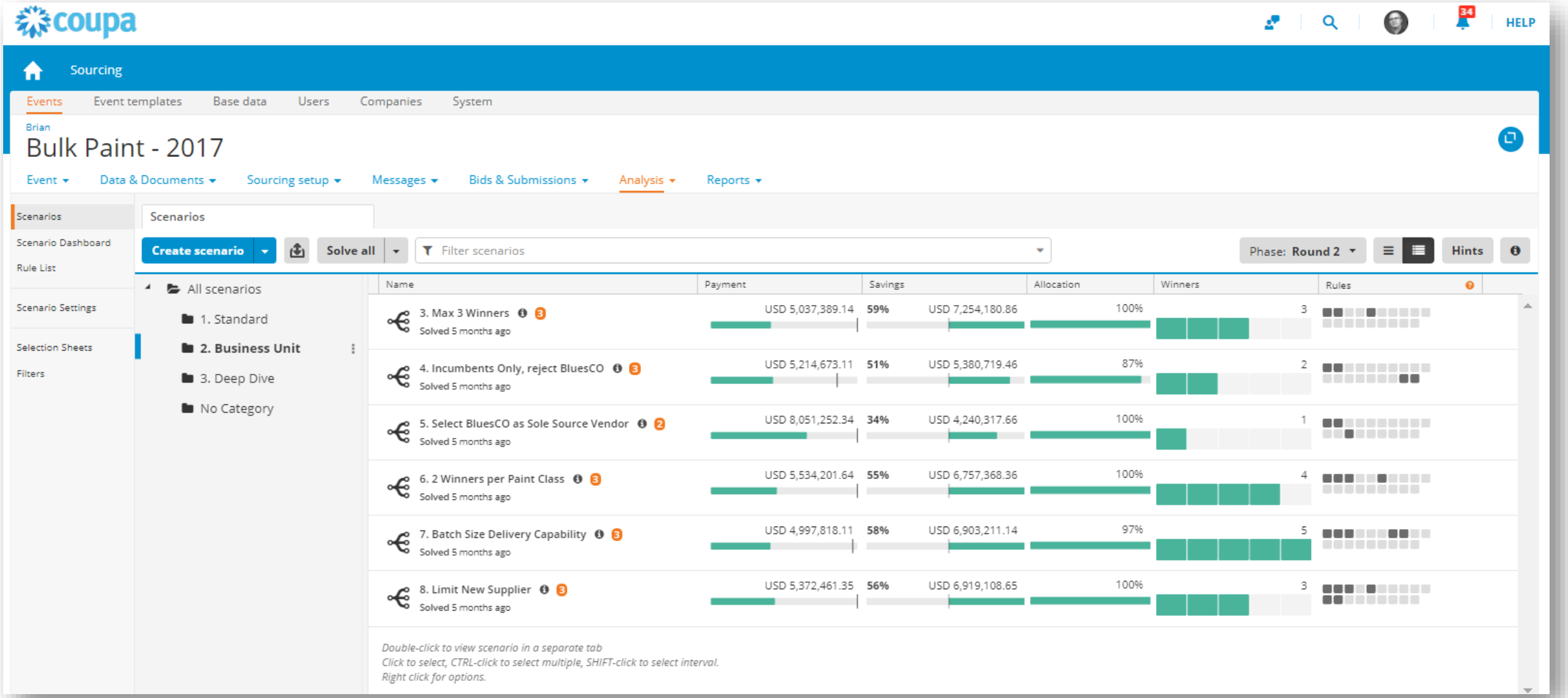
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HELP
Sourcing
Events
Event templates
Base data
Users
Companies
System
Brian
Bulk Paint - 2017
Event
Data & Documents
Sourcing setup
Messages
Bids & Submissions
Analysis
Reports
Scenarios
Scenario Dashboard
Rule List
Scenario Settings
Selection Sheets
Filters
Scenarios
Create scenario
Solve all
Filter scenarios
Phase: Round 2
Hints
All scenarios
1. Standard
2. Business Unit
3. Deep Dive
No Category
Name
Payment
Savings
Allocation
Winners
Rules
3. Max 3 Winners
Solved 5 months ago
USD 5,037,389.14
59%
USD 7,254,180.86
100%
3
4. Incumbents Only, reject BluesCO
Solved 5 months ago
USD 5,214,673.11
51%
USD 5,380,719.46
87%
2
5. Select BluesCO as Sole Source Vendor
Solved 5 months ago
USD 8,051,252.34
34%
USD 4,240,317.66
100%
1
6. 2 Winners per Paint Class
Solved 5 months ago
USD 5,534,201.64
55%
USD 6,757,368.36
100%
4
7. Batch Size Delivery Capability
Solved 5 months ago
USD 4,997,818.11
58%
USD 6,903,211.14
97%
5
8. Limit New Supplier
Solved 5 months ago
USD 5,372,461.35
56%
USD 6,919,108.65
100%
3
Double-click to view scenario in a separate tab
Click to select, CTRL-click to select multiple, SHIFT-click to select interval.
Right click for options.

Solve all

Filter scenarios

Name		Savings	Allocation
3. Max 3 Winners Solved 5 months ago	389.14	59% USD 7,254,180.86	
4. Incumbents Only Solved 5 months ago	673.11	51% USD 5,380,719.46	
5. Select BluesCO a Solved 5 months ago	252.34	34% USD 4,240,317.66	
6. 2 Winners per Pa Solved 5 months ago	201.64	55% USD 6,757,368.36	
7. Batch Size Delivery Capability 3 Solved 5 months ago	USD 4,997,818.11	58% USD 6,903,211.14	

Optimisation value (USD)

Adjusted payment	5,214,673.11
Rule violation penalty	0.00
+ Non-allocated volume penalty	490,589,621.94
Computed cost	**USD 495,804,295.05**

Solve time

Preparation	00s
Creation	00s
Computation	00s
+ Storing	00s
Total Solve Time	**01s**

Buyer-defined scenarios: Typical constraints

- At most 50 winners in total.
- At most 10 winners per factory.
- No more than 5% of suppliers turnover in award.
- No more than 25% to new suppliers
- Suppliers discounts:
  - If I get these five lanes in combination I can offer a different transit time.
  - I offer 30% discount on backhauls.
  - If I get more than 3MUSD of business I offer a 5% discount.

Our task: Helping buyers to easily set-up such rules, solve the optimization problems, and provide means for quickly and in detail compare different scenarios of allocation. (What is the impact by factory if changing from 45 to 50 suppliers in total?)

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Example 1: Understanding Reserve Cost

- Constraint: At most one winner

Lane	Supreme Transport	Mediocre Transport
Berlin – Hamburg	1 000 000	1 200 000
Hamburg – Salzburg	1 500 000	1 700 000
Gothenburg – Uppsala	400 000	600 000
Rotterdam – Amsterdam	2 000 000	2 300 000
Bern – Innsbruck	300 000	400 000
Paris – London	3 000 000	3 400 00
Tranemo – Svenljunga		50 000

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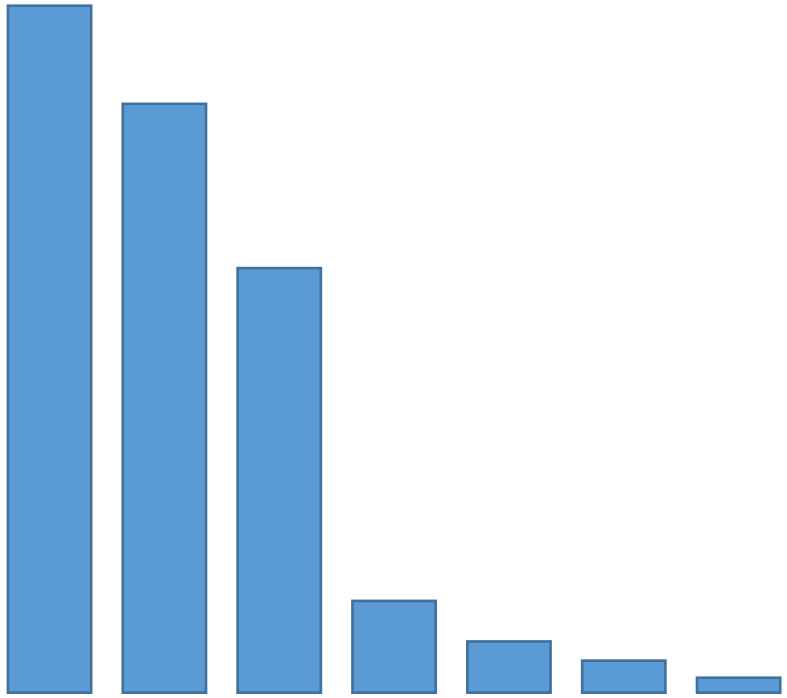
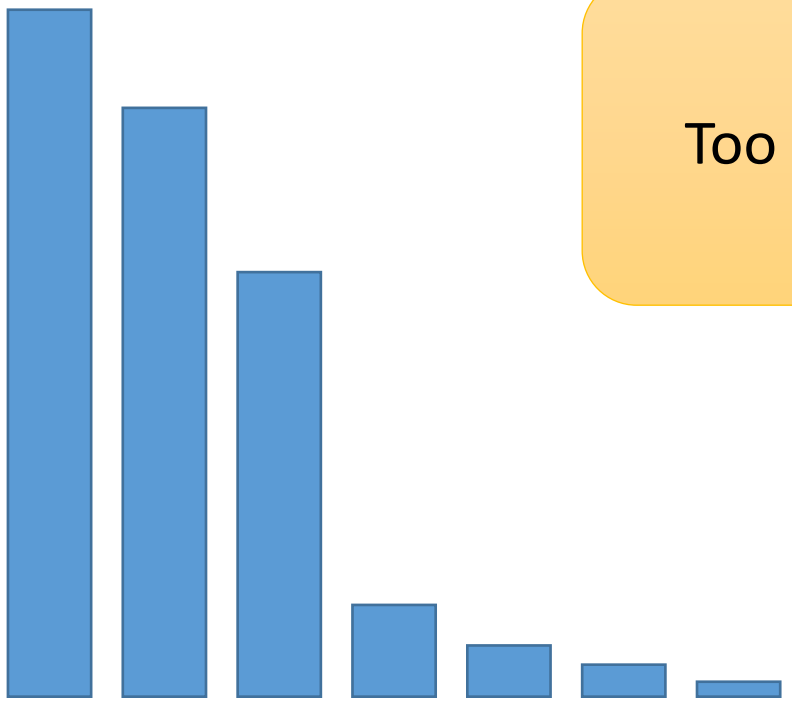
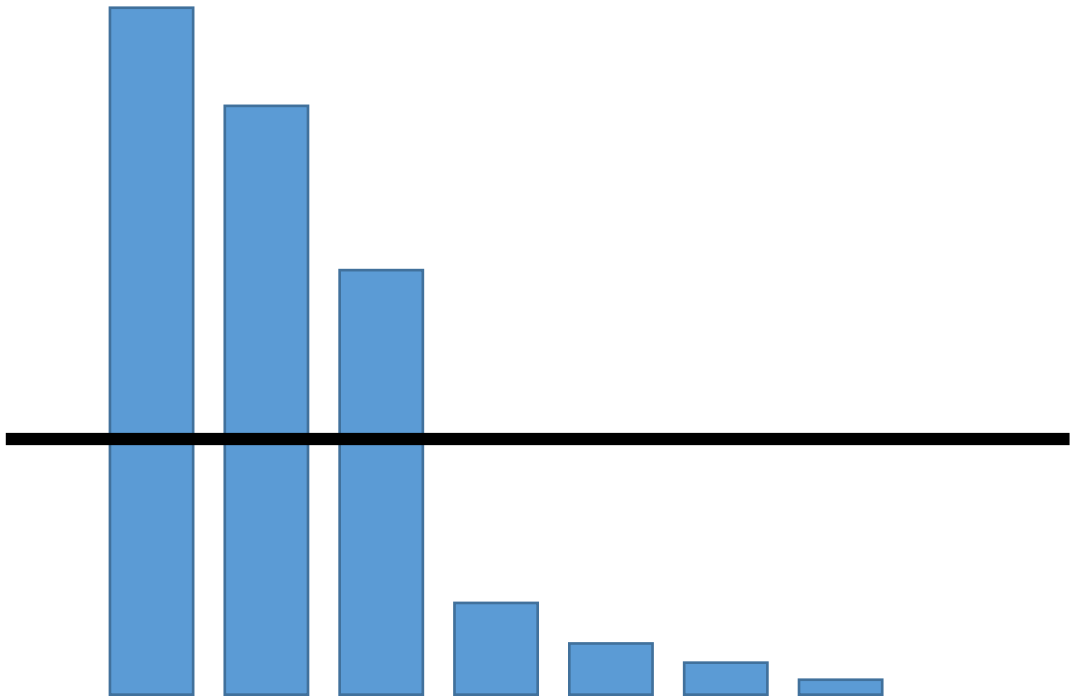
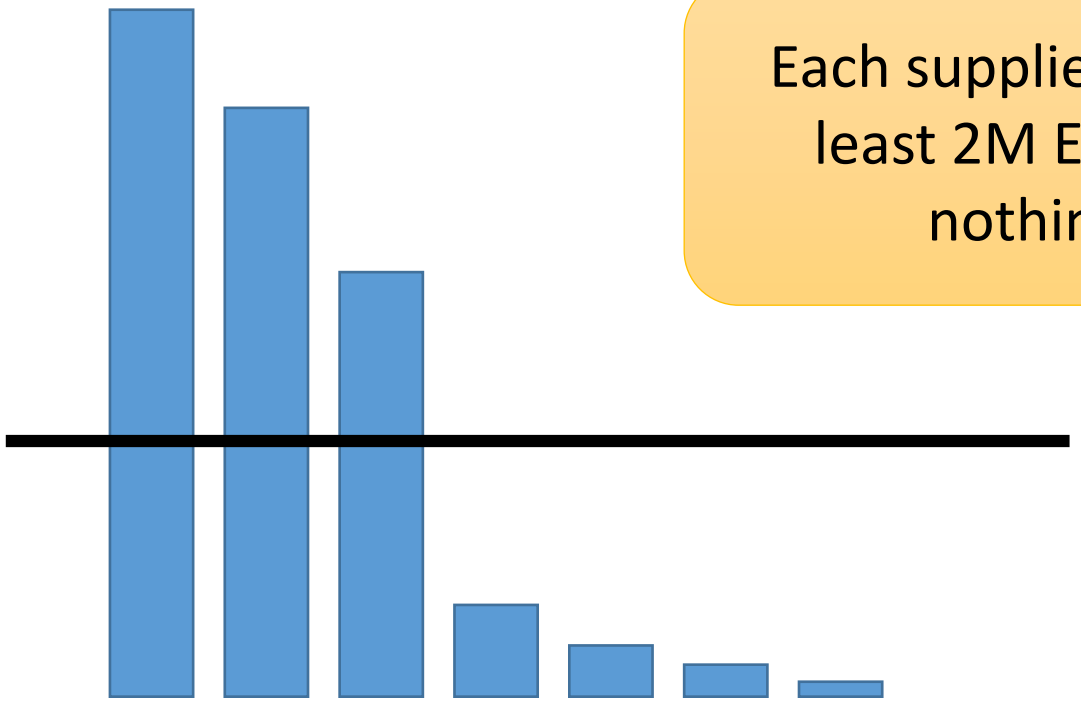
Example 2: Pick the right constraint



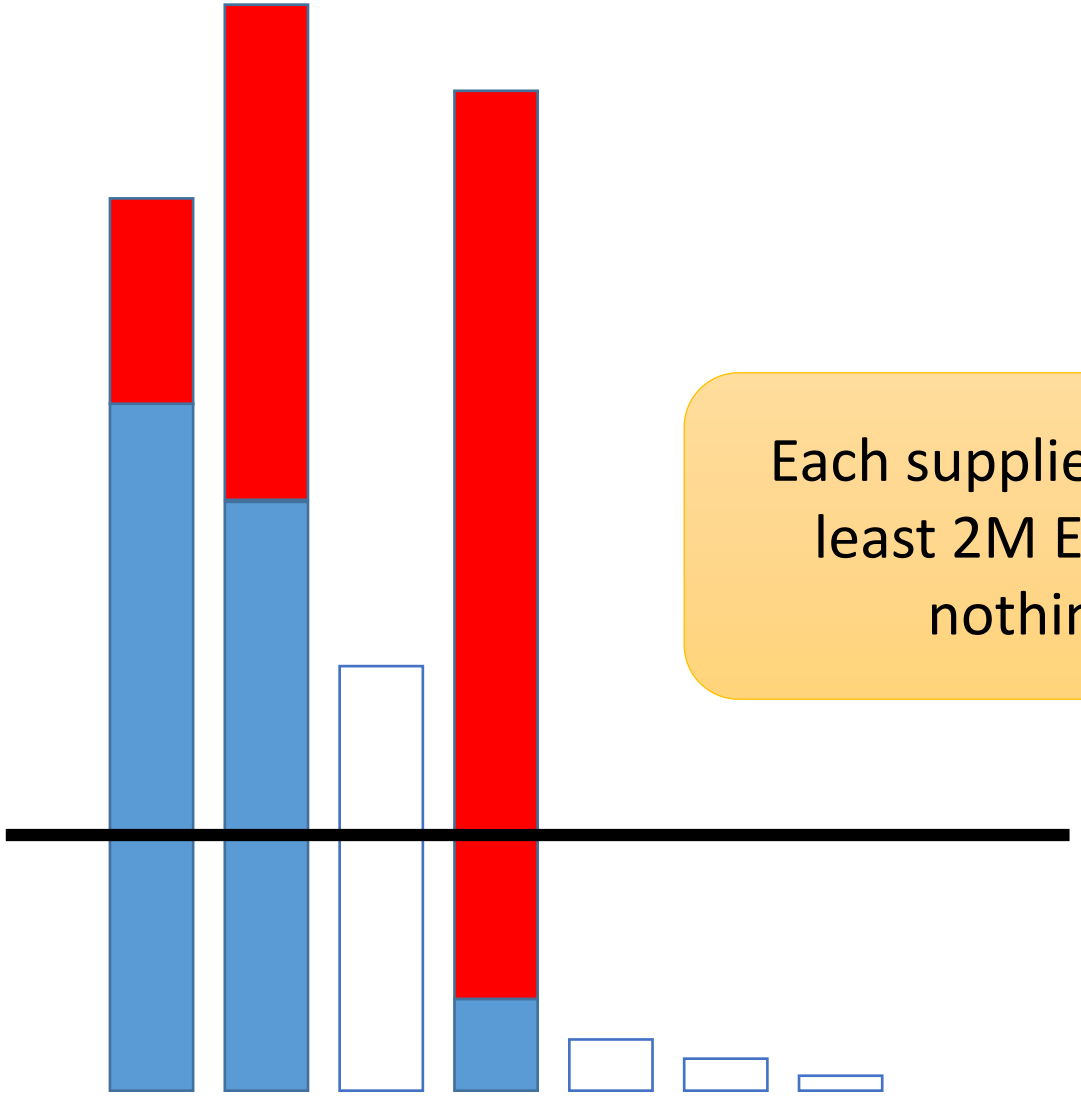


Too many suppliers





Each supplier gets at least 2M Euro, or nothing.



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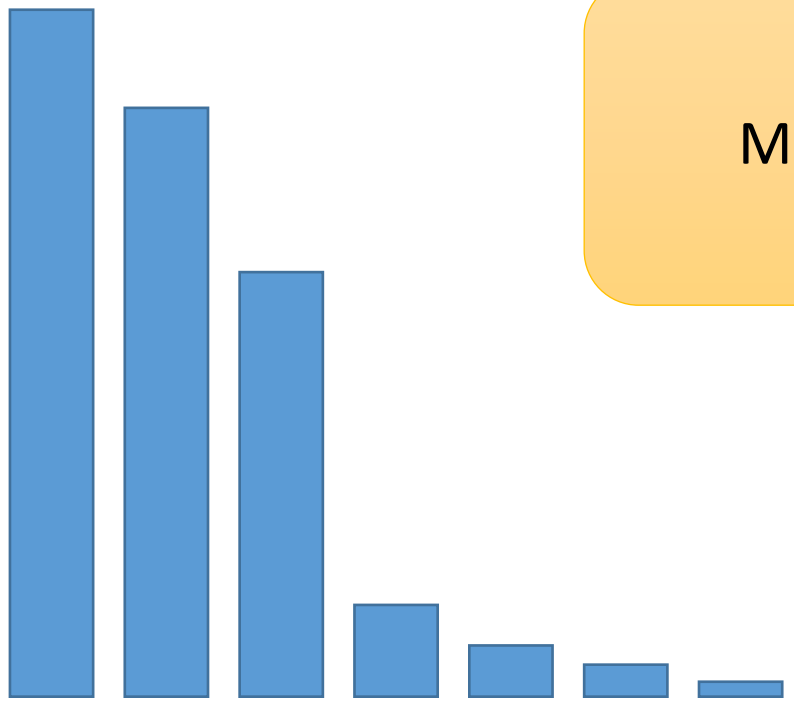
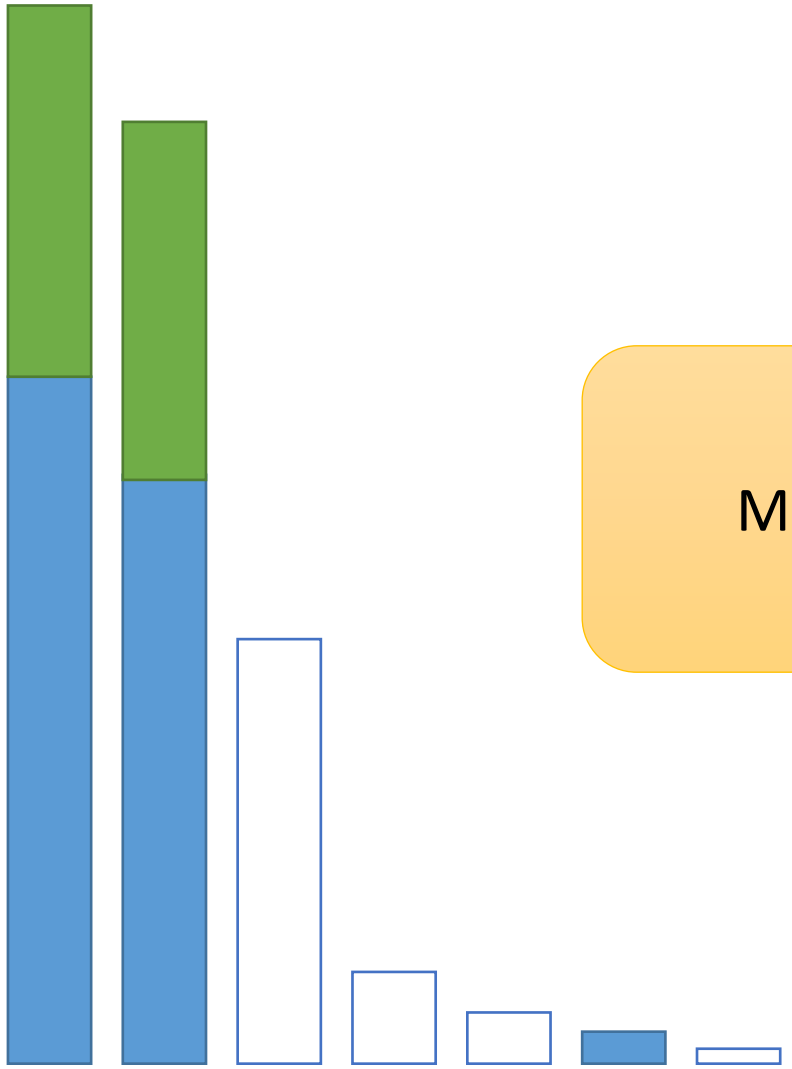


Max 3 winners.



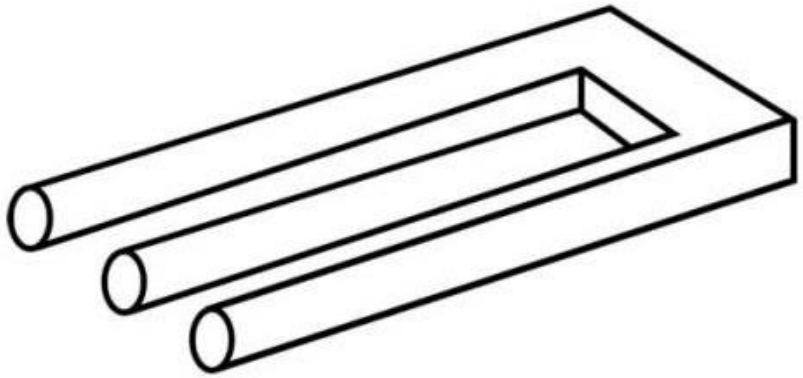
Max 3 winners.

Example 3: Rounding

Supplier	Number of weekly containers awarded
Supreme Transport	134.5
Mediocre Transport	34.1
Splendid Transport	100.4
Transporting Hipsters	22

Example 4: ”2nd best solution”

Example 5: infeasibility



Example 6: Automated User Guidance

Max 3 winners.

Example 6: Automated User Guidance

Max 3 winners.

Max 3 winners per Country.

Example 6: Automated User Guidance

Max 3 winners.

Max 3 winners per Country.

Max 3 winners per country except France.

Summary

- Bringing optimization to the real world
- Large Data Sets
- Many challenges

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