

Prevenar Factory Schedule Optimization: A Mixed Integer Programming Approach



Capstone Team:
Julia Monti & Desiree Waugh

Faculty Advisor:
Dr. Dimitris Bertsimas

Pfizer Team:
Jonathan Lowe & Dr. Marcel Schumann

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

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

Constraints

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

$$q_{jks} \geq 0 \quad \forall j, k, s$$

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

$$x_{ijks} = x_{ijks'} \quad \forall i, j, k \in [\text{same_days}], s \neq s'$$

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

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

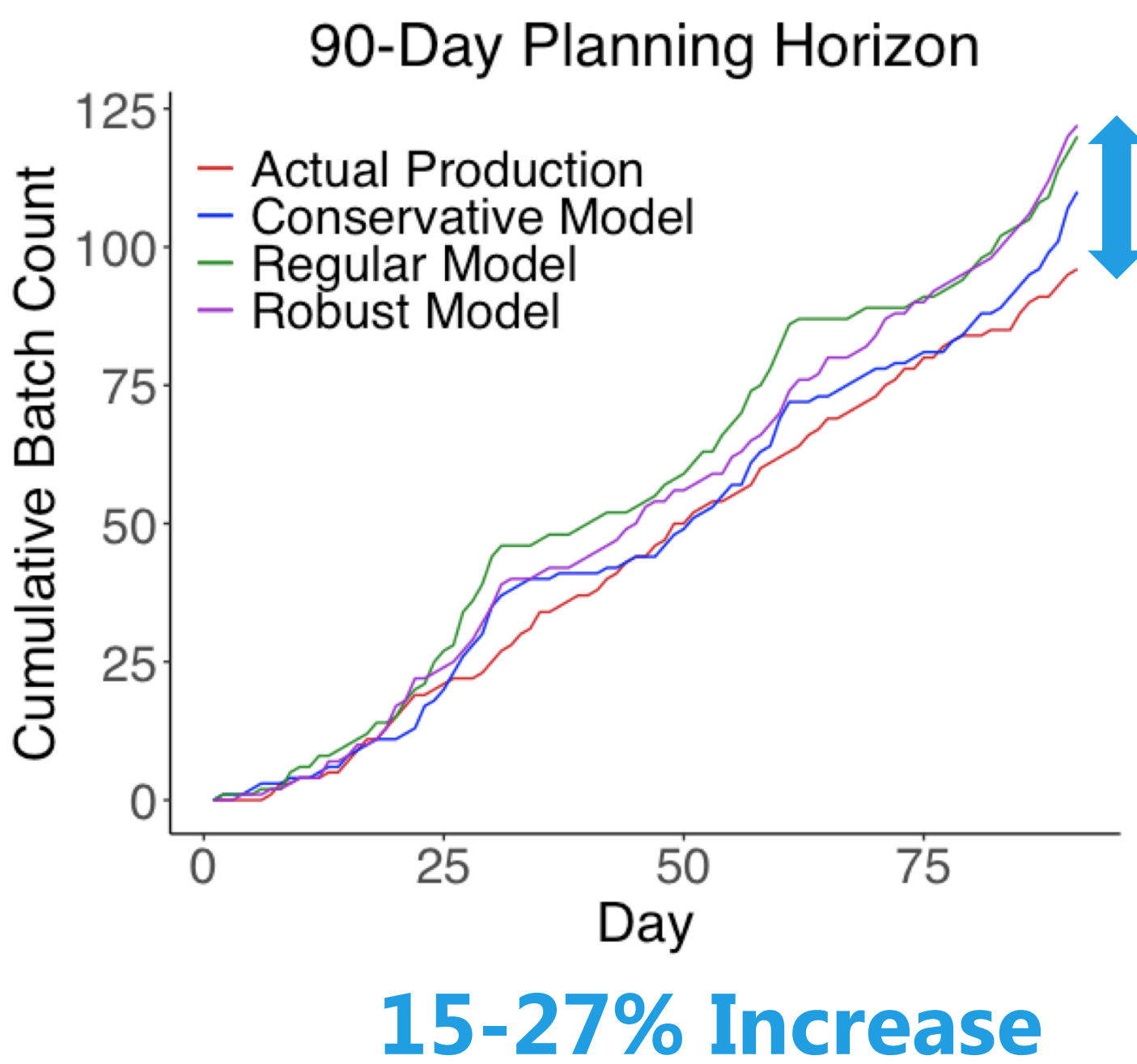
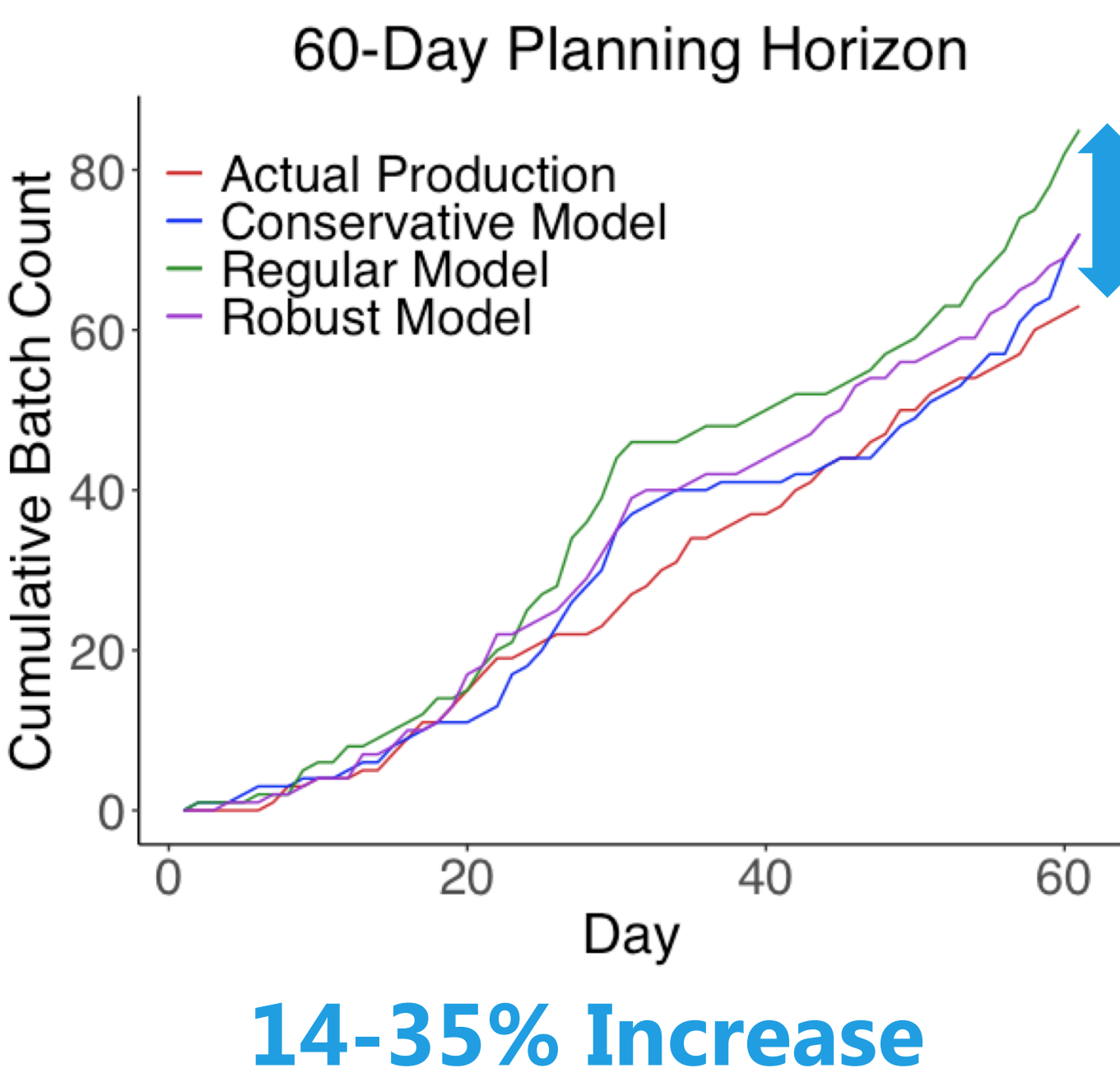
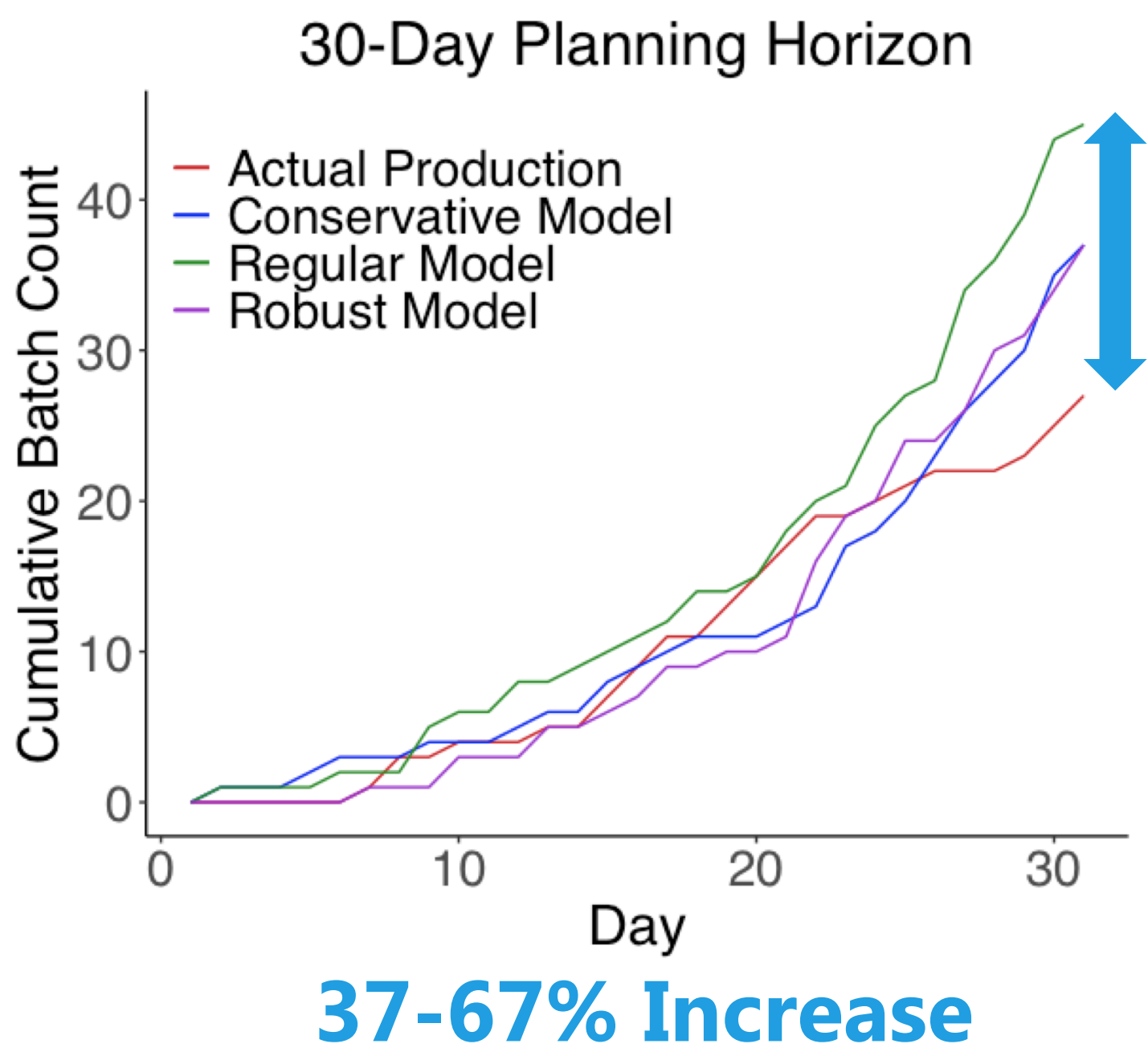
$$x_{ij'ks} \leq 1 - x_{ijts} \quad \forall i, j, j' \neq j, s, p_{ijs} \geq 1, t \leq [K - p_{ijs}], t \leq k \leq [t + p_{ijs}]$$

$$x_{ijks} \leq 1 - x_{ijts} \quad \forall i, j, s, p_{ijs} \geq 1, t \leq [K - p_{ijs}], t + 1 \leq k \leq [t + p_{ijs}]$$

$$x_{ijks} = 0 \quad \forall i, j, s, p_{ijs} \geq 1, [K - p_{ijs} + 1] \leq k \leq K$$

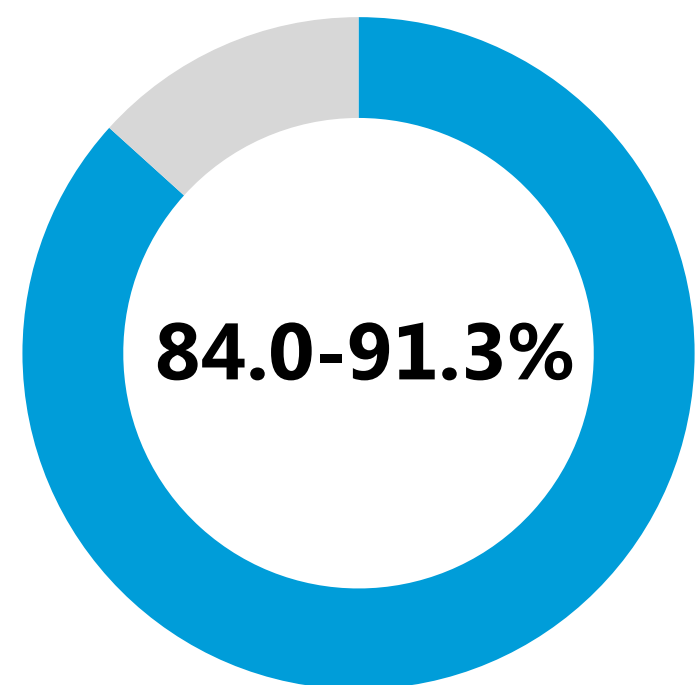
$$\sum_i \sum_{j'} b_{j,j'} x_{ij'ks} \leq q_{jks} \quad \forall k, j, s$$

Results: Cumulative Final Product Batch Count

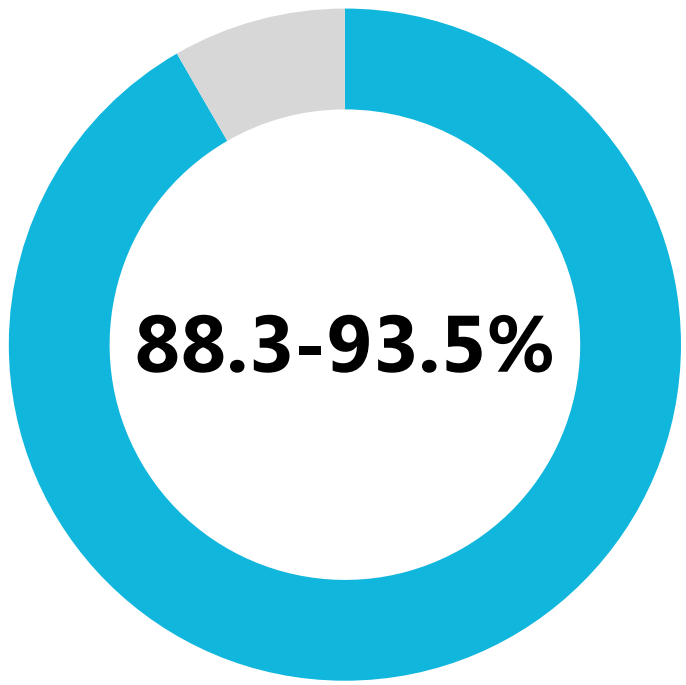


Simulations

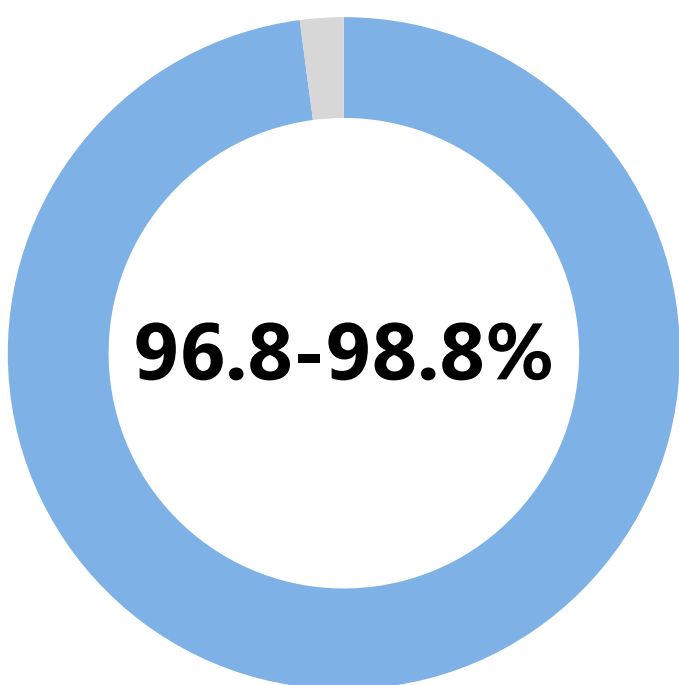
Sampled manufacturing time distributions to model uncertainty and evaluate average final product batch totals



Conservative Model



Regular Model



Robust Model

Business Value

**5-15%
Production
Increase**



**\$30-90M
Profit
Increase**