Production Scheduling in an Industry 4.0 Era

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Public private partnership between:

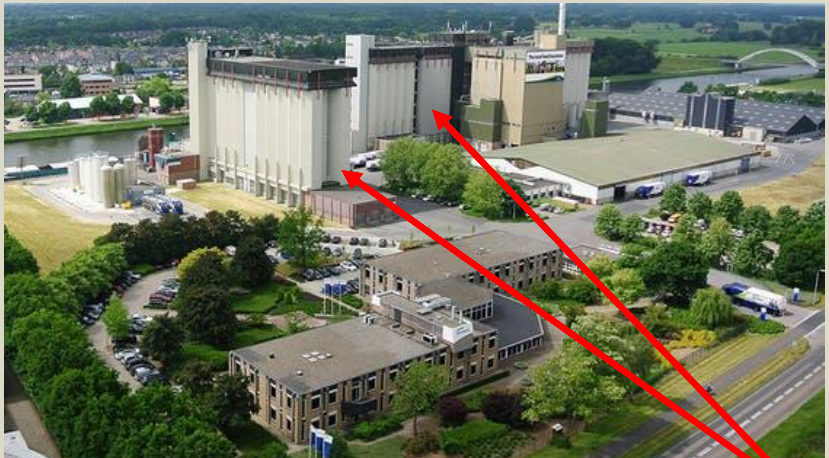
Centrum Wiskunde & Informatica

ENGIE automates plants

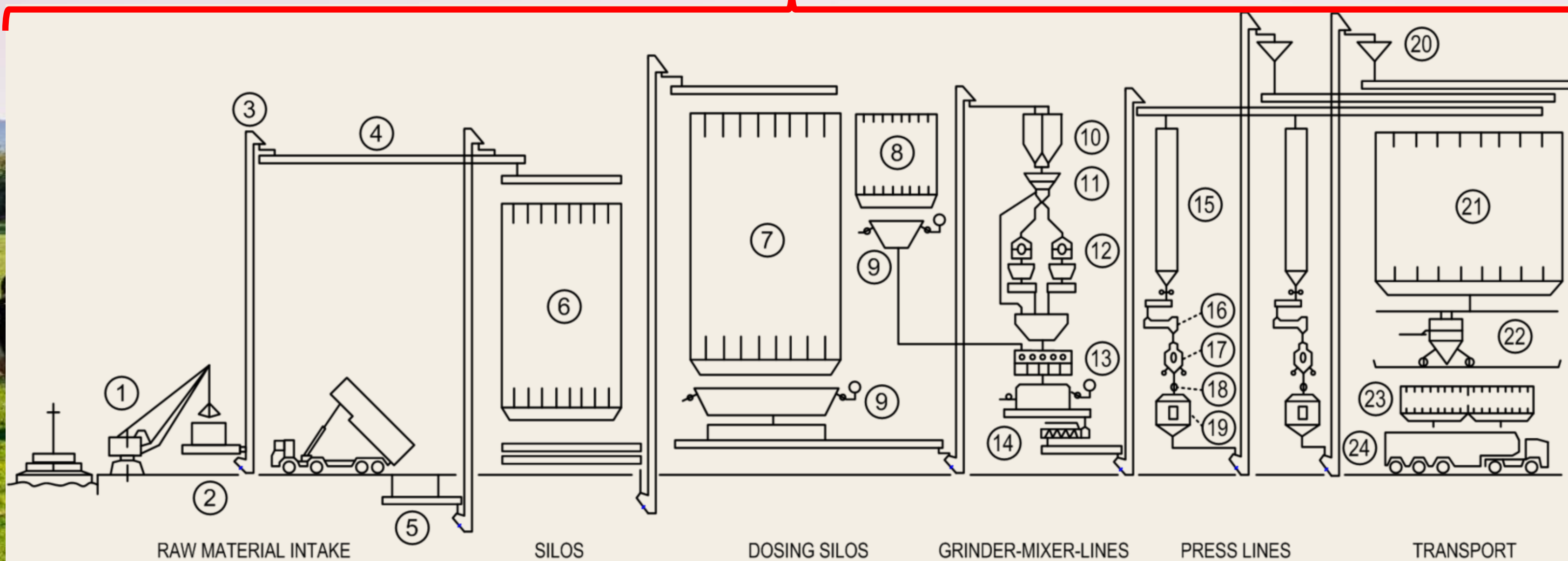
Content Presentation

- Scheduling in animal-feed plants
- Research approach
- Results
- Concluding remarks

Scheduling in Animal-Feed Plants



- World-wide: 10^{12} kg
- **120** plants in Holland
- Production aspects:
  - Customer order due dates
  - Contamination
  - Changeover times
  - …



Production Scheduling Problem

Trends: 'big data' & mass-customization (industry 4.0)

Goal: How to efficiently schedule orders to meet due dates?

Current situation: planners 'schedule by hand' ...

As a result: time-consuming and opportunity loss (inflexible and 'big data' unused)

Research Approach:

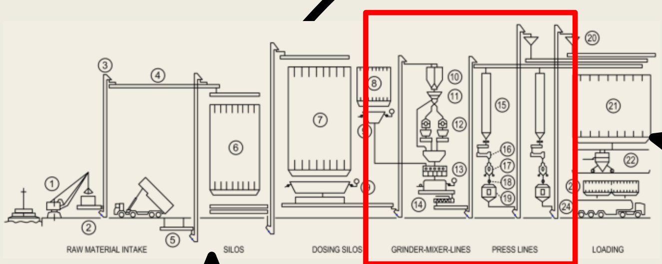
Mixed integer linear programming (MILP):

$$\min_{\mathbf{x},\mathbf{y}} \quad z \triangleq \mathbf{c}^T\mathbf{x} + \mathbf{d}^T\mathbf{y}$$
$$\text{s.t.} \quad \mathbf{A}\mathbf{x} + \mathbf{E}\mathbf{y} \left\{ \begin{matrix} \leq \\ = \\ \geq \end{matrix} \right\} \mathbf{b}$$
$$\mathbf{x}_{\min} \leq \mathbf{x} \leq \mathbf{x}_{\max}, \quad \mathbf{y} \in \{0,1\}^{n_y}$$

MILP implementation:

Accuracy testing:

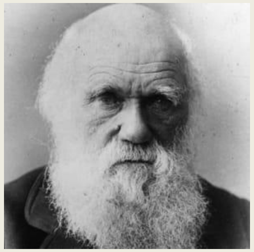
Simplification:



Schedule advice:

Solve MILP:

GUROBI OPTIMIZATION +



(Darwin)

+ *"Common sense"*

MILP solving strategies:

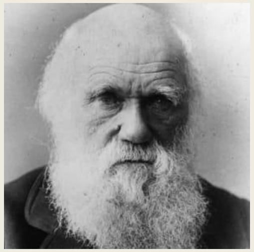
For **small** instances:
(max. 3 hour time horizon)

For example: only consider schedules that produce roughly in order of the customer order due dates

For **medium** instances:
(max. 6 hour time horizon)

+ *"Common sense"*

For **large** instances:
(> 6 hour time horizon)



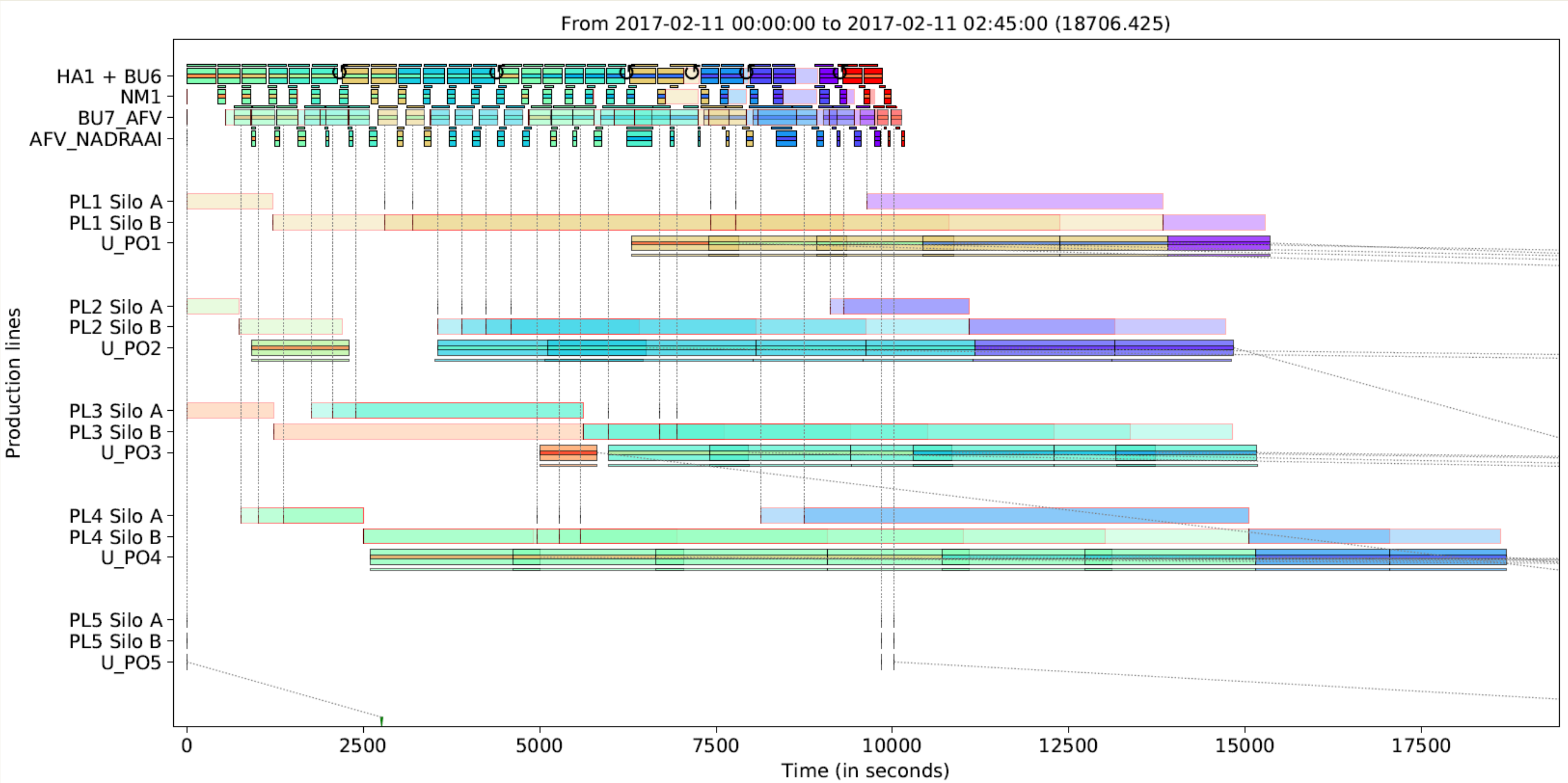
Evolutionary computing on bottleneck production area*

+

* By extending the ideas from "Expanding from Discrete Cartesian to Permutation Gene-pool Optimal Mixing Evolutionary Algorithms" from Bosman et al. (2016) to flexible flowshops

Results:

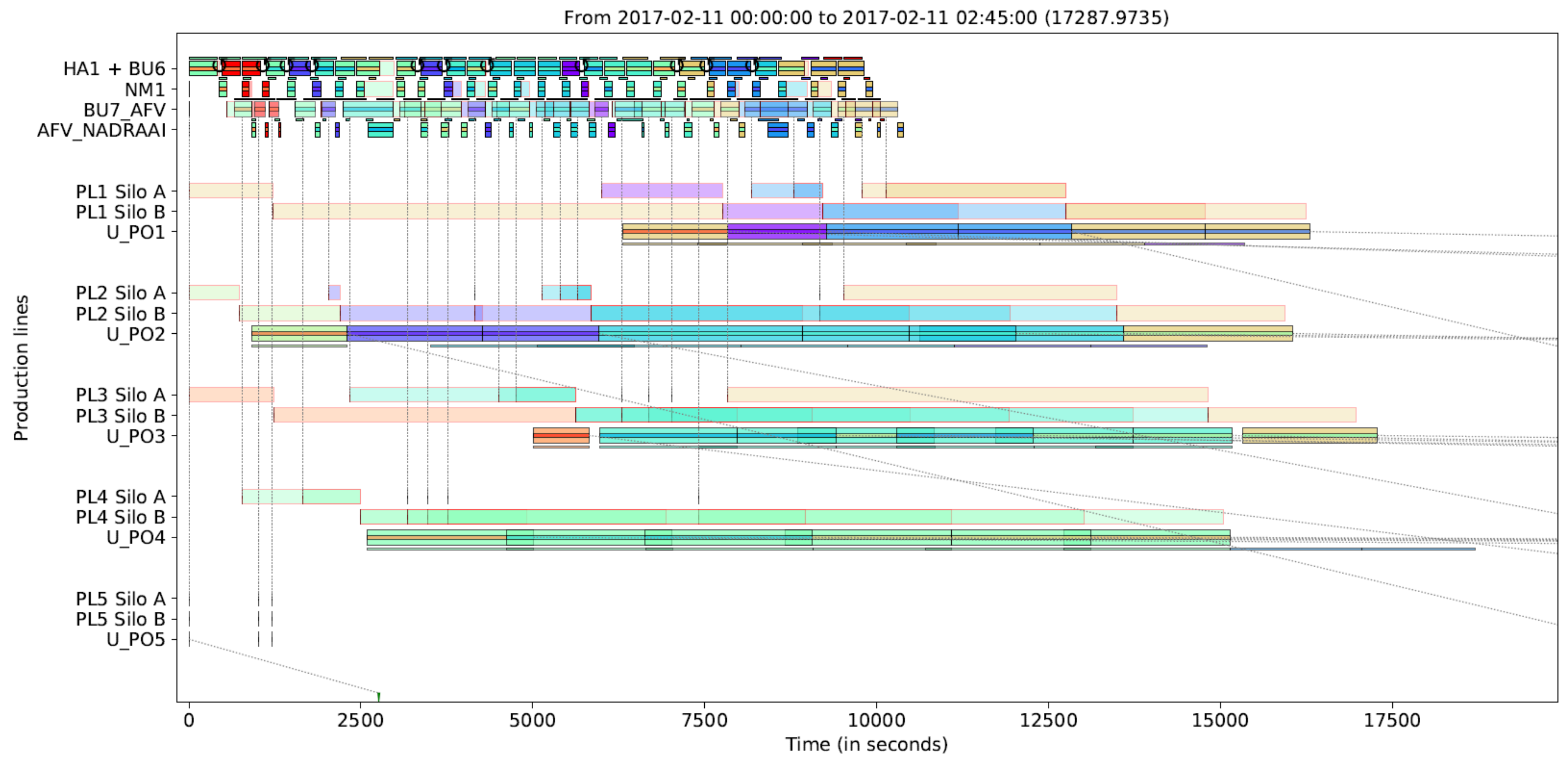
Example of a realized schedule:



Results:

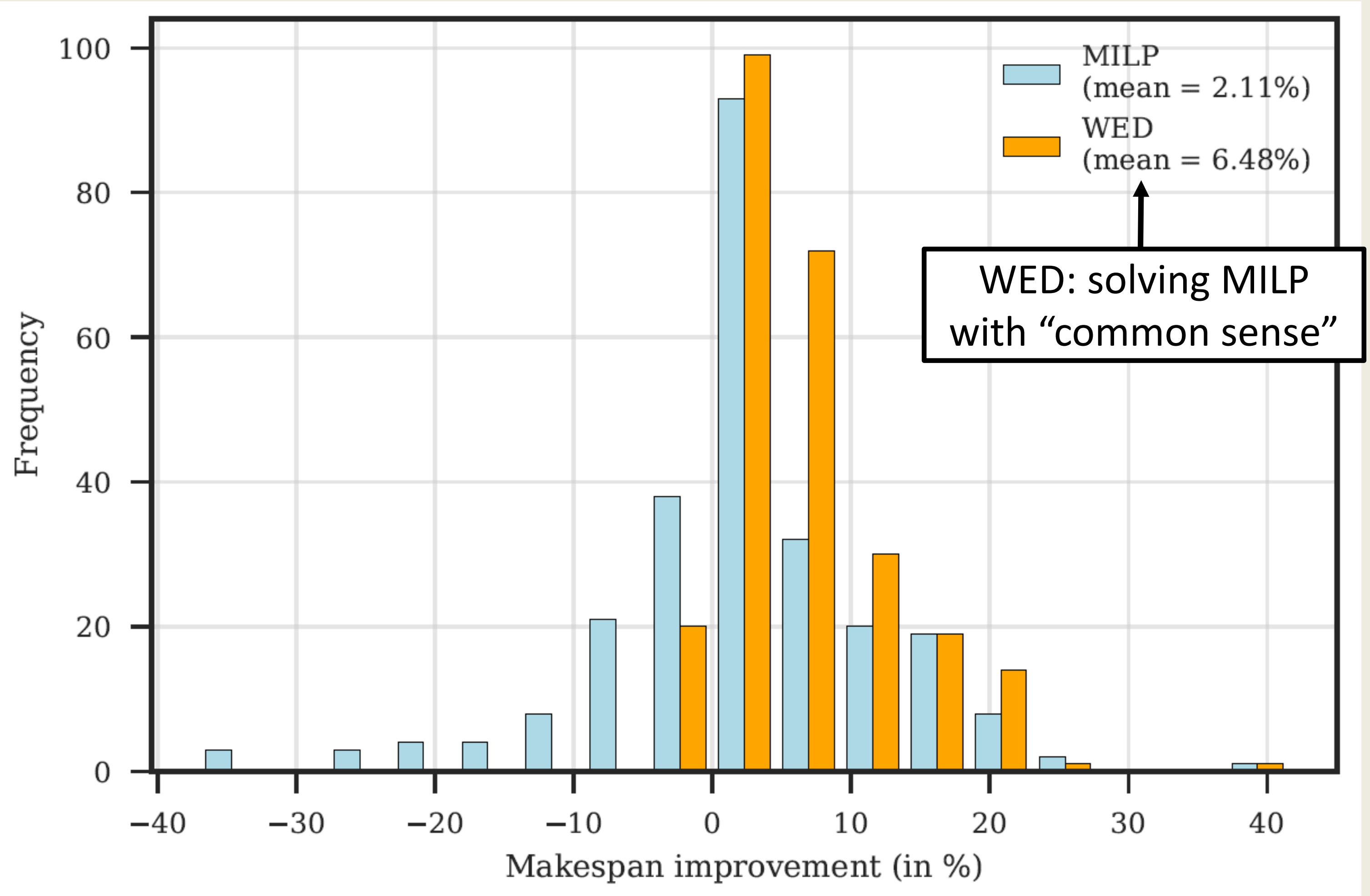
Optimized schedule:

Solved for 180 seconds, 23 minutes earlier finished (7.5%)



Results (Efficiency Gain):

Comparison to realized schedules for 267 instances (5h) when solving for 180 seconds (all found schedules respect the due dates)



Concluding Remarks

- Model is implemented in a pilot plant in Limburg (for testing w.r.t. accuracy and optimization gain)
- Further research:
  - Model extension (transport and finished product silos)
  - Further development of (tailored) heuristics
  - Taking **stochastic nature** into account:
    - Robust optimization
    - Efficient rescheduling (emergency order, machine breakdown)

Thanks for your attention!

Any questions?

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