Minimizing Changeover Time in Pet Food Production using Integer Programming

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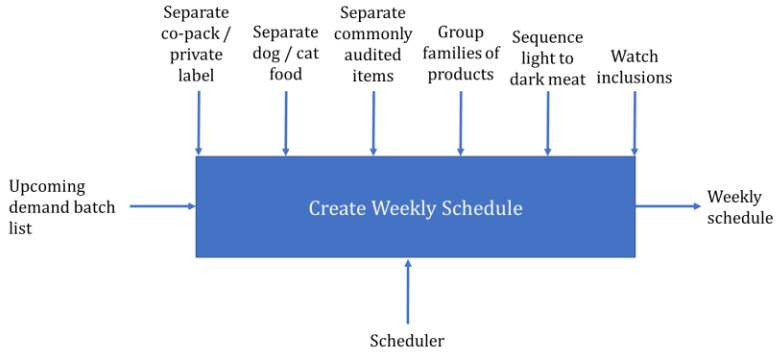
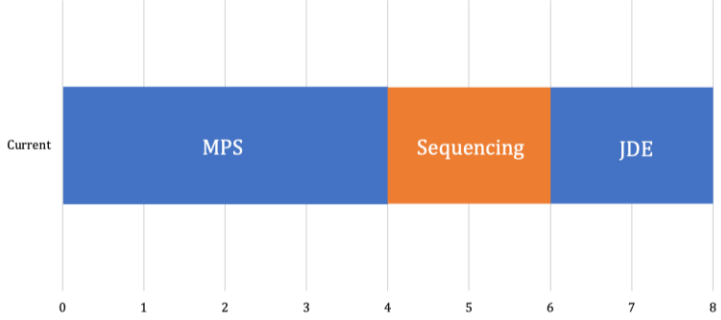
Simmons Pet Food (SPF)

Simmons Pet Food, a division of Simmons Foods, Inc., is headquartered in Siloam Springs, AR. The division has four facilities in the United States and Canada, producing pet food in cups, cans, and pouches. Our focus is the canned pet food production location in Emporia, KS.

SPF's scheduling process is highly manual and relies on tribal knowledge of schedulers. The process has no mathematical approach. Batches are grouped and sequenced according to schedulers' best guesses at minimizing changeover times between batches.

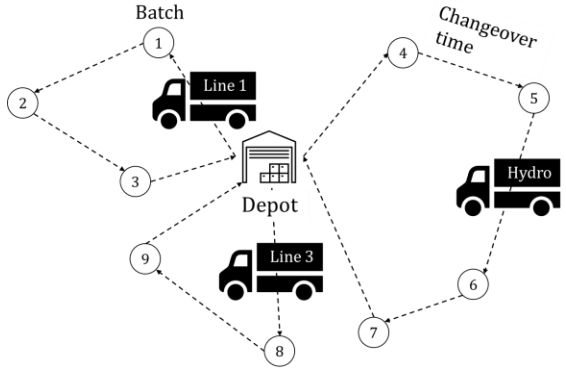


SPF's production scheduler currently spends roughly eight hours a week on the scheduling process, two of which are spent sequencing batches. This is based on an experienced scheduler with more knowledge of production processes. A new scheduler likely will spend far more time sequencing. We hope to greatly reduce this time by applying optimization to provide recommended batch sequences to schedulers.



Batch Sequencing through Optimization

Our team uses an adapted vehicle routing problem (VRP) to schedule weekly canned food production. Similar to a traditional VRP, we are scheduling batches along different canning lines or "routes" to minimize changeover time. We have created a dummy depot node that all schedules will start and end on.



The model assigns batches to canning lines and sequences the order they will run to minimize total changeover time. Changeover times are estimated using predictive modeling. This model schedules an entire week's batches over the three canning lines in Emporia, KS. The model sequences all batches on exactly one canning line. The model ensures that subtours are eliminated from sequences. The model considers a line's maximum capacity and some of the constraints that prevents some batches from running on specific lines.

Parameters

c_{kj} = changeover time from batch k to j
t_j = time to produce batch j
d_r = maximum time capacity on line r
f_{jr} = feasibility of batch j on line r

Decision Variables

$$X_{kjr} = \begin{cases} 1 & \text{batch } j \text{ is sequenced after } k \text{ on line } r \\ 0 & \text{otherwise} \end{cases}$$

Objective

$$\text{Minimize } \sum_k \sum_j \sum_r X_{kjr} * c_{kj}$$

Constraints

$$\sum_j X_{kjr} - \sum_j X_{jkr} = 0 \forall r \forall k \quad \text{Flow constraint}$$

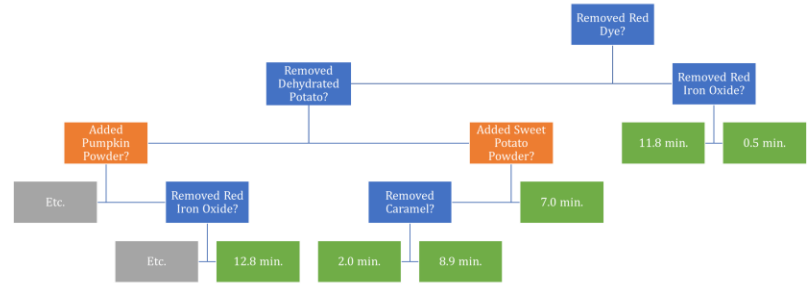
$$u_{kr} + X_{kjr} \le u_{jr} + (J-1) * (1 - X_{kjr}) \; \forall k \forall j \forall r \quad \text{Subtour elimination constraint}$$

$$\sum_k \sum_j X_{kjr} * t_j + X_{kjr} * c_{kj} \le d_r \forall r \quad \text{Capacity constraint}$$

$$X_{kjr} \le f_{jr} \forall k \forall j \forall r \quad \text{Feasibility Constraint}$$

Better Understanding Changeover Times

SPF lacks sufficient insight into changeover time durations between batch production. Our team used predictive modeling fed by historical production data to estimate these durations based on additions and removals of key ingredients between batches. A truncated version of the final decision tree is shown below:



Scheduler Decision Support

Our team created an Excel tool to provide batch production sequence recommendations. The scheduler inputs a sequence of upcoming batches to run. The tool generates a data file specific for the problem, which the scheduler can solve using an open-source optimization software. The solution is loaded into the Excel tool and translated into a readable sequence.