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Can maths out-plan an expert? Data-driven production planning at Oatly

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Link to the full thesis

Every week, an oat-drink factory must decide the exact order in which to make dozens of products, a scheduling puzzle with an almost incomprehensibly large number of possible answers. This thesis developed a mathematical model to crack it, then tested the computer against an experienced human planner across a full year of real production. The result was not a clear winner but a surprising partnership: mathematics and human judgement together plan the factory faster than either can alone.

The global shift to plant-based food has put real pressure on the factories that supply it. At Oatly's site in Landskrona, demand keeps climbing while the same machines must produce an ever-growing range of products: plain, organic, barista and flavoured. The catch is that these products cannot be made in just any order. Switching from one to another often forces the line to stop for a thorough wash, a so-called Clean-In-Place, to protect hygiene and prevent cross-contamination. Some switches need no cleaning at all, while others demand a full sterile scrub lasting hours.

This turns each week's order list into a giant puzzle: in which sequence should the products run so the whole week finishes as quickly as possible, with the costly washes kept to a minimum? The number of possible orderings explodes. For just 50 products, the number of possible orderings is almost incomprehensibly large. Mathematicians recognise this as a cousin of the famous Travelling Salesman Problem, which is provably impossible to solve perfectly by hand. Yet at Oatly the task has rested largely on one experienced planner working in Excel, juggling tank availability, flow rates and colour-coded cleaning rules from memory.

Ok to switch according to routine MSDOC#1291 (no cleaning after formulation tank)
Cleaning of mixer and transfer line and formulation tank (OK with ACIP if full CIP not applicable
Cleaning of formulation tank, mixer and transfer line (excluding UHT, sterile tank and filter)
Cleaning from fermentation tank onwards
Cleaning of oat base line

Figure 1, Oatly's colour-coded changeover rules. Every switch between two products carries a cleaning requirement, from no wash at all (green) to a full sterile clean (red). Choosing the right order is what keeps the slow, costly washes to a minimum.

The approach. To tackle this, the thesis developed a mathematical model, a Mixed-Integer Linear Programming (MILP) model written in Python, that sifts through millions of candidate sequences and selects the one that minimises the total production time, known as the makespan. The model was then put to a fair test: its schedules were benchmarked against the real human plans across 39 weeks of actual 2025 production.

The findings. The model found a faster schedule in 26 of the 39 weeks, cutting total production time by 2.9% on average, roughly 13 hours saved every week; equivalent to an estimated 7 million additional litres of production capacity per year. The twist lay in the other 13 weeks, where the human won, and these were always the most complex ones. Under a tight time budget, the model simply could not search deeply enough. When it was allowed to think longer on the two hardest weeks, however, it overtook the planner after all. Along the way the laptops ran for more than 21 hours of non-stop calculation and overheated when pushed further.

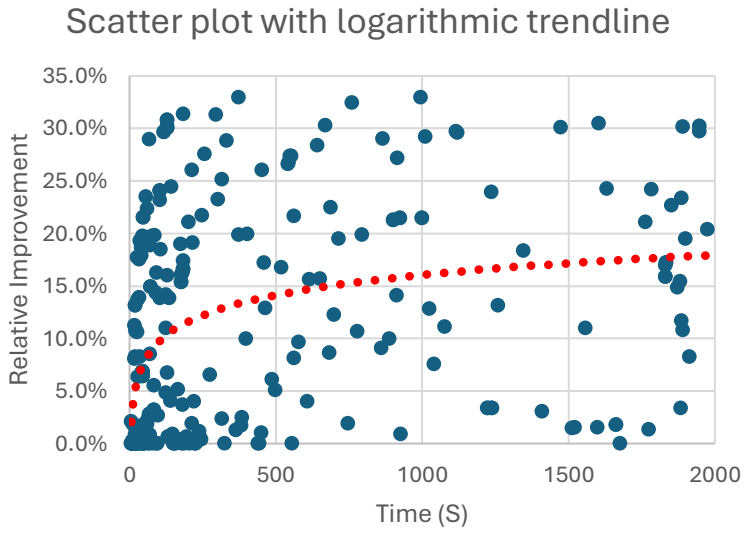

Figure 2, Relative improvement over time across all tested weeks. Each dot marks a new, better schedule found by the model, compared to its first solution. Most gains arrive within the first few minutes, yet on the toughest weeks the extra time was enough to overtake the human planner.

Why it matters. The clearest lesson is that neither side should work alone. The best outcome was a partnership: the model generates a strong baseline schedule in minutes, and the human planner then refines it for the messy realities a model ignores, such as breakdowns, delays and last-minute changes. This frees the planner from tedious sequencing, captures expertise that today lives in a single person's head, and shortens the hours the factory runs each week, saving electricity, heating and cooling and unlocking millions of litres of additional annual production capacity, supporting Oatly's sustainability goals. In short, mathematics and human judgement together plan a faster, more resilient factory than either can alone.

> **IN PLAIN TERMS**
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> **Makespan:** the total time to finish a whole week's production, from the first product started to the last one completed.
>
> **Clean-In-Place (CIP):** an automated deep clean of pipes and machines between products. Vital for food safety, but it halts production.
>
> **MILP:** a mathematical method that finds the best option among an enormous number of yes/no choices, such as what runs where and in which order.