How to Integrate your Production and Logistics Strategy for a CPG Company

A NEW FORMULATION

MIT Supply Chain MANAGEMENT

Production Planning with Complex Cost Drivers

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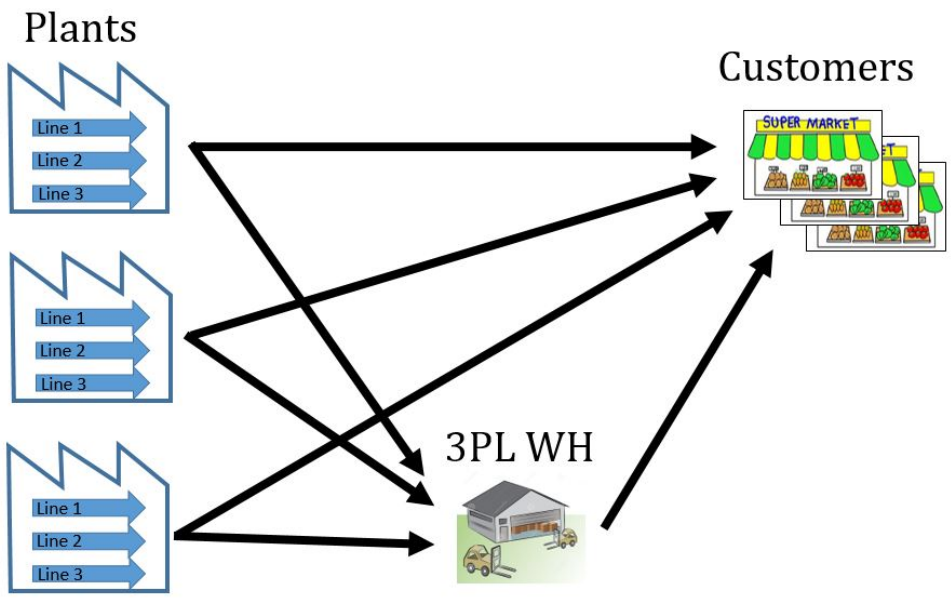
Agenda

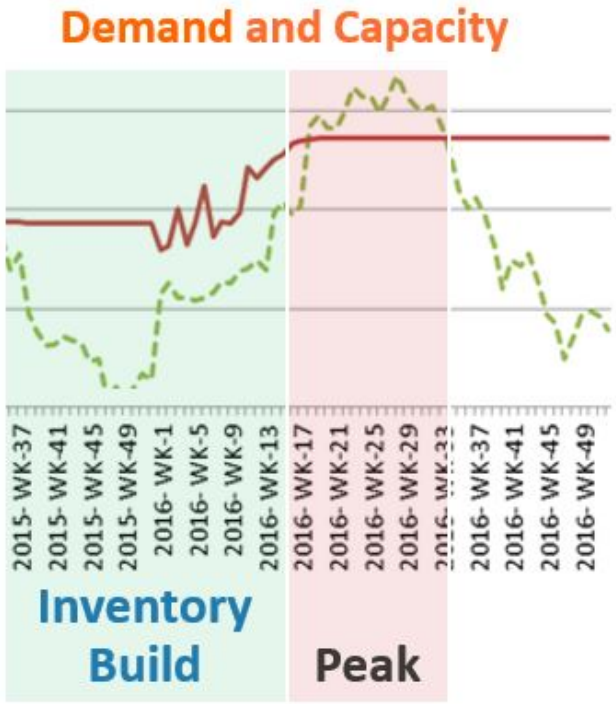
1. Overview of Problem
2. Overview of Model
3. Benchmarking
4. Sensitivity Analysis
5. Key Takeaways
6. Further Research Areas

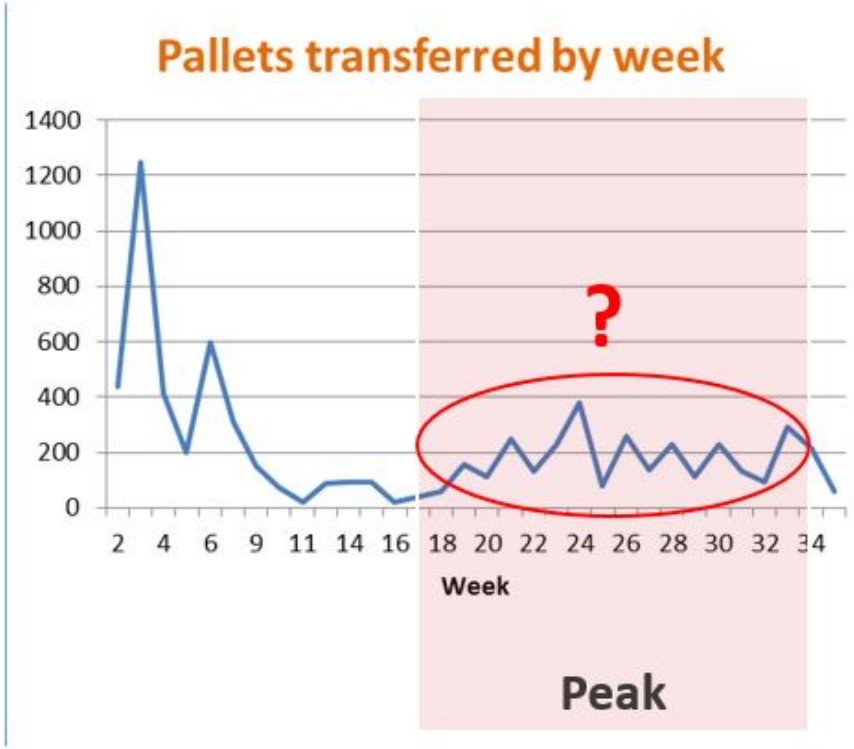
Key Messages

1. Manual planning processes are **time consuming** and **cannot** consider all **cost drivers**.
2. Implementation of lot sizing problems requires the **right formulation** that fits the business environment.
3. Production lot sizing optimization is not always a trade-off between **setups** and **inventory**.

Overview of Problem



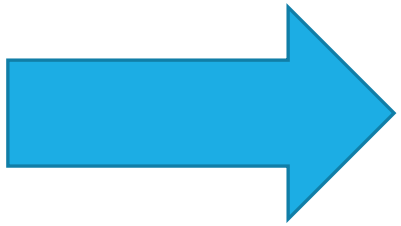




Is this caused by the lot sizing decision?

Model Overview Selection

- Seasonality
  - Deterministic Demand
- Capacitated
- Multiple Lines
- Multiple Items
- Plant and 3PL Storage



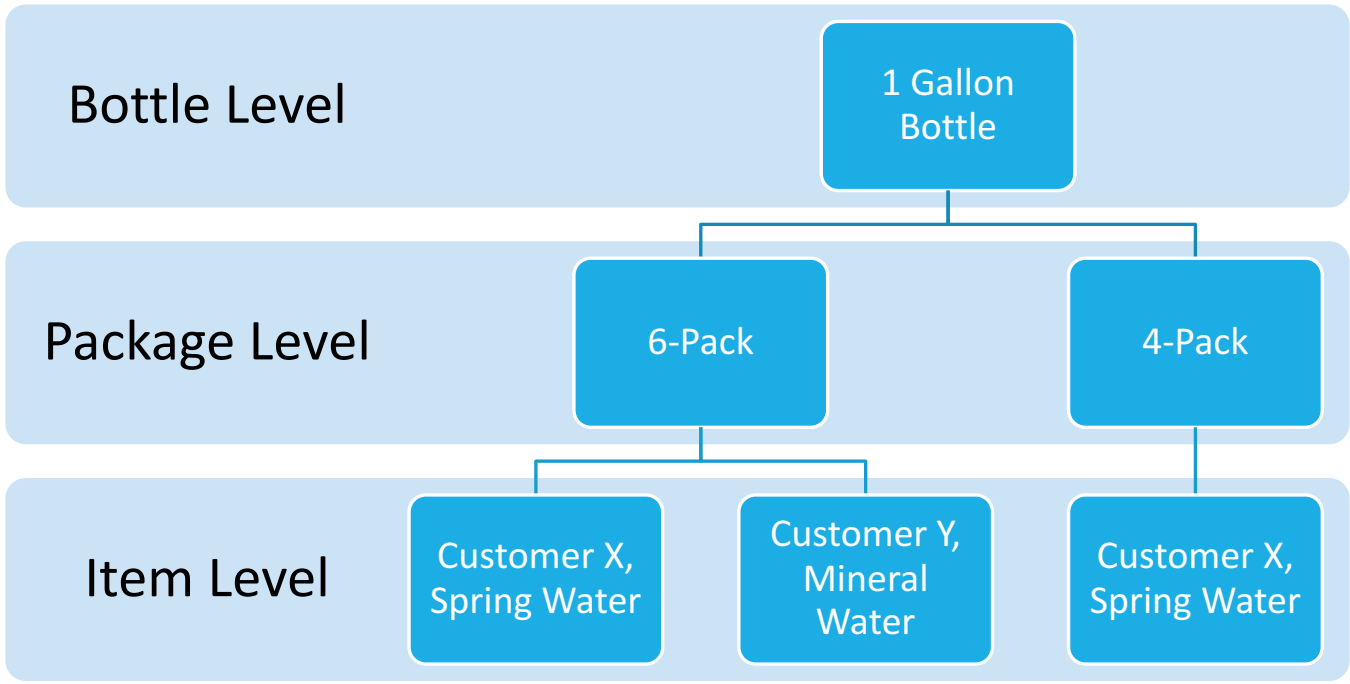
~~EOQ~~?

Capacitated Lot Sizing Problem (CLSP)

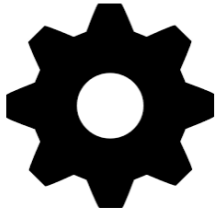
with new extensions

Model Overview
New Extensions

- Double Echelon Setups Costs
  - Product families with shared setups
- Double Echelon Inventory Costs
  - Plant and 3PL Warehouses
- 3PL Transport and Handling Cost
- Beginning and Ending Inventory Positions



Costing Methodology



Setups Costs

- Opportunity cost of not producing product while the machine is down for setups

Holding Costs

- Rent, Labor, Tax, Insurance → Annual cost per footprint → Weekly cost per bottle

Transfer Cost

- Freight Cost ($ per TL)
- Handling Cost ($ per pallet) → Handling Cost ($ per TL)
- Estimated Transfer Size (TLs per week)

Model Overview Comparison

Basic CLSP

$$\text{Minimize} \quad Z = \sum_{i=1}^{n}\sum_{t=1}^{T} S_{it} \cdot Y_{it} + C_{it} \cdot X_{it} + h_{it} \cdot I_{it}$$

Setup Costs

Inventory Costs

Thesis Model

$$\text{Minimize} \quad \sum_{t=1}^{T}\left[\sum_{i=1}^{n}[(h_{1i} \cdot I_{it}) + (h_{2i} \cdot W_{it}) + (h_3 \cdot H_{it})] + \sum_{j=1}^{J}(S_{1ij} \cdot Y_{ijt})\right] + \sum_{l=1}^{L}\sum_{j=1}^{J}[S_{2lj} \cdot Z_{ljt}]]$$

Inventory Costs

Setup Costs

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Basic CLSP vs Model

Basic CLSP		Model
$X_{it} + I_{i,t-1} - I_{it} = d_{it} \quad \forall i, t$	Inventory	$d_{i,t} = X_{i,t} + (I_{i,t-1} + W_{i,t-1}) - (I_{it} + W_{it}) \quad \forall i, t$
NA	Plant Storage Capacity	$\sum_{i=1}^{n} I_{it} \leq R_{2t} \quad \forall t$
NA	Transfer Event Binary	$\sum_{i=1}^{n} [W_{it} - W_{i,t-1}] \leq M \cdot H_{it} \quad \forall t$
NA	Setup Level 1 Binary	$\sum_{Nj-1}^{Nj} Y_{ijt} \leq M \cdot Z_{ljt} \quad \forall l, j, t$
NA	Setup Level 2 Binary	$\sum_{i=1}^{n} X_{ijt} \leq M \cdot Y_{ijt} \quad \forall t$
NA	Machine Capability Binary	$\sum_{i=1}^{n} X_{ijt} \leq M \cdot C_{ij} \quad \forall i, j, t$

Process Flow

Inputs:

- Weekly Demand Forecast per item
- Plant Capacities (MSA)
- Setup Costs/Times
- Inventory Costs
- Line Capabilities

Outputs:

- Lot Size Plan
- Inventory
- Setups

Model Formulation:

$$\text{Minimize} \quad \sum_{t=1}^{T}\left[\sum_{i=1}^{n}[(h_{1i}\cdot I_{it})+(h_{2i}\cdot W_{it})+(h_3\cdot H_{it})]+\sum_{j=1}^{J}(S_{1ij}\cdot Y_{ijt})\right]+\sum_{l=1}^{L}\sum_{j=1}^{J}[S_{2lj}\cdot Z_{ljt}]$$

Regional Benchmark
Scenario Selection Rationale

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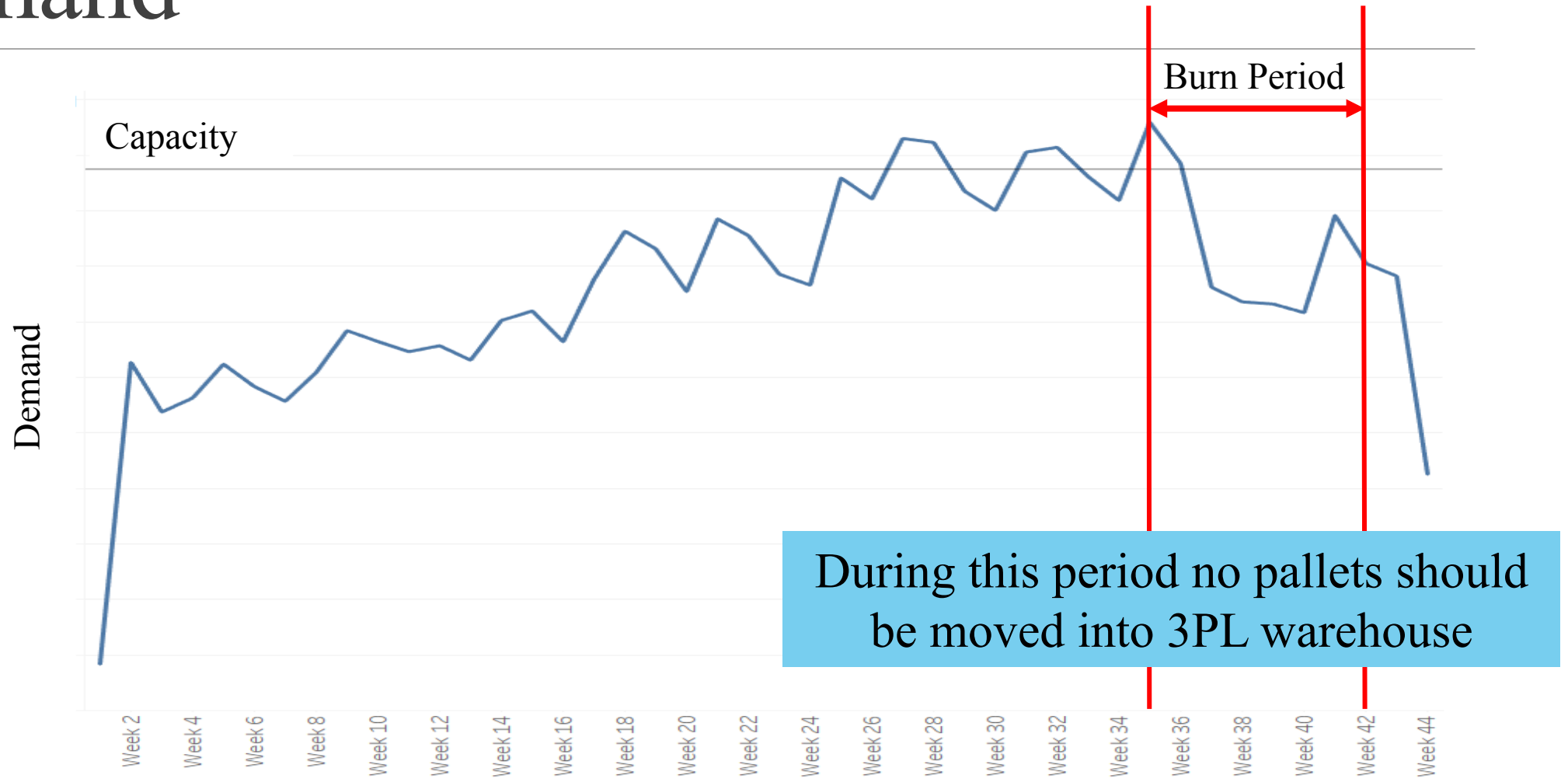
Strength - Represents network complexity

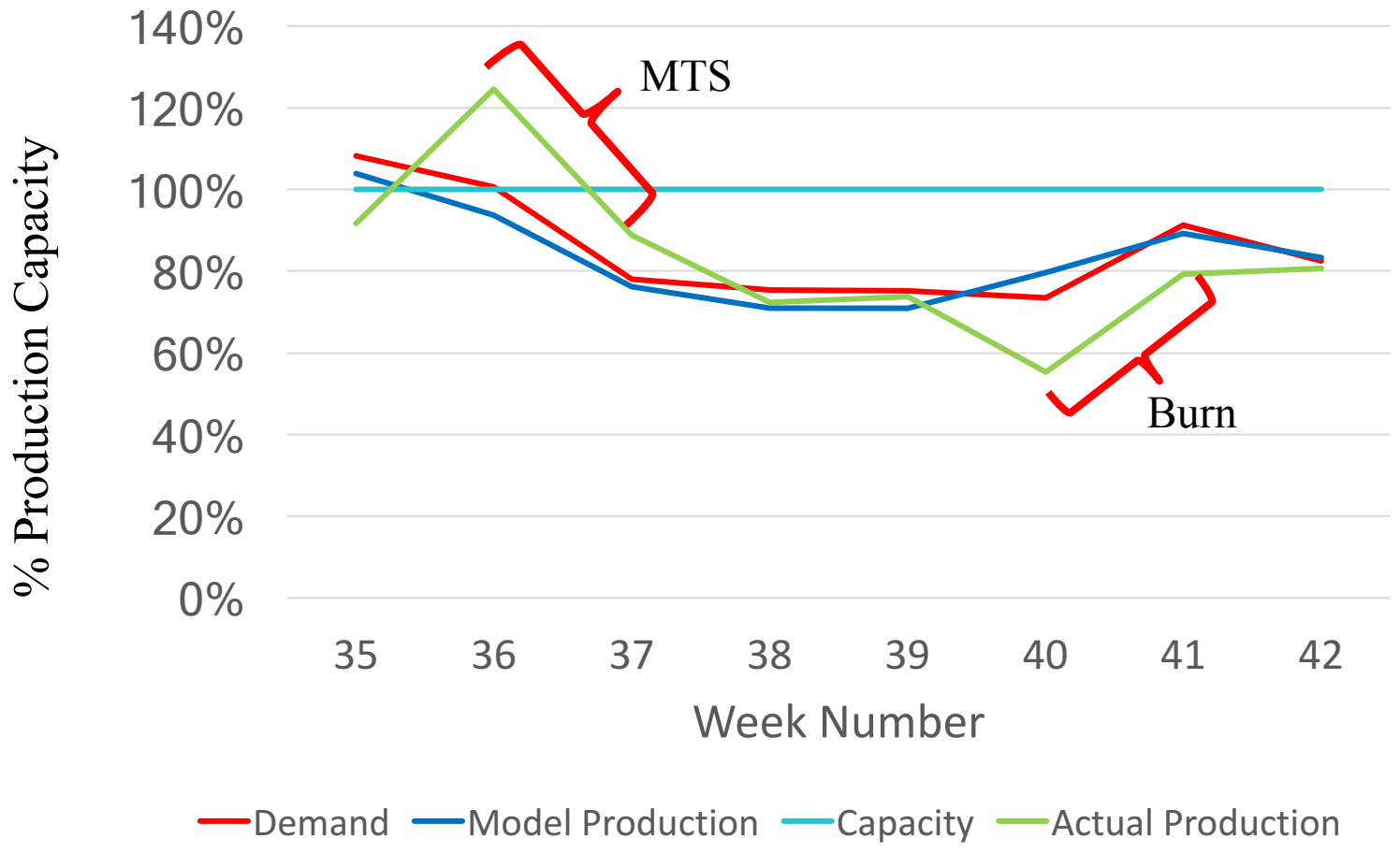
- Assets – 3 plants, 12 lines, 1 3PL Warehouse
  - Lines have varying capacity and capabilities
- Products – 5 bottle sizes, 14 bottle-pack categories
  - Represents both core and non-core products

3,504 DECISION VARIABLES

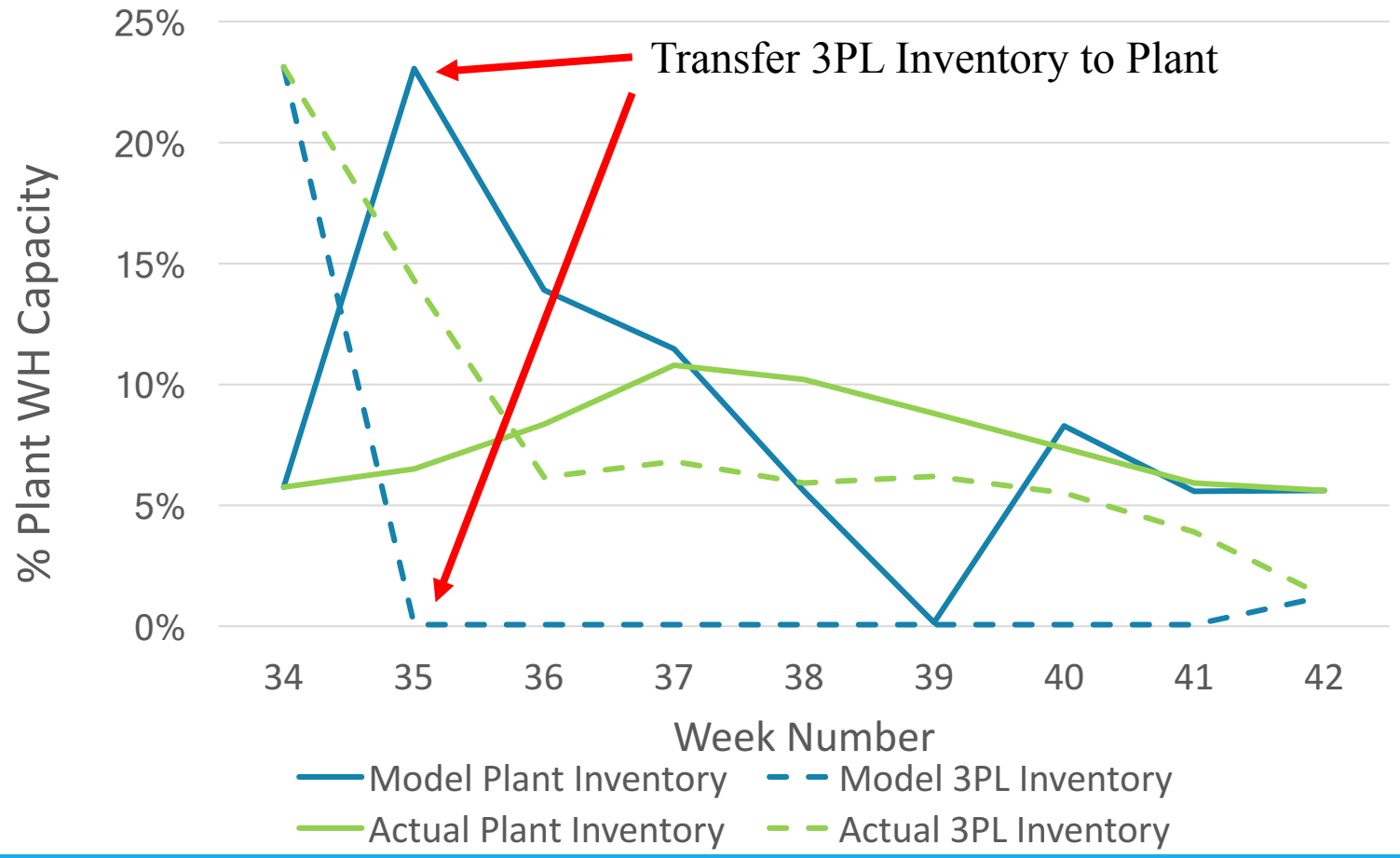
Regional Benchmark Demand



Regional Benchmark Production



Regional Benchmark Inventory



Regional Benchmark

Weakness : Actual Production Data doesn't match Demand Data

- Actual Production data produces 17% more bottles than forecast data requires
  - Dynamic Sourcing?
- Actual Production data is not a good benchmark for a planning comparison
- Need alternative benchmarking data

Manual Plan Benchmark
Scenario Selection Rationale

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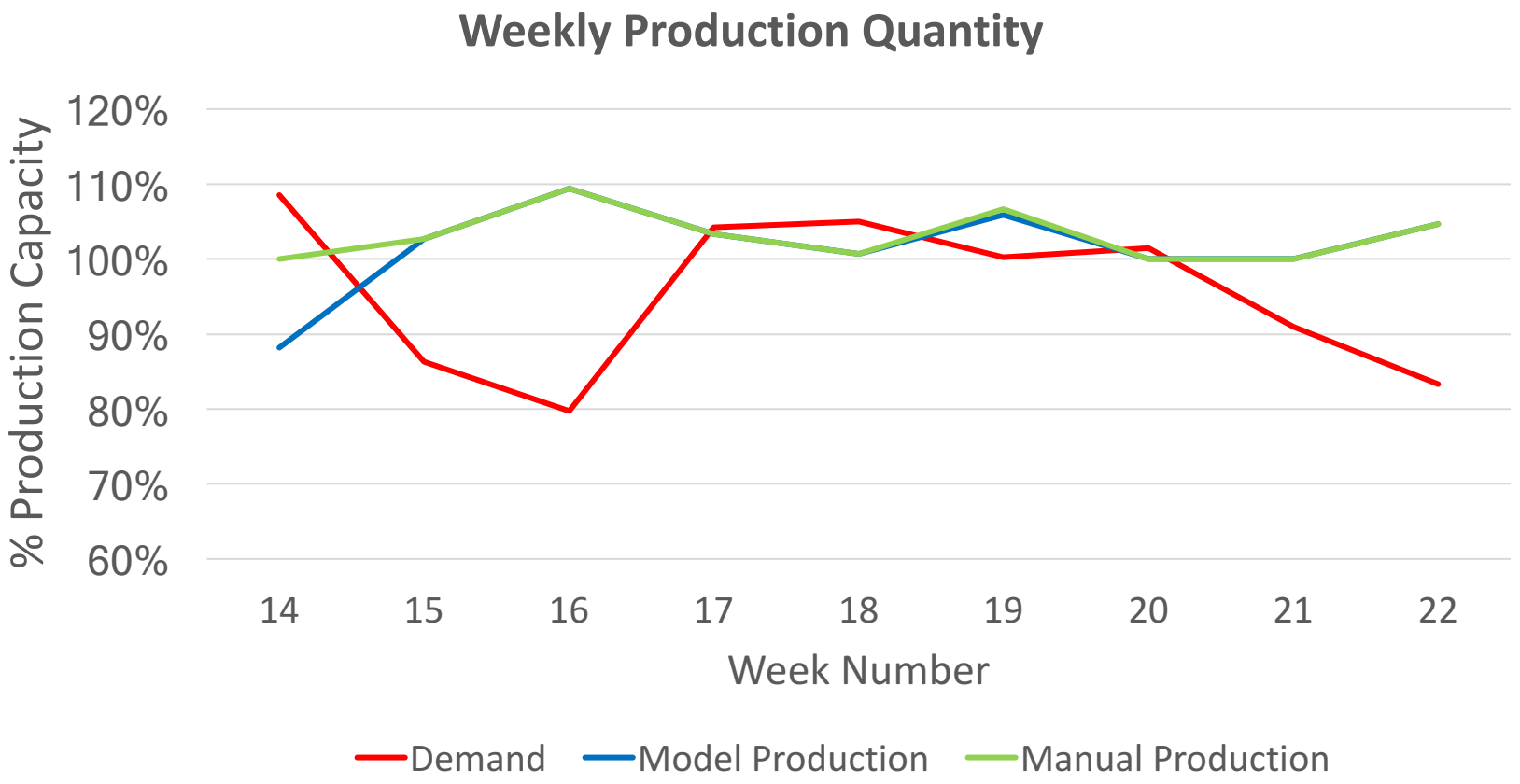
Simplified Data set

- 1 Plant
- 3 Lines
- 4 Products : 2 fast movers, 2 slow movers

Scenario Features

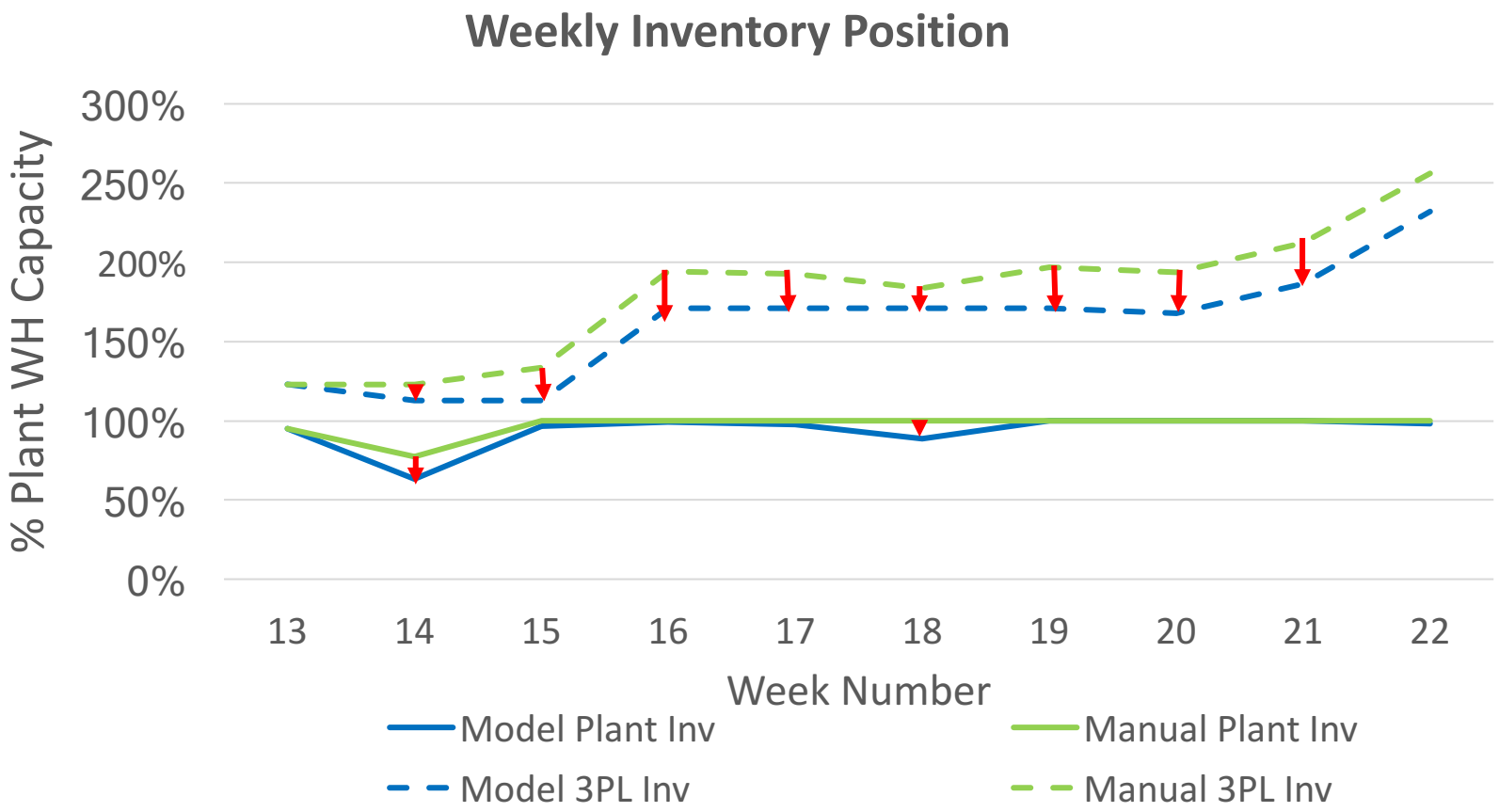
- Build Period – Full Capacity and significant inventory build target

Manual Benchmark Production



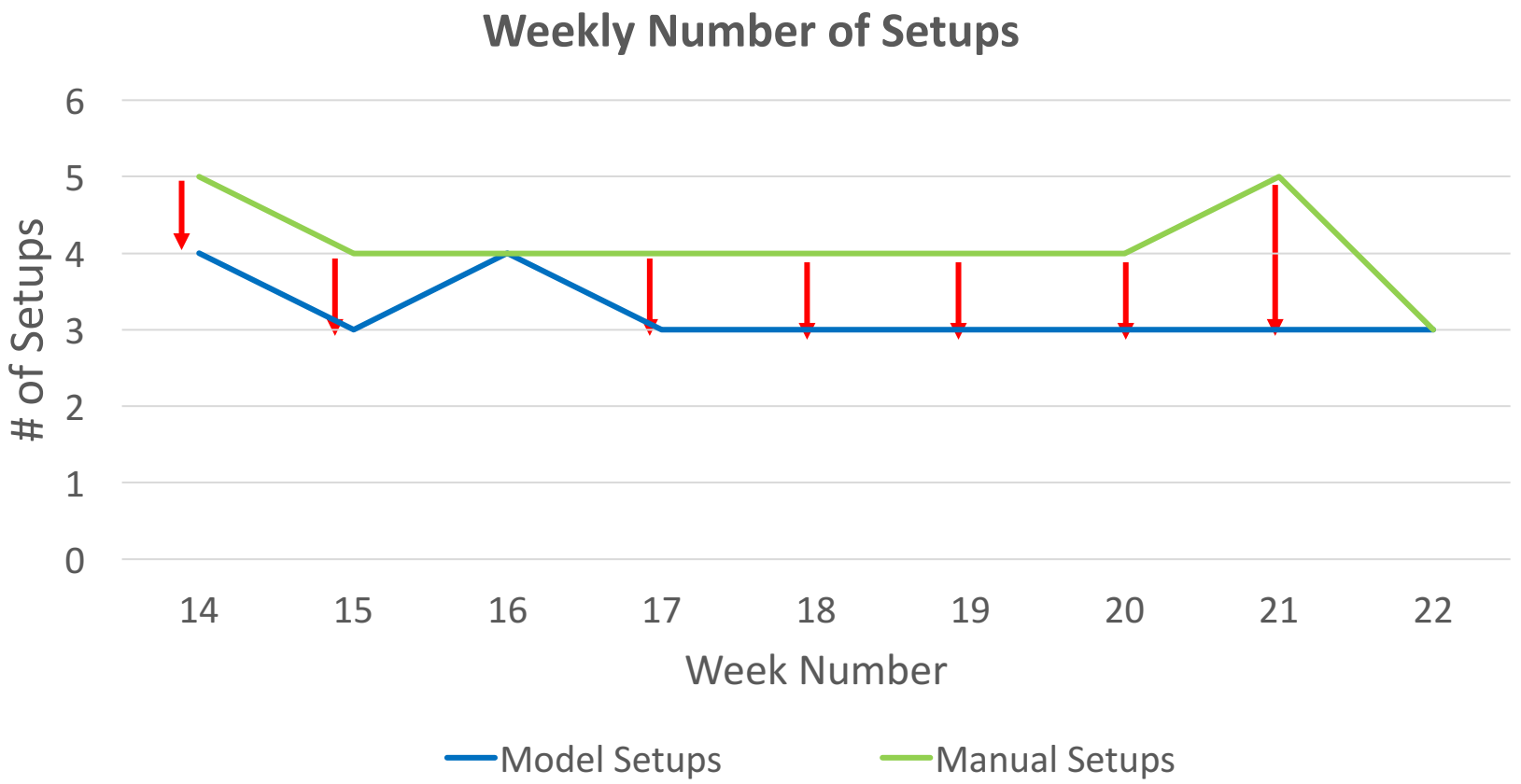
Both plans have similar overall production

Manual Benchmark Inventory



Model Plan lowers inventory

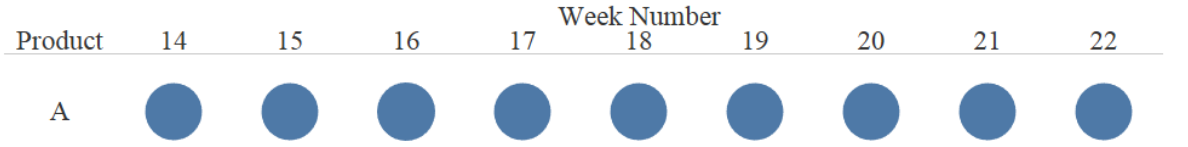
Manual Benchmark Inventory



Model Plan lowers Setups

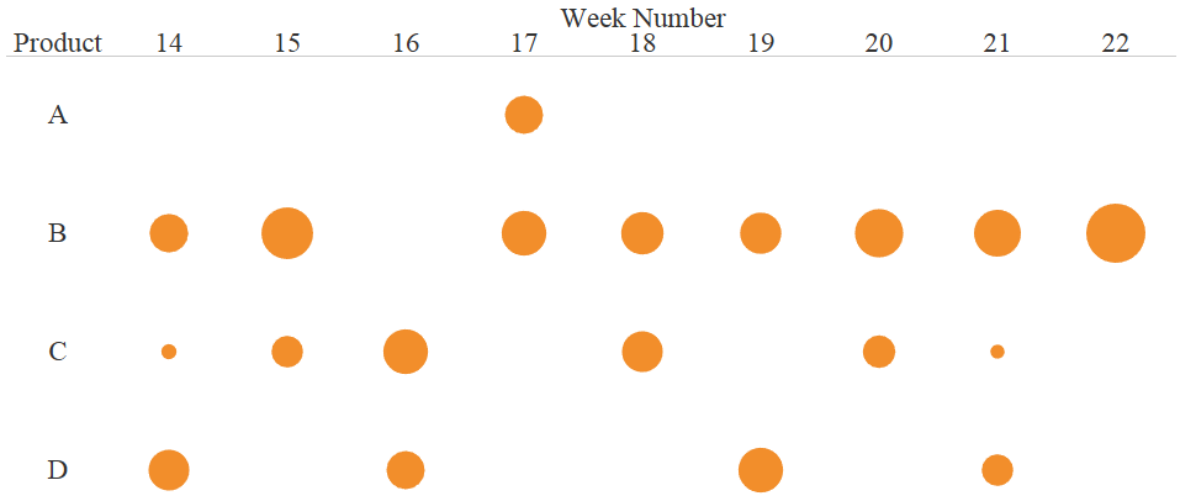
Performance Benchmark
Manual Planning Method

Line 1 - Manual Plan Lot Size



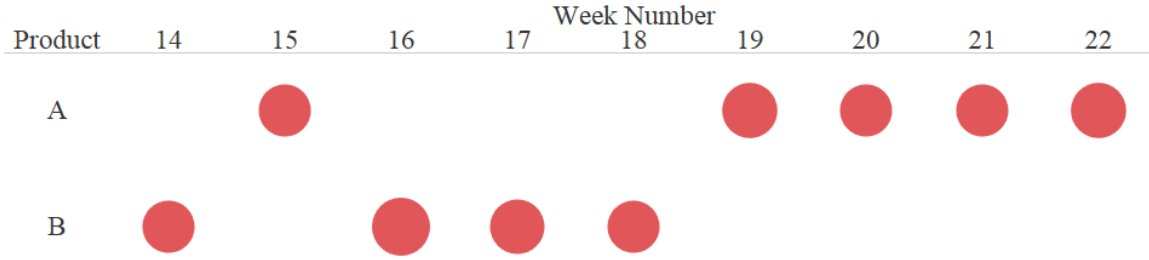
Line 1 Setups: 9

Line 2 - Manual Plan Lot Size



Line 2 Setups: 19

Line 3 - Manual Plan Lot Size

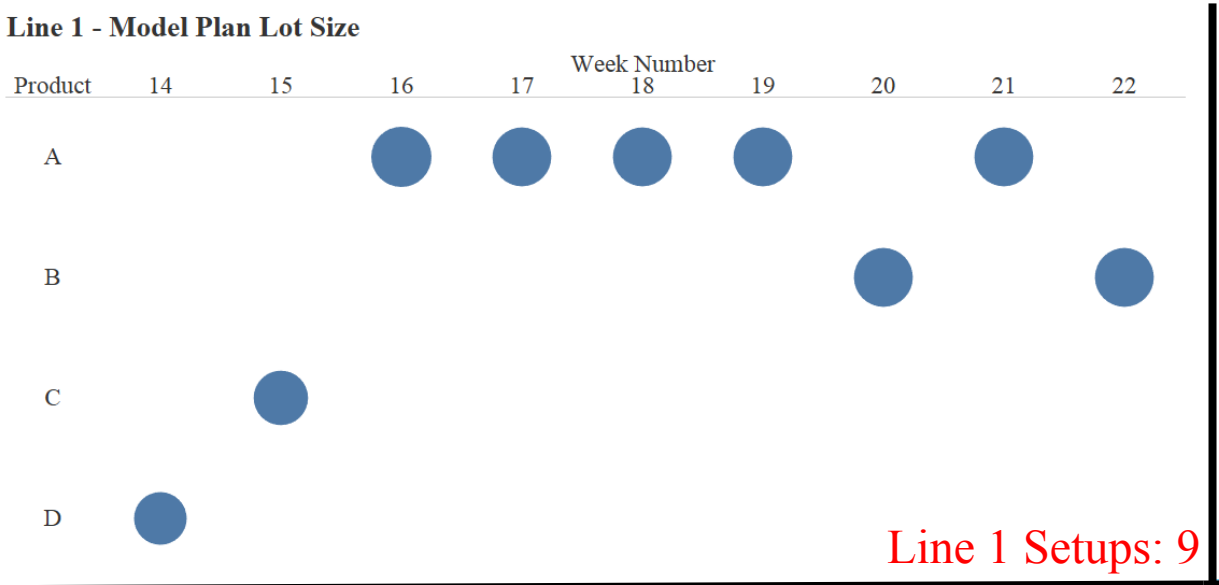


Line 3 Setups: 9

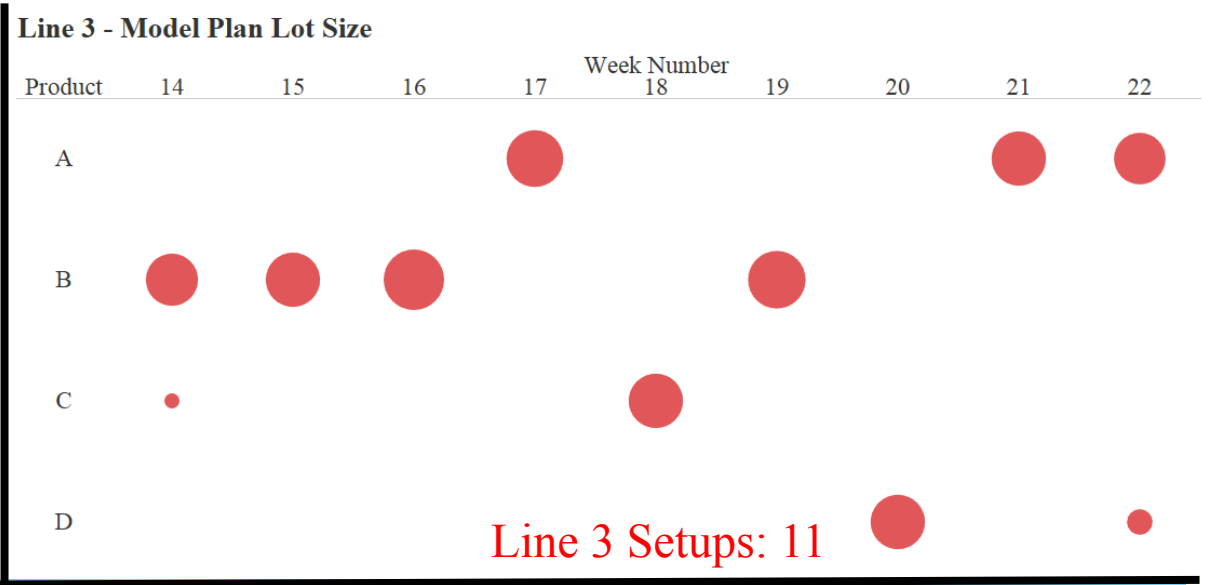
- Current method uses average demand every period for fast movers
- Planning done one line at a time to reduce complexity

Total Setups: 37

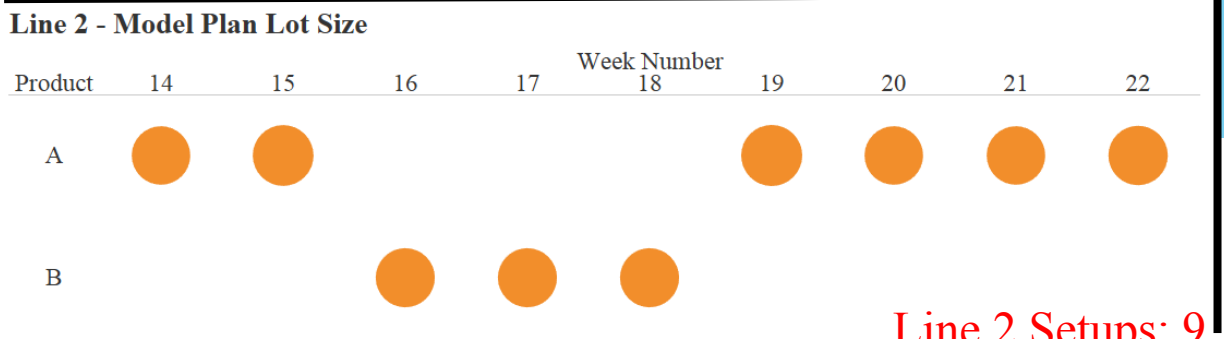
Performance Benchmark Model Planning Results



Line 1 Setups: 9



Line 3 Setups: 11

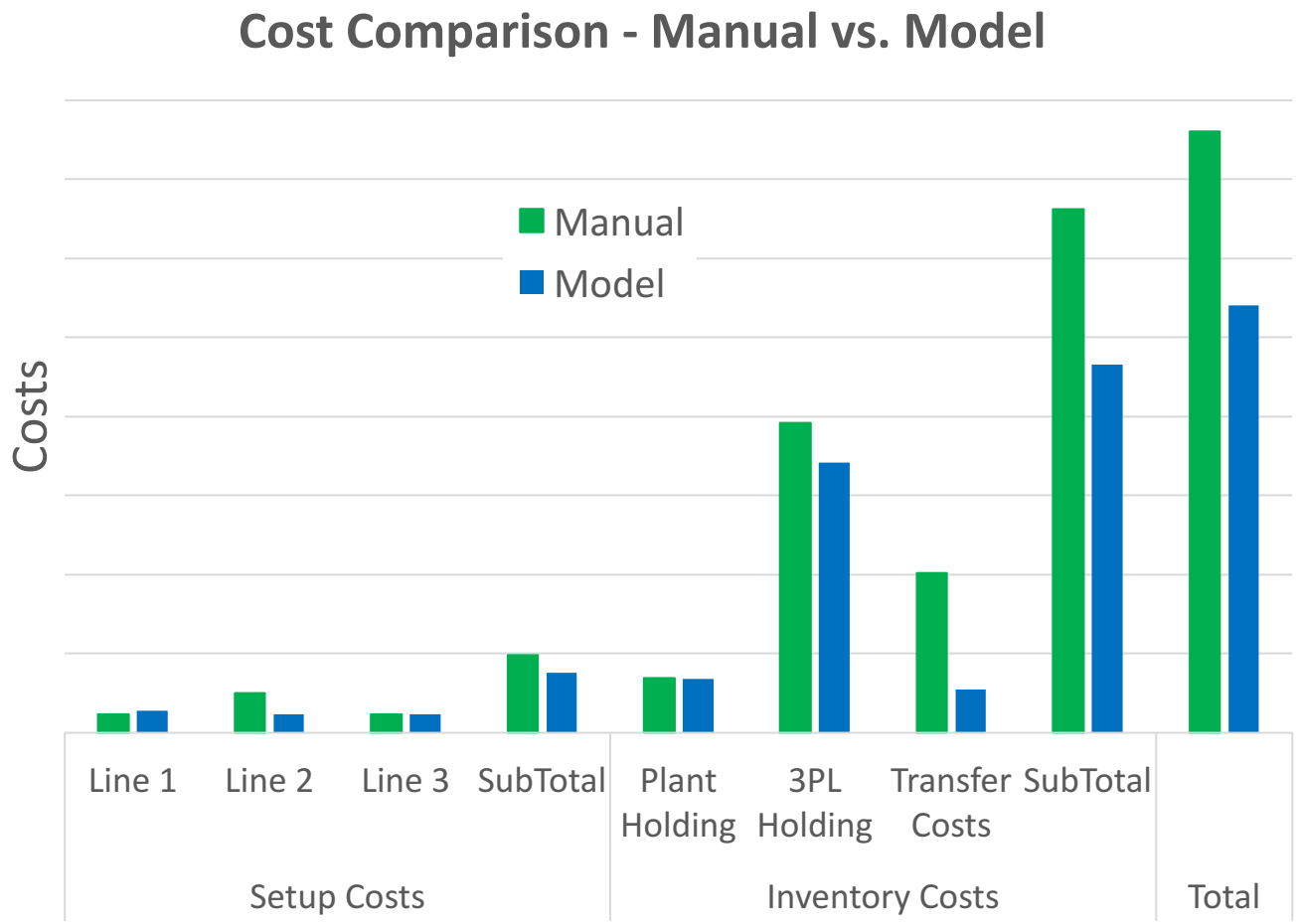


Line 2 Setups: 9

- Utilize flexibility to make the right product at the right time and reduce inventory

Total Setups: 29

Performance Benchmark
Manual Planning Method vs Model Plan



Setup Reduction: 22%

Inventory Reduction: 9%

Transfer Event Reduction: 73%

Total Relevant Cost Savings: 29%

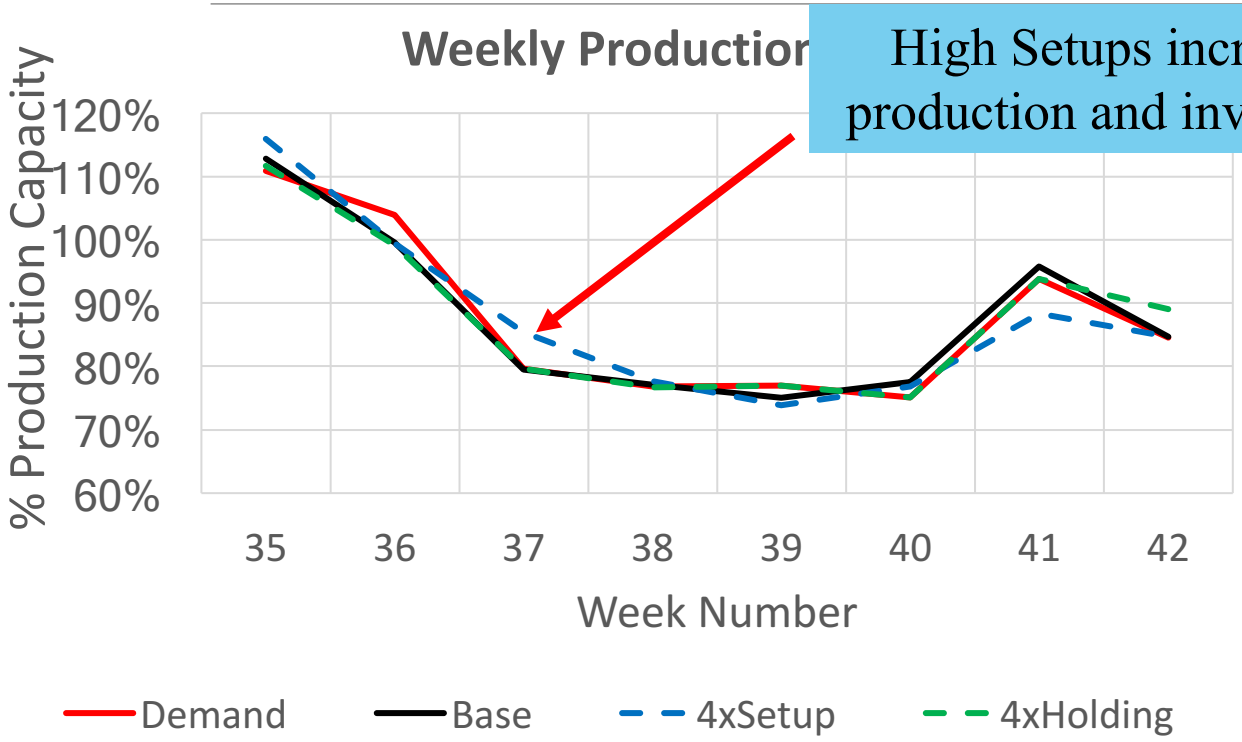
Sensitivity Analysis Rationale

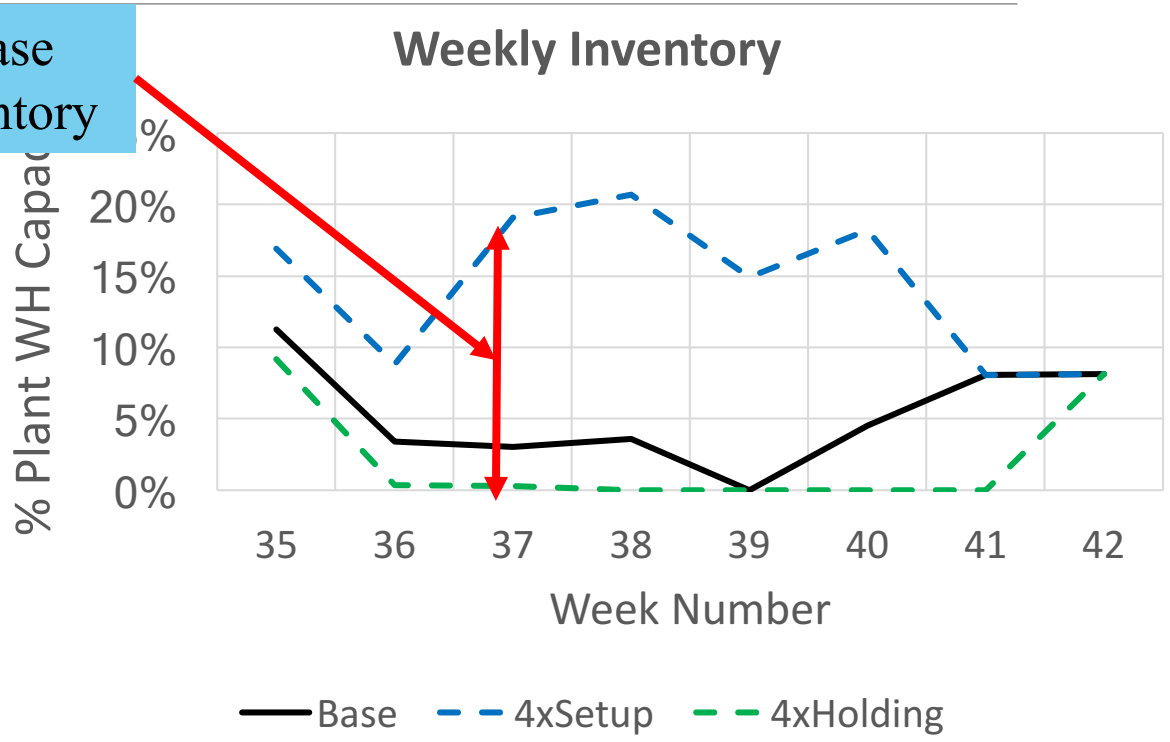
Regional Benchmark Dataset

- Burn period offers best scenario for sensitivity analysis
  - Spare Production Capacity
    - Increasing setup costs should increase lot sizes → need spare capacity to see this
  - Spare Inventory Capacity
    - Increased lot sizes should add inventory

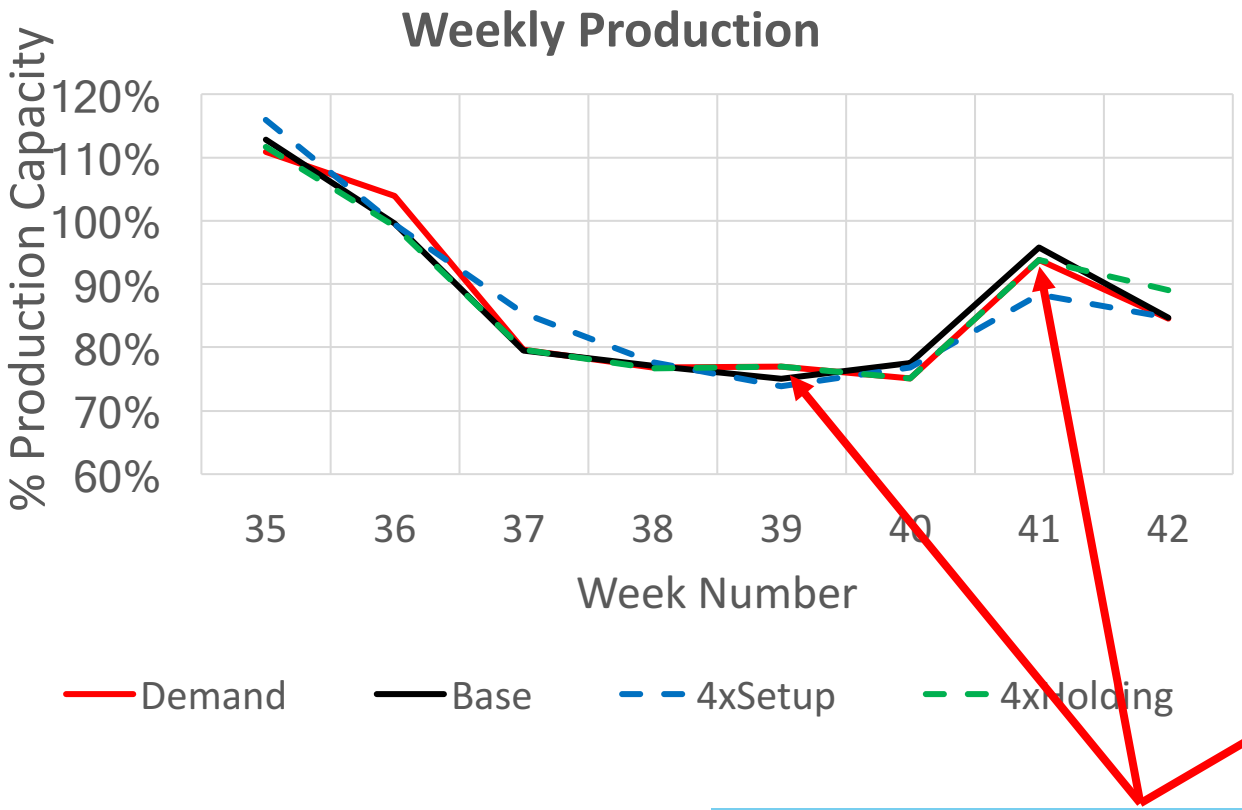
Sensitivity Analysis
Production & Inventory

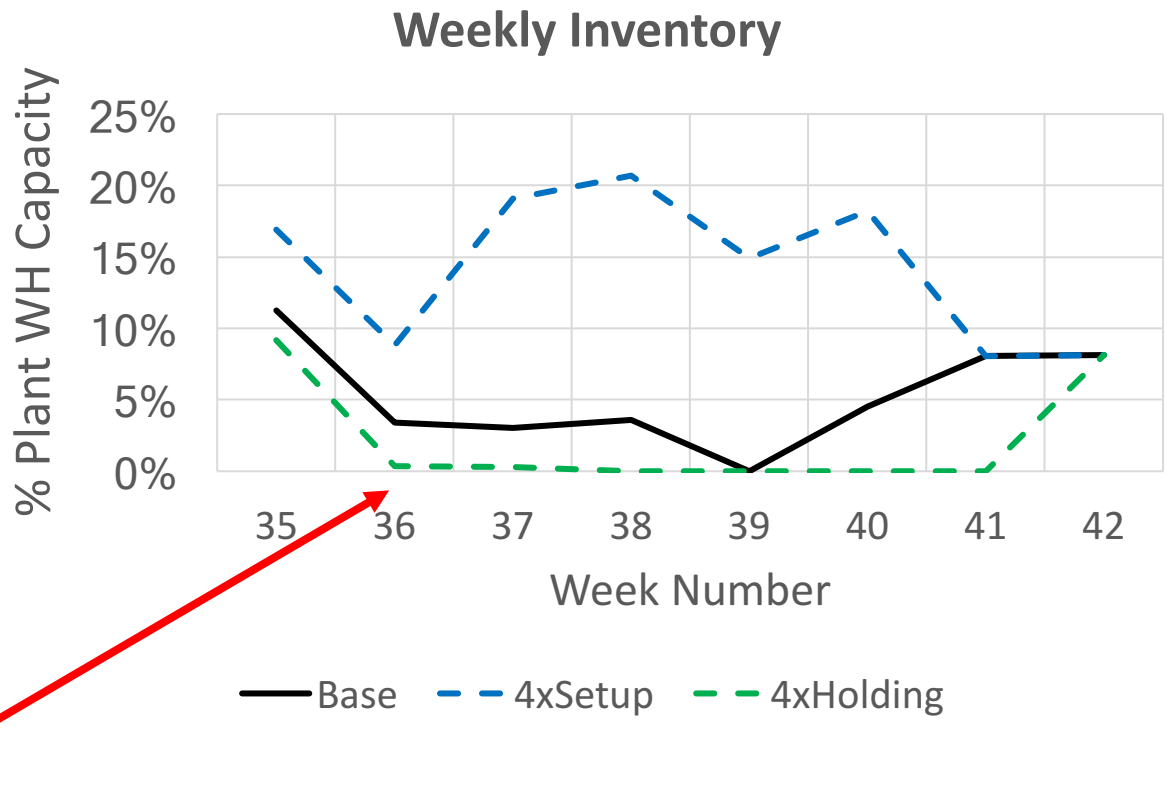
High Setups increase production and inventory





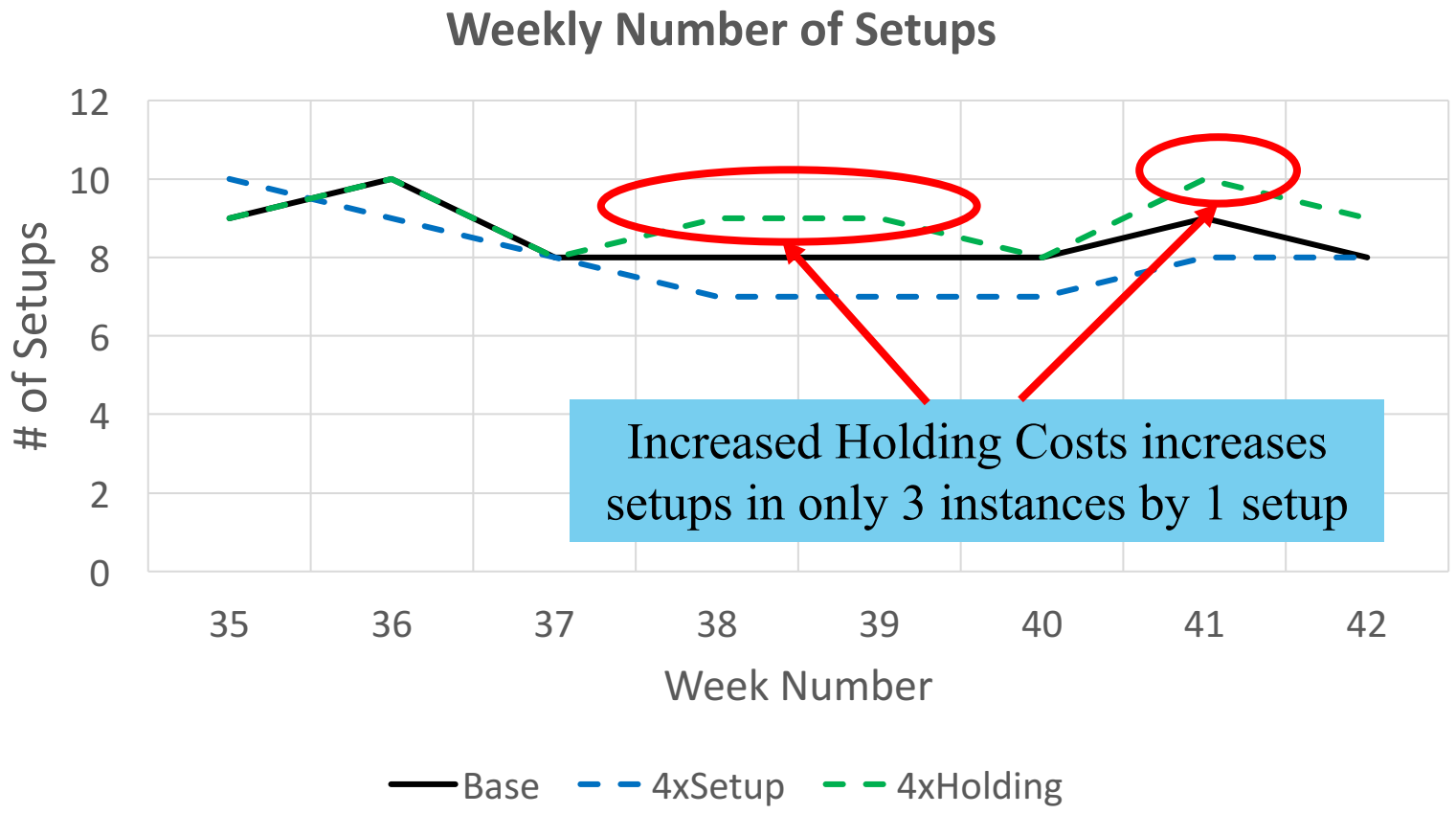
Sensitivity Analysis Production & Inventory





High holding costs increases make to order and reduces inventory

Sensitivity Analysis Setups



Sensitivity Analysis Conclusions

	Base	4xSetup		4xHolding	
		Value	Change	Value	Change
Setups (Qty)	68	64	-6%	72	6%
Plant Inventory (Utilization)	3.4%	9.4%	174%	1.5%	-57%

Change in Setups

- +/- 6% change in setups for +/-4x change in relative setup to holding cost value shows robustness

Change in Inventory

- Plant warehouse utilization only increased to 9.4% with a 4x increase in setup cost

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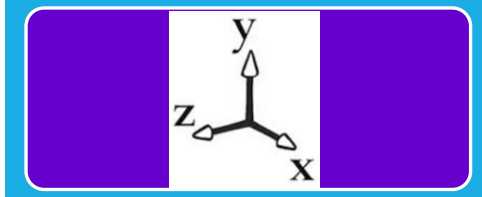
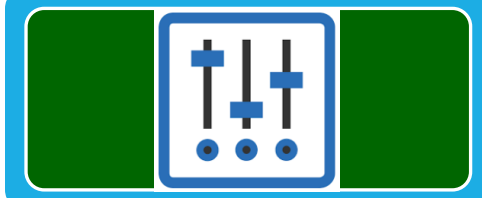
Key Takeaways

Improve Plant Warehouse Utilization

Reduce Transfer Events to the 3PL



Plan on Multi-Dimensions



Utilize Flexibility of all Lines

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Further Research Areas

- Three Echelon Formulation for Bottle-Packsize-Label
- Backordering and Safety Stock features
- Transportation Cost
- Uncertain Demand/Capacity

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Thank You

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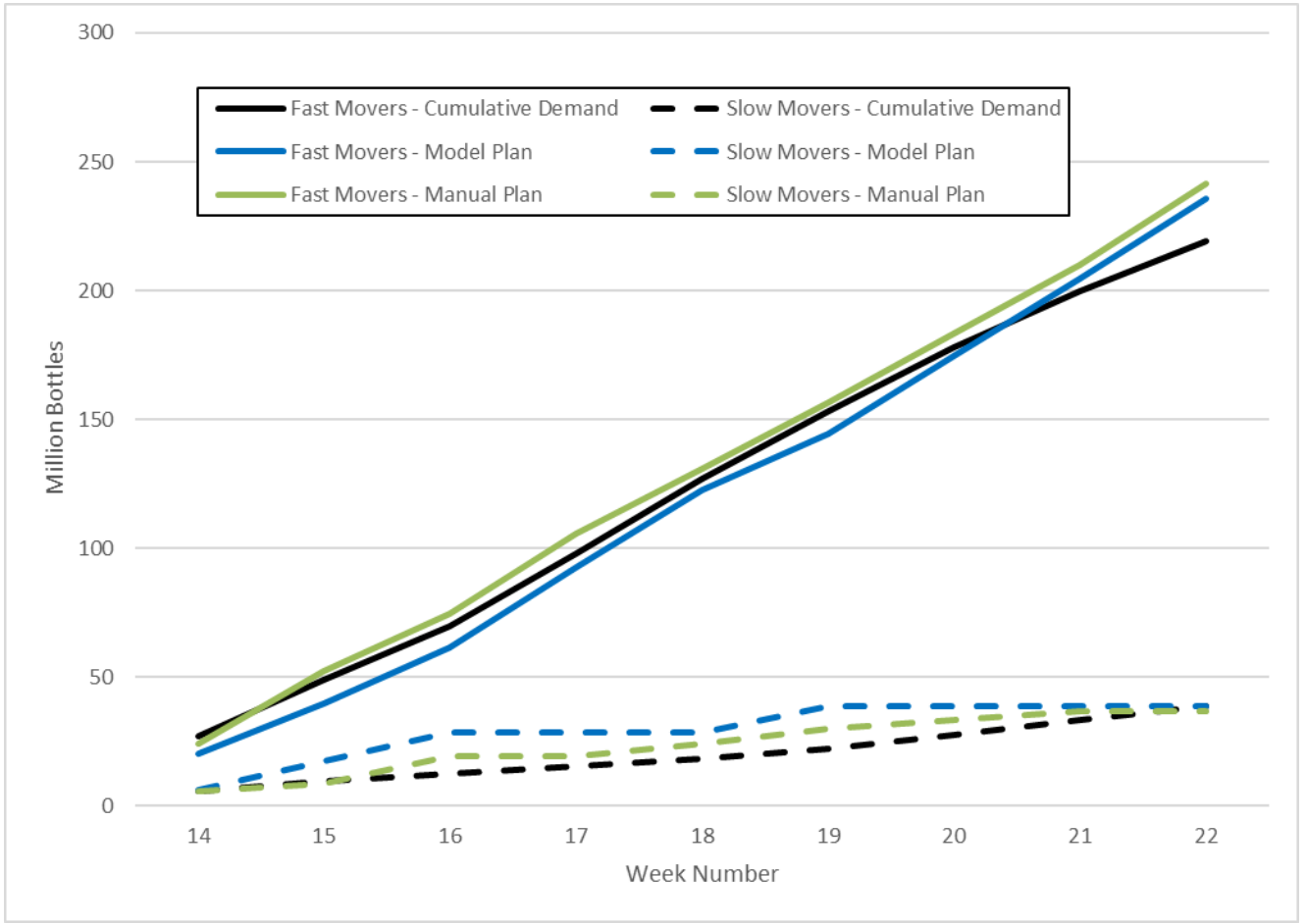
Performance Benchmark
How Do you Reduce Setups and Inventory?



- Manual Plan uses average
  - carries extra inventory throughout when you have inventory build target

- Model Plan uses inventory early and builds to inventory target later
  - Uses extra capacity to build slow mover inventory to reduce setups
  - Slow mover inventory build is less than inventory reduction on fast movers