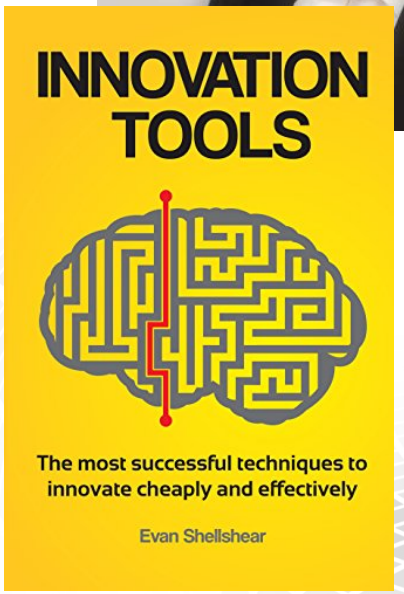
GUROBI
OPTIMIZATION

Welcome to the webinar

The Grain Drain: Large-scale Grain Port Terminal Optimization

Speaker Introduction

- **Dr. Evan Shellshear**
  - Head of Analytics at Biarri
    - Certified Analytics Practitioner
    - BA/BSc in Maths, Dipl. Wirt. Math from Bielefeld University
  - Ph.D. in Game Theory, University of Bielefeld (Germany)
  - Many years of experience in the development and design of decision support systems using mathematical optimisation methods. Wrote global best algorithm for ISO 3832 packing standard.
  - Author of the best selling book, Innovation Tools.



Biarri
COMMERCIAL MATHEMATICS

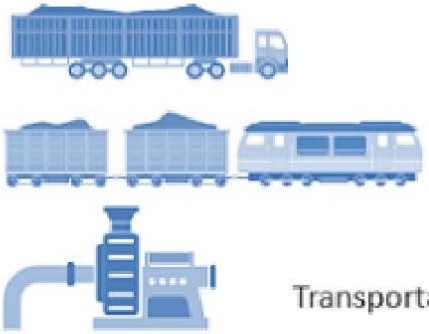
THE GRAIN DRAIN

LARGE SCALE GRAIN PORT OPTIMISATION

Supply chain costs contribute roughly 30% of grain production cost, adding up to $75/t.

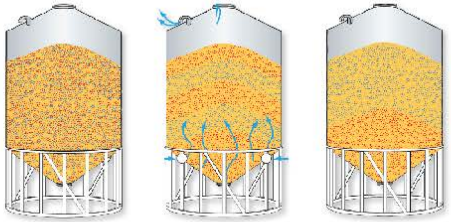
Farm

Harvest



Transportation

Ports & shipping



Blending

- The efficiency of the port is a major driver of these costs.

Why is this important?

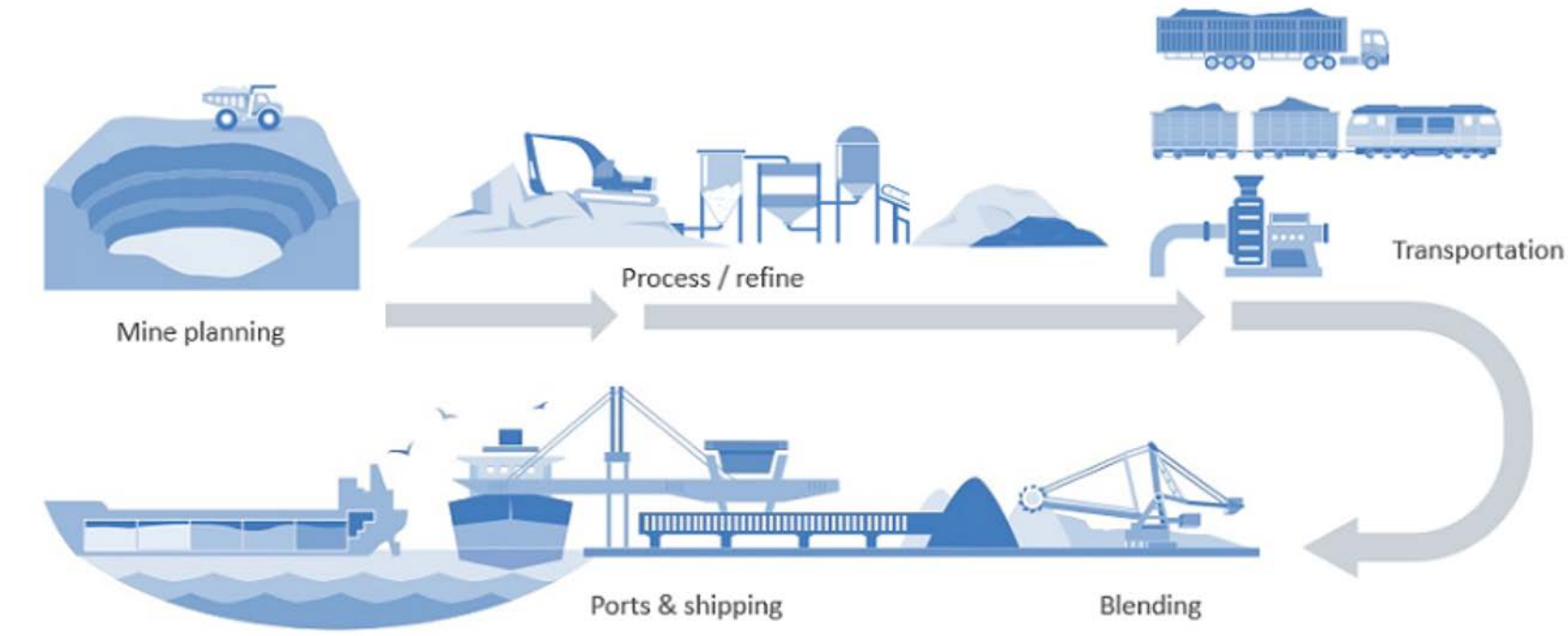
WHY is this important?

BEER IS CREATED WITH JUST FOUR KEY INGREDIENTS...

MALT + HOPS + YEAST + WATER = BEER

(THE SOUL) (THE SPICE) (THE MAGICAL INGREDIENT) (THE UNSUNG HERO)

This is a typical supply chain problem for multiple industries.

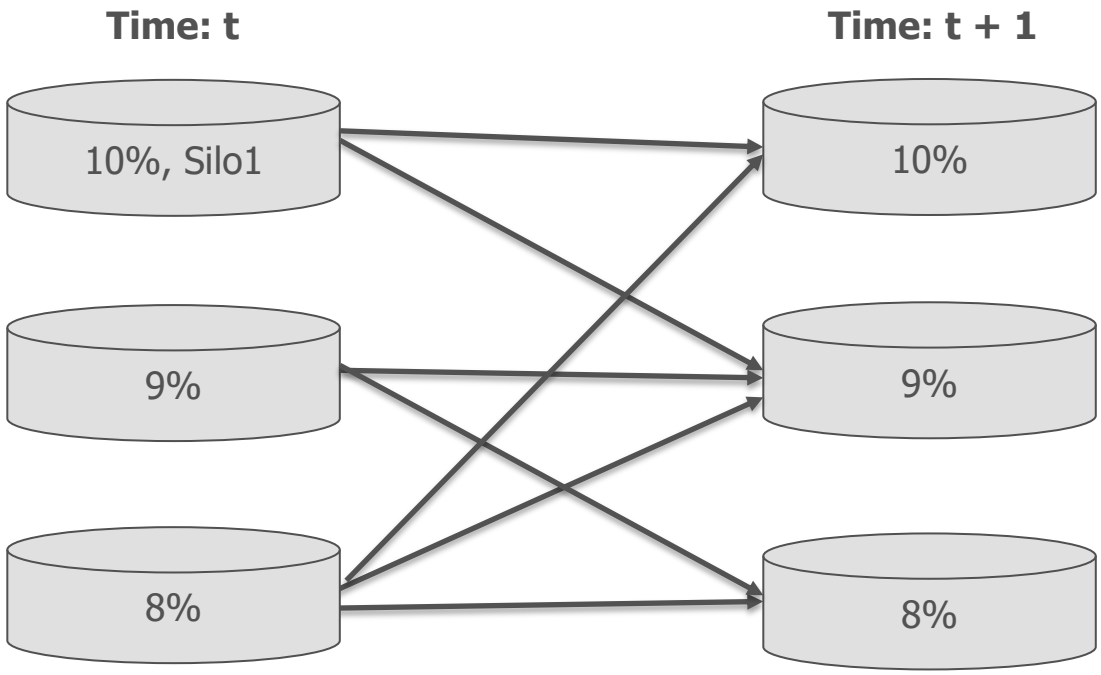


THE MATHEMATICAL PROBLEM

The Pooling Problem

- A multicommodity network flow, with blending. Known as the pooling problem in the literature.
- At a high level, we use a MIP in a very similar way to a typical MCNF problem, but allow arcs between nodes where the product can transform type.
- We then enforce that the right mix of product has been transformed.
- We ultimately did away with nodes in our formulation but it may help to think of there being one node, for each (Silo, Timestep, Commodity) combination and an arc from all nodes at Timestep, t to Timestep t+1

The Pooling Problem



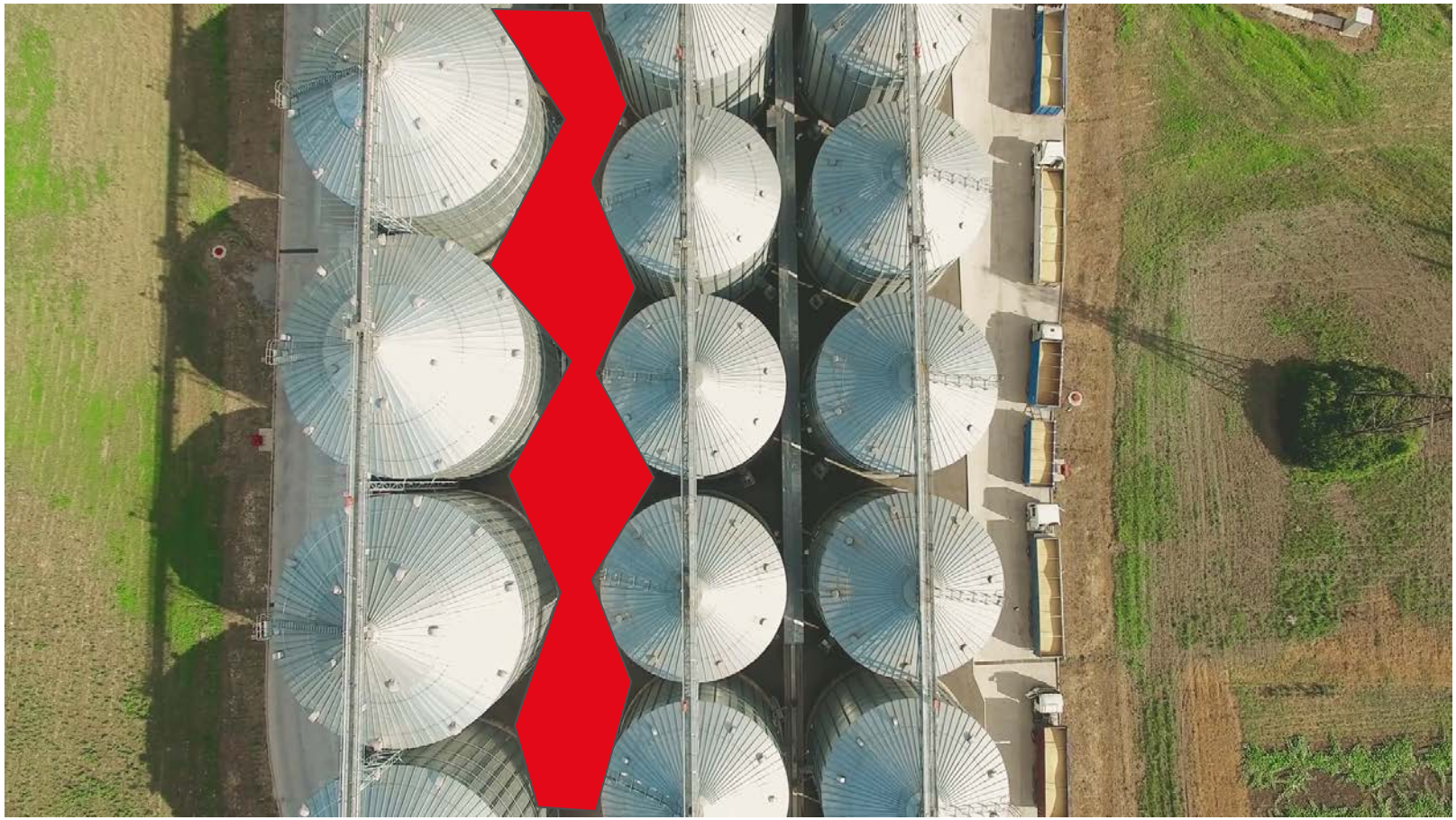
We have cross commodity protein limits so that the protein composition of the outflows from a set of silos is equal to the require protein grade

THE PRACTICAL DETAILS

The client has a 12 floor silo building, 1m tonnes of storage on site

The ‘Mad Mile’, 700m of belt out to the vessels. The belt only runs one way…

Our client even use the space between silos as cells. In total 254 silos plus annexes and bulk heads.



Silos are connected via a complex network of lifts

And conveyors

The Scale

- **15 million tonnes of product moved, the majority through the closest port**. Oats and Lupins in addition to Grain, Barley and Canola.
- Currently product is pushed onto the port. We must accept all product delivered and only **decide how product is moved within the port**.
- Labour and electricity power bills are still the two major cost drivers at the port. We wanted to minimise these costs. **60% of product is moved more than once**.
- The engine must be able to schedule **fumigations, cyclical cleaning and preventive maintenance**.
- Target tight **protein levels, to the nearest 0.1%**. This impacts the commodity count.

The Pooling Problem

- We ultimately did away with nodes in our formulation but it may help to think of there being one node, for each (Silo, Timestep, Commodity) combination and an arc from all nodes at Timestep, t to Timestep t+1

Flows from **#Silos** to **#Silos** every **#Timestep** for each **#CommodityType**

260 * 260 * (7*24*4) * ((13-8)*10 + 50)

=

4, 452, 720, 000 variables

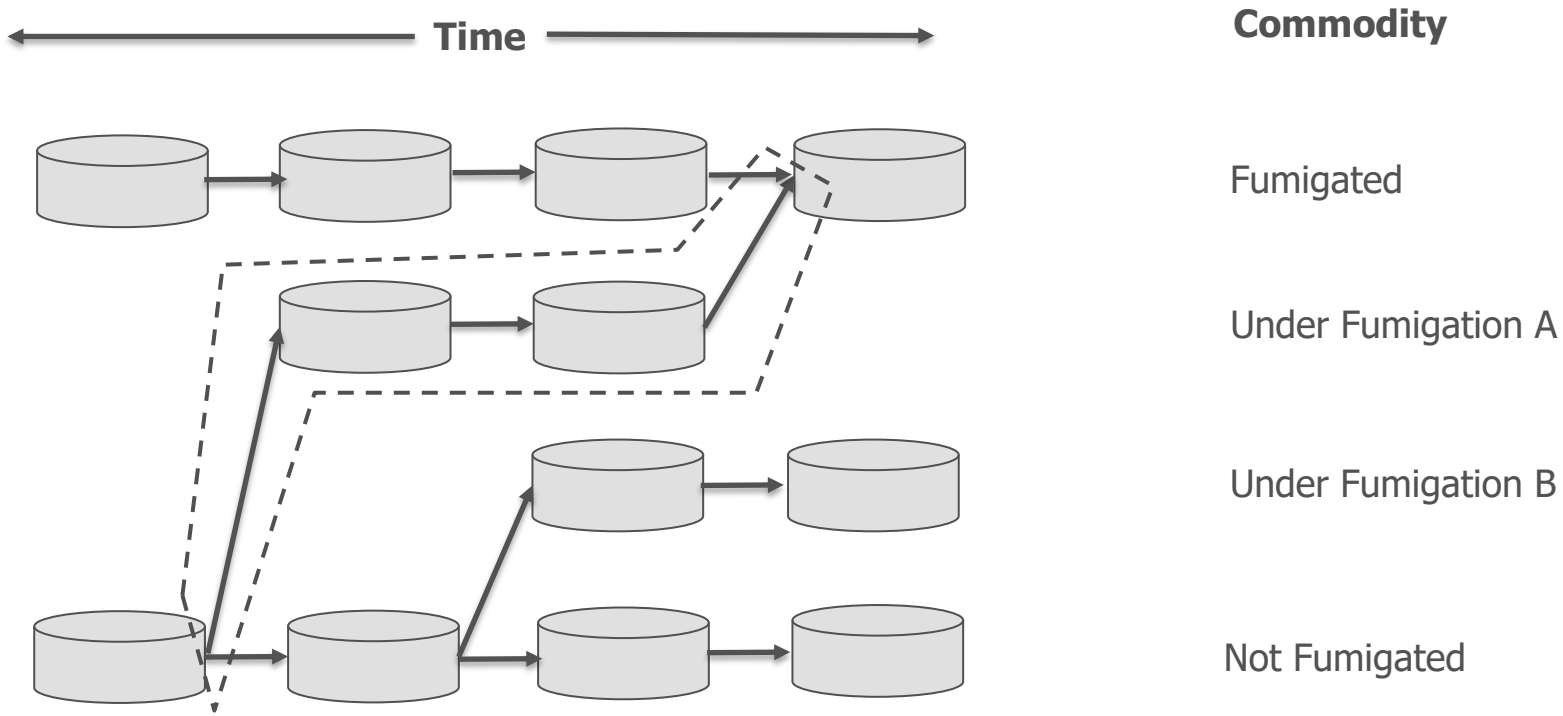
+ Staffing
+ Fumigation
+ Cleaning, Maintenance

Fumigation


2XE
DANGER
METHYL BROMIDE
HAZCHEM 2WE
DANGER
KEEP OUT
AUTHORISED PERSONNEL ONLY

Arc Generation - Fumigation

- Fumigation



FORMULATING THE PROBLEM

The MIP – Sets

To define the objective function we need to define some sets. Those being:

1. Set of time periods
2. Set of commodities
3. Set of "buckets"
4. Set of vessels
5. Set of shifts
6. Set of nodes. Nodes are composed of time periods, commodities and "buckets"
7. Set of Arcs (abstracted conveyor belts grouped together)
8. Set of Incompatible Arcs (paths that shared a conveyor belt)
9. Set of priority-dependant buckets (for silos with different emptying strategies)

These comprise the sets of the variables.

The MIP – Objective

The object is to minimize the cost of all port operations, including active operations, staffing costs and demurrage costs. This is defined by:

Minimise (Arc Fixed Costs + Arc Variable Costs + Staffing Costs + Demurrage Costs)

We used both the continuous variable on the arc for quantity and a binary variable to indicate usage to handle the fixed costs and the variable costs.

The MIP - Constraints

Have a variety of constraints to reflect that most important parts of the problem such as:

1. Arc capacities for used arcs
2. Node capacities with inflows
3. The usual flow conservation properties
4. Arc group usage, tonnage and timings
5. Preventing the mingling of different commodities
6. Closing profile (status of inventory at end of solve period)
7. Vessels are filled with pre-ordered goods
8. Demurrage constraints for waiting ships
9. Staffing constraints

As well as a variety of other less important constraints that define the problem

Solve Time


MY GUN--BY SPECIAL RADIATION--
CAUSES THE BODY TO ABSORB
MOISTURE FROM THE AIR AT AN
INCREDIBLE RATE, AND SWELLS
ITS VICTIM LIKE A BALLOON!
I'M GETTING HEAVIER--
SLOWING
ME
DOWN!
I CAN...
HARDLY
MOVE--!

Speedups

- Successful speed ups
  - Arc culling: same silo type
  - Arc culling: blending to non-ordered products
  - Presolve – with "combined silos" (*)
  - Presolve – without staffing, labour cost on arcs
  - Longer timestep
  - Silo group formulation
  - Campaign Shipping

- Unsuccessful speedups
  - Slack variables on orders/closing profile constraints
  - Shorter timestep, replacing arc timing maximum with single arc usage
  - Adding additional staffing constraints to remove staffing linking constraints

- Potential speedups
  - Network-based demurrage implementation
  - Staff "jiggle" after no staffing pre-solve
  - Rolling horizon

Silo Groups

- Silo group formulation:
  - Group like silos together, e.g. all row 1 on the north side of the building.
  - Same flow paths to get to and from silos in these groups.
  - Can get from any silo in this group to any other
  - Resolve with all silos with extra constraints around flows to silo groups.

Silos: 260 -> 20

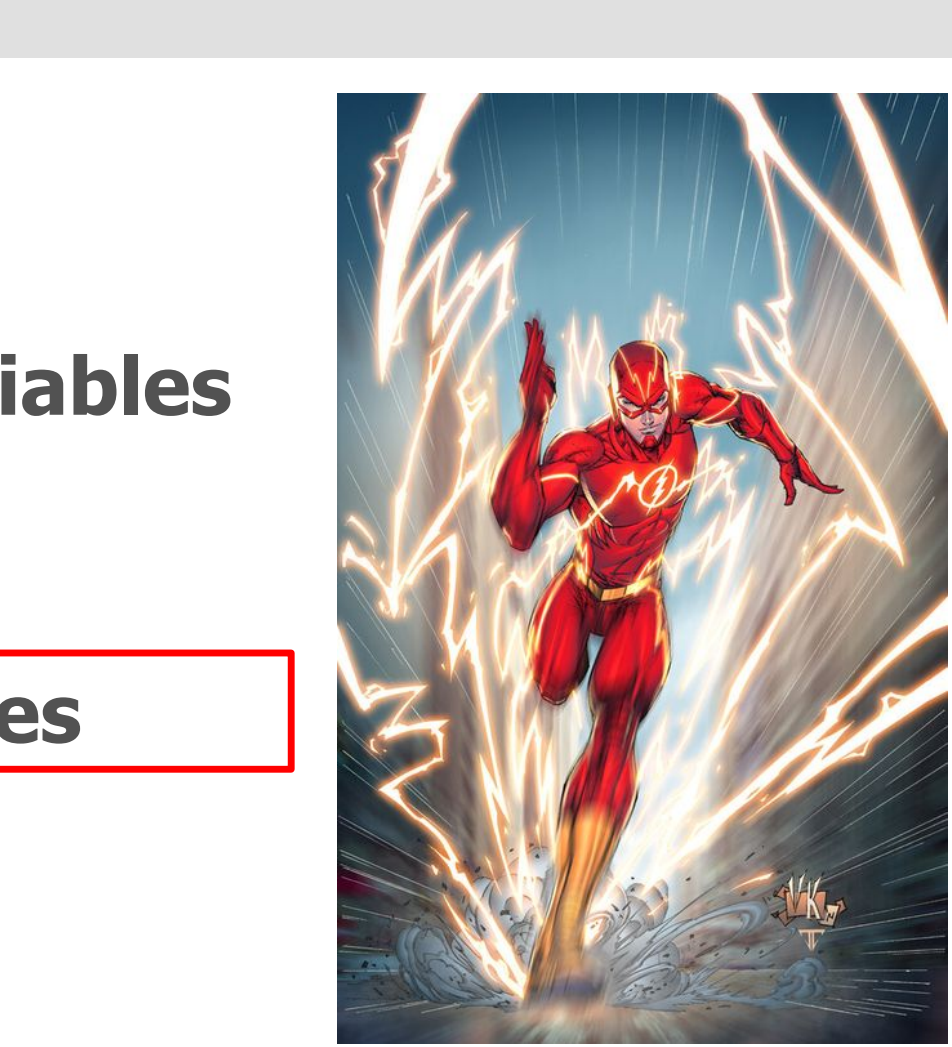
Campaign Shipping

- Campaign Shipping:
  - Treat orders as a commodity type, not each 0.1% of underlying product.
  - Reduces the number of commodity types (and variables) but also the number of constraints:
    - Only need an assignment of product coming in to the port to an order (or product already in the port) and a constraint ensuring all product assigned to an order by the time a vessel leaves blends to the correct specification.

CommodityType: 100 -> 20

Massive reduction in problem size

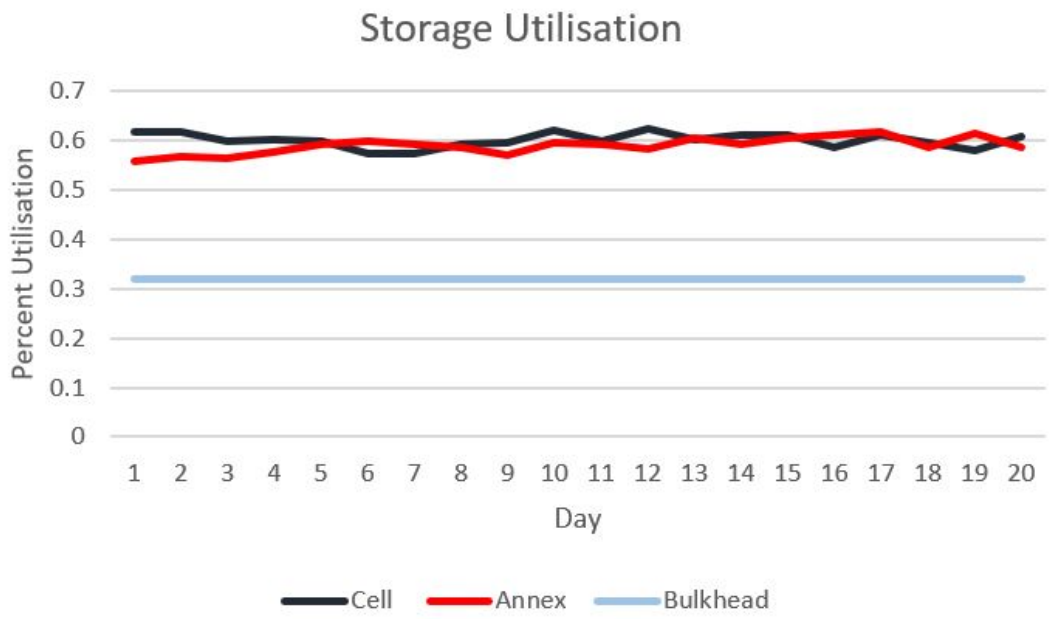
4, 452, 720, 000 variables



896, 000 variables

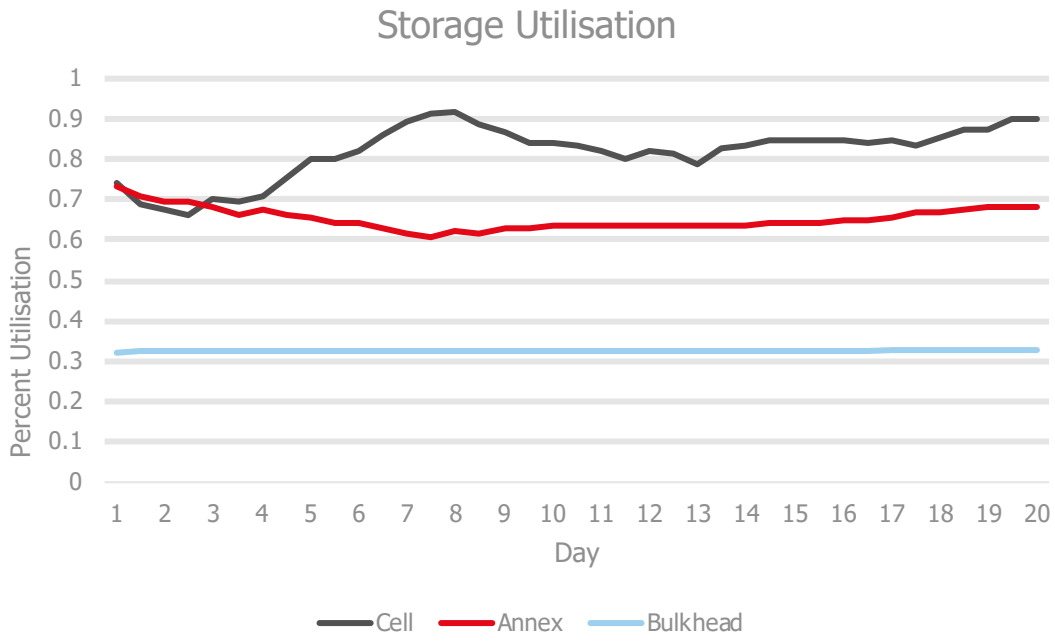
Before Optimisation

- Planners operated at around 60% of the optimal solution.
- Planners had an operations where one row of planners with excel sheets was watched by a second row of planners
- An inability to respond to issues and so extra capacity and redundancy was required.



After Optimisation

- Planners operate at 90% of the optimal solution.
- Gives planners at operational staff confidence.
- Gives them the power to react to day to day challenges (pest infestation, vessel failing survey).



The final result – client mind blown

"On one of the test runs I notice it decided to slow load a vessel towards the end?! But!! We found it was planning stock for the 4th ship down the track. What we lost slow loading 4 hours but what we gained was 10 hours plus less grain movements."

- Client

Next Steps

GUROBI OPTIMIZATION

- If you haven't already done so, please register for an account at www.gurobi.com.
- For questions about Gurobi pricing contact sales@gurobi.com or sales@gurobi.de.
- A recording of this webinar, including the slides, will be available in one week.
- Join us for future live webinar sessions! Check www.gurobi.com/events.