Prevenar Factory Schedule Optimization: A Mixed Integer Programming Approach

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Problem Statement

- Maximize factory production of Prevenar by designing the optimal factory production schedule
- On each day, determine which piece of equipment to use for which step in the manufacturing process
- Goal: 3% increase in production

Why Prevenar?

- Most complex value stream
  - Over 300 materials
  - ~40 pieces of equipment
- Pfizer's best-selling drug

$5.8B in Sales

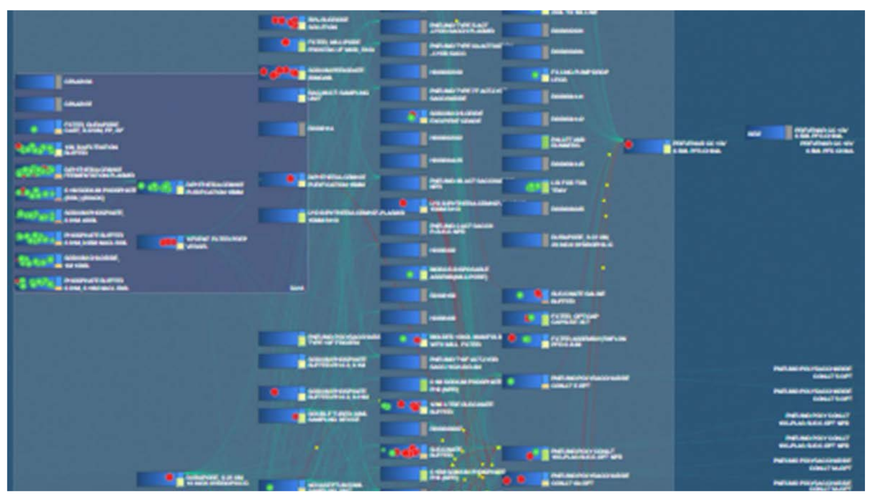
2018

Project Timeline

Exploratory Data Analysis → Model Drug Recipes → Construct Production Network → Model Manufacture Times → Optimization Models → Simulations

Recipe Modeling

- Back-calculate into drug recipe with historical data
- Build linear regressions to predict output quantities as a function of ingredient quantities



Robust Optimization Formulation

Objective Function

$$Max \sum_s \sum_i \sum_j \sum_k w_j x_{ijks} + \sum_s \sum_{j \in j_{final}} Y_j y_{js} + \sum_s \sum_{j \in j_{final}} Z_j z_{js} + \sum_s \sum_{j \in j_{final}} D_j d_{js}$$

Constraints

$$q_{jks} = q_{j(k-1)s} + W_j \sum_i l_j x_{ij(k-p_{ij}-1)s} - \sum_i \sum_{j'} b_{j,j'} x_{ij'(k-1)s} + d_{jk-1} \quad \forall j, j', s, 1 \le k \le K$$

$$q_{jks} \ge 0 \; \forall j, k, s$$

$$x_{ij0s} = 0 \; \forall i, j, s$$

$$x_{ijks} = x_{ijks'} \quad \forall i, j, k \in [same\_days], s \ne s'$$

$$\sum_j x_{ijks} \le 1 \quad \forall i, k, s$$

$$x_{ijks} \le r_{ij} \quad \forall i, j, k, s$$

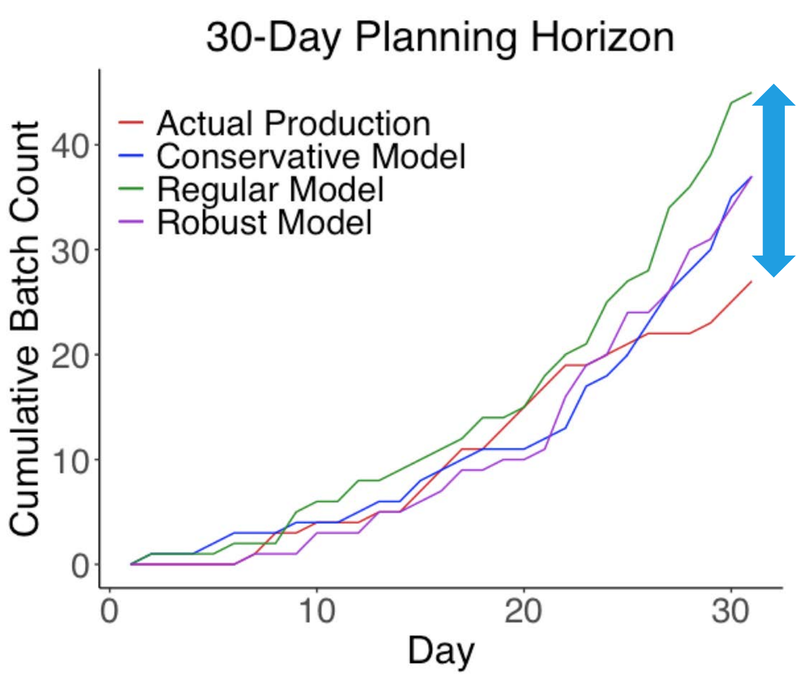
$$x_{ij'ks} \le 1 - x_{ijts} \quad \forall i, j, j' \ne j, s, p_{ijs} \ge 1, t \le \lfloor K - p_{ijs} \rfloor, t \le k \le \lfloor t + p_{ijs} \rfloor$$

$$x_{ijks} \le 1 - x_{ijts} \quad \forall i, j, s, p_{ijs} \ge 1, t \le \lfloor K - p_{ijs} \rfloor, t + 1 \le k \le \lfloor t + p_{ijs} \rfloor$$

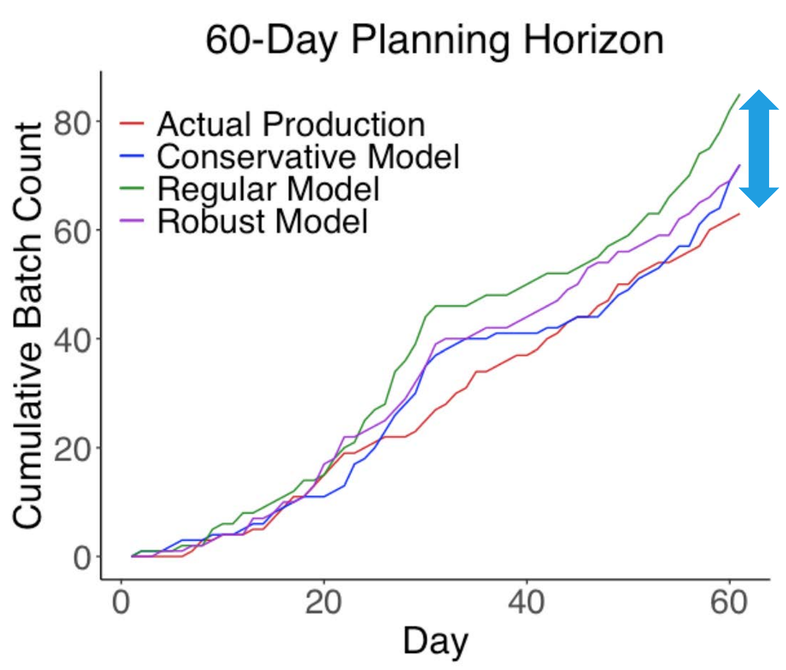
$$x_{ijks} = 0 \quad \forall i, j, s, p_{ijs} \ge 1, \lceil K - p_{ijs} + 1 \rceil \le k \le K$$

$$\sum_i \sum_{j'} b_{j,j'} x_{ij'ks} \le q_{jks} \; \forall k, j, s$$

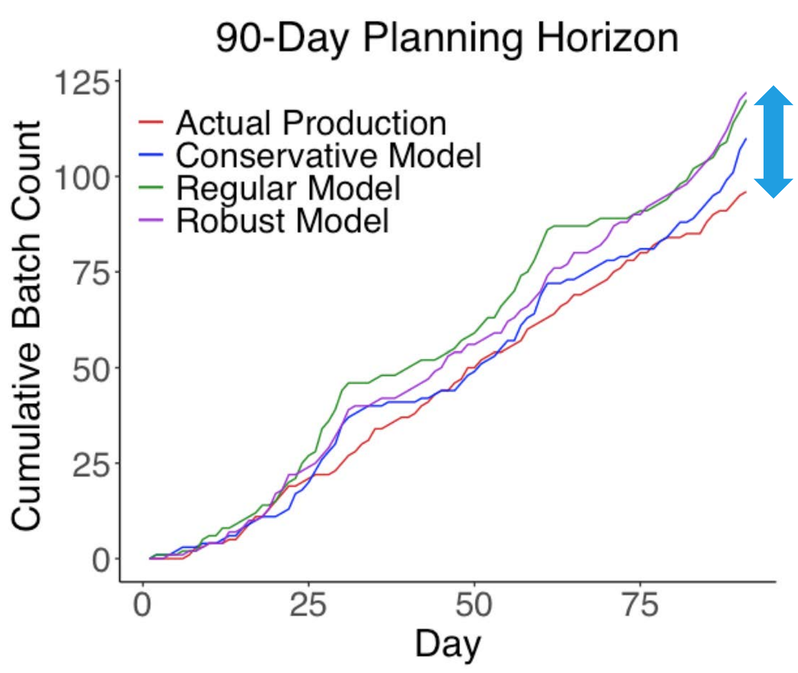
Results: Cumulative Final Product Batch Count



37-67% Increase



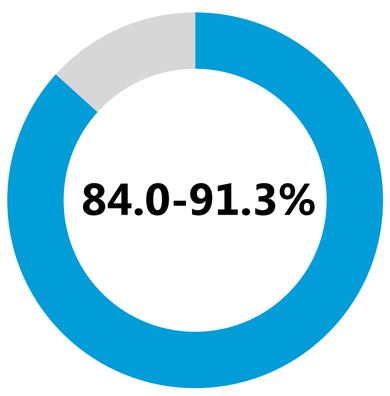
14-35% Increase



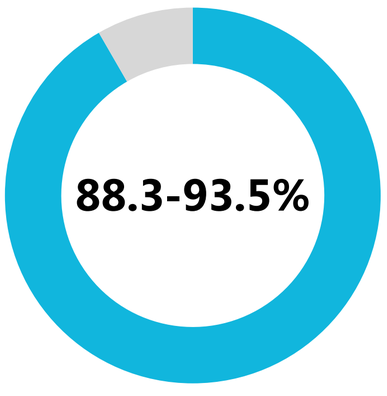
15-27% Increase

Simulations

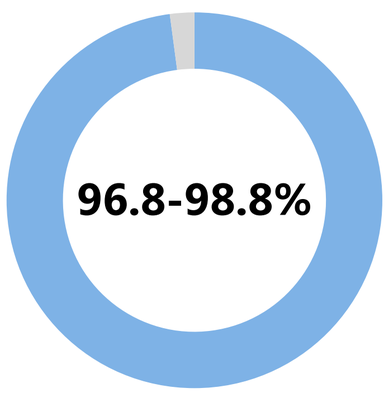
Sampled manufacturing time distributions to model uncertainty and evaluate average final product batch totals



Conservative Model



Regular Model



Robust Model

Business Value

5-15% Production Increase → **$30-90M Profit Increase**