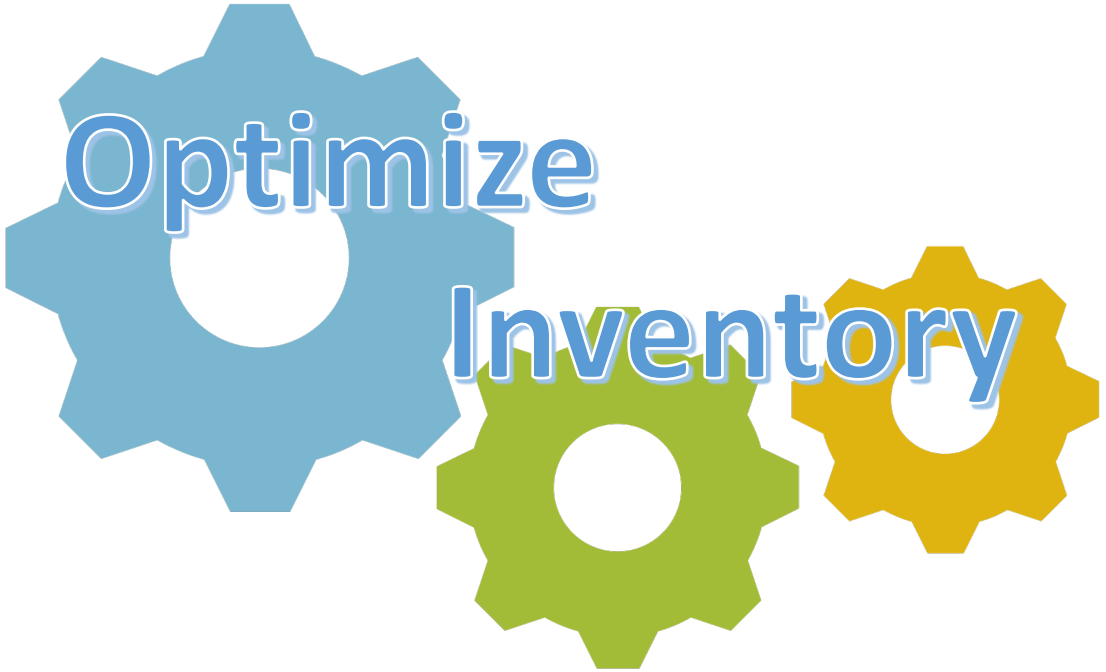
Replenishment Policies for Retail Pharmacies in Emerging Markets

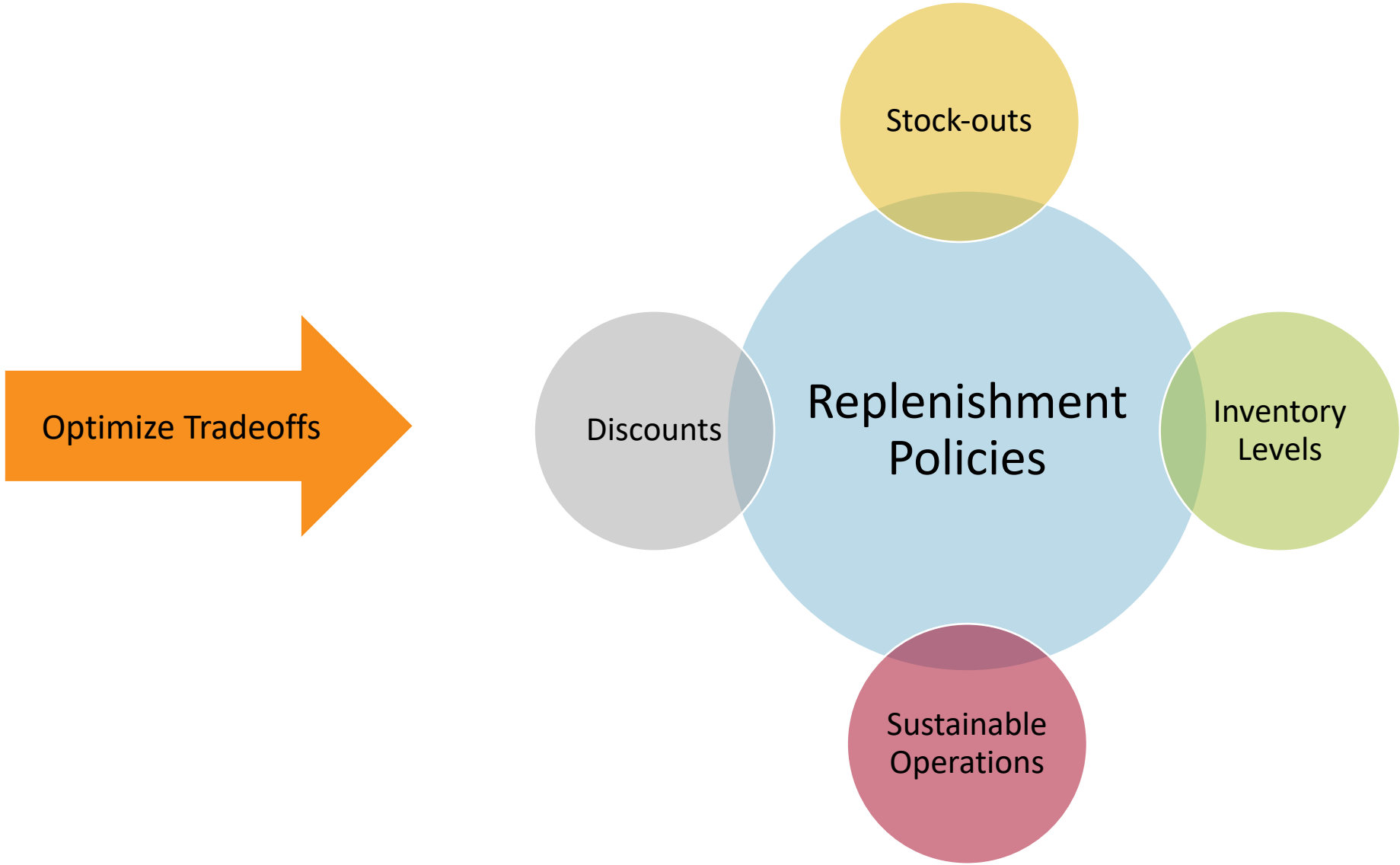


Kevin Chu & Juan Martínez
Advisor: Dr. Christopher Mejía
Sponsor: Retail Pharmacy Chain in Emerging Market

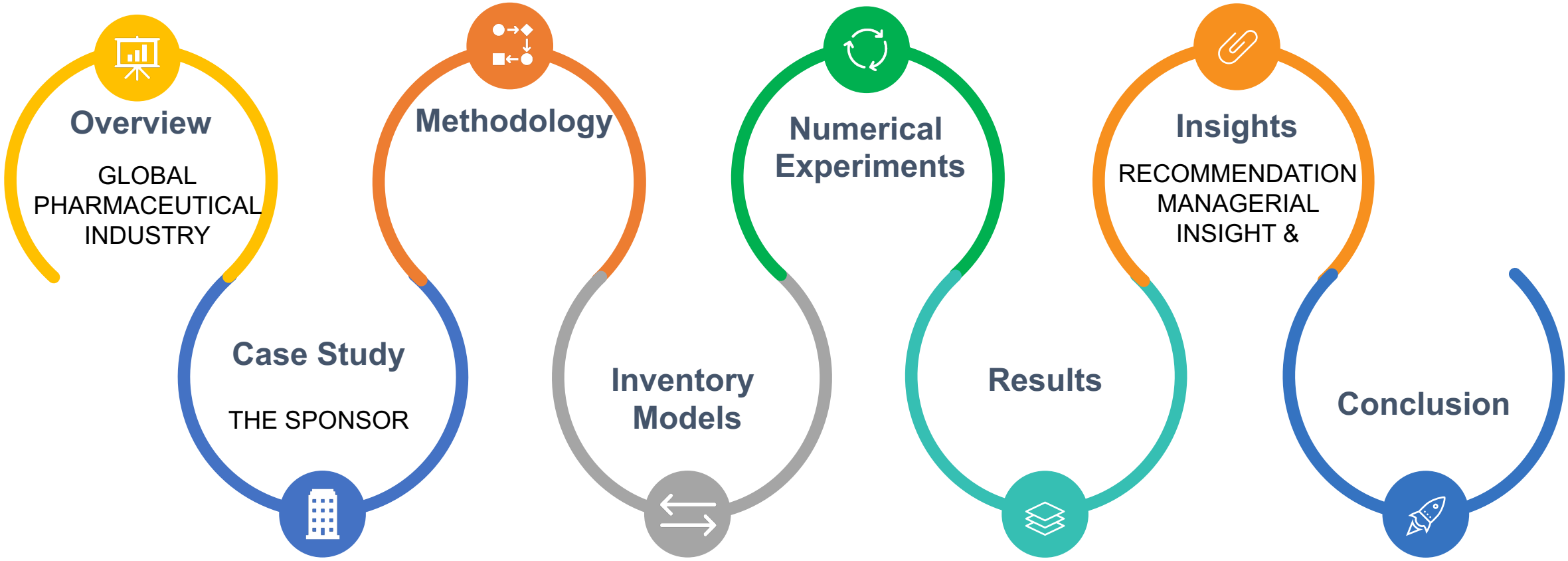
Supply Chain MANAGEMENT

Images from: Getty Images
https://www.excess2sell.com/landing
https://www.nssf.org/lean-retailing-a-better-way-to-manage-inventory-and-increase-profits/

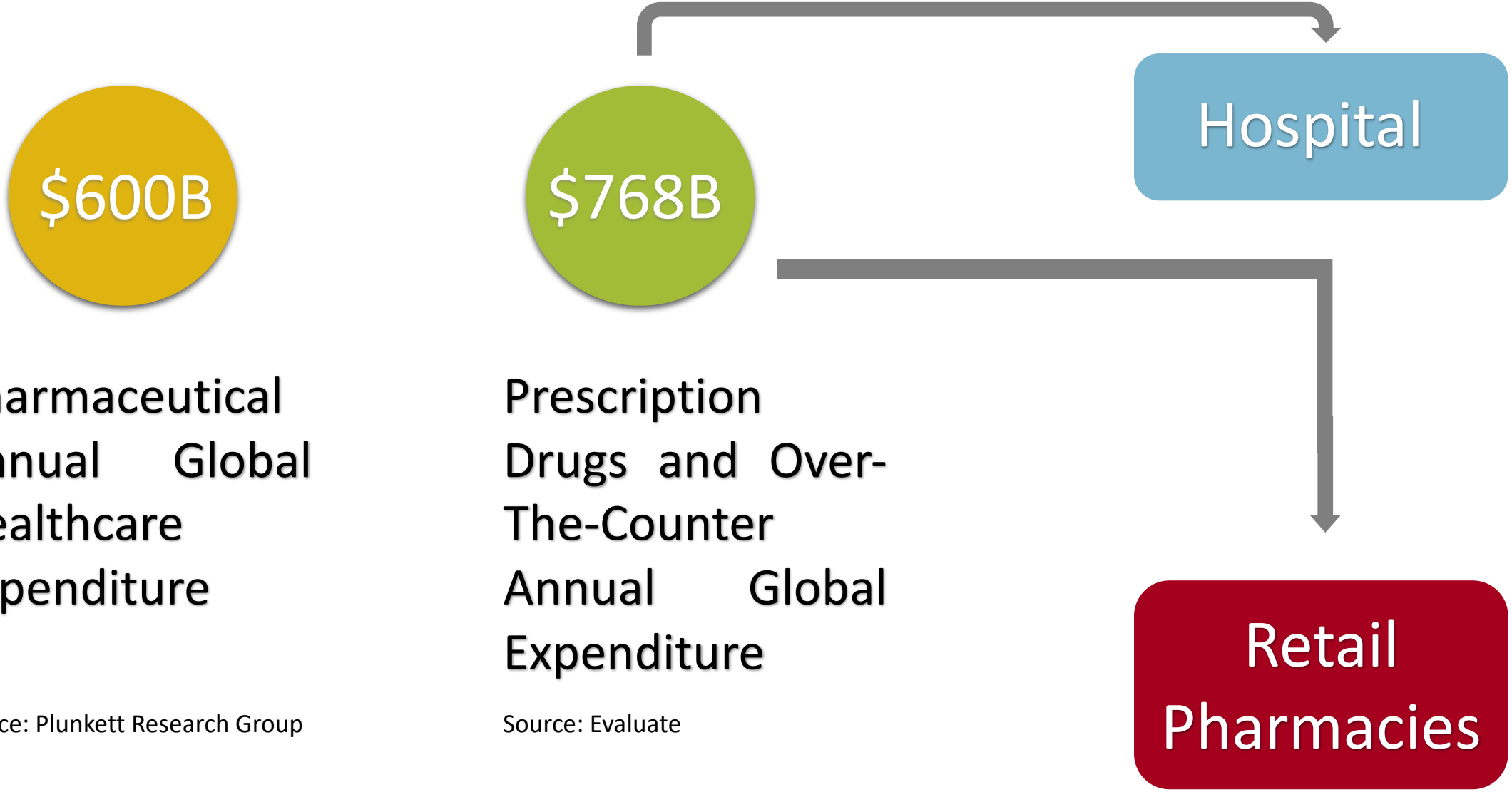
Research Question



Agenda


Overview
GLOBAL PHARMACEUTICAL INDUSTRY
Case Study
THE SPONSOR
Methodology
Inventory Models
Numerical Experiments
Results
Insights
RECOMMENDATION MANAGERIAL INSIGHT &
Conclusion

Global Pharmaceutical Industry



Pharmaceutical Annual Global Healthcare Expenditure

Source: Plunkett Research Group

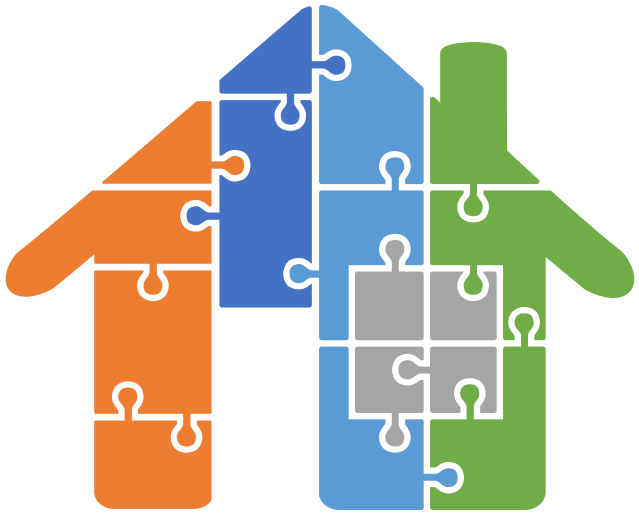
Prescription Drugs and Over-The-Counter Annual Global Expenditure

Source: Evaluate

Case Study: The Company

Background

- Retail Pharmacy Chain
- Top 2 in the Country
- Emerging Market



Opportunities

- 10,000 SKU
- High Complexity, #SKU x #Stores
- Reduce DIO 72 days
- Supplier-pushed Discounts

Peer Review

- Industry Average DIO 57.8
- Walgreen's DIO 34.2
- CVS DIO 35.2

Finance

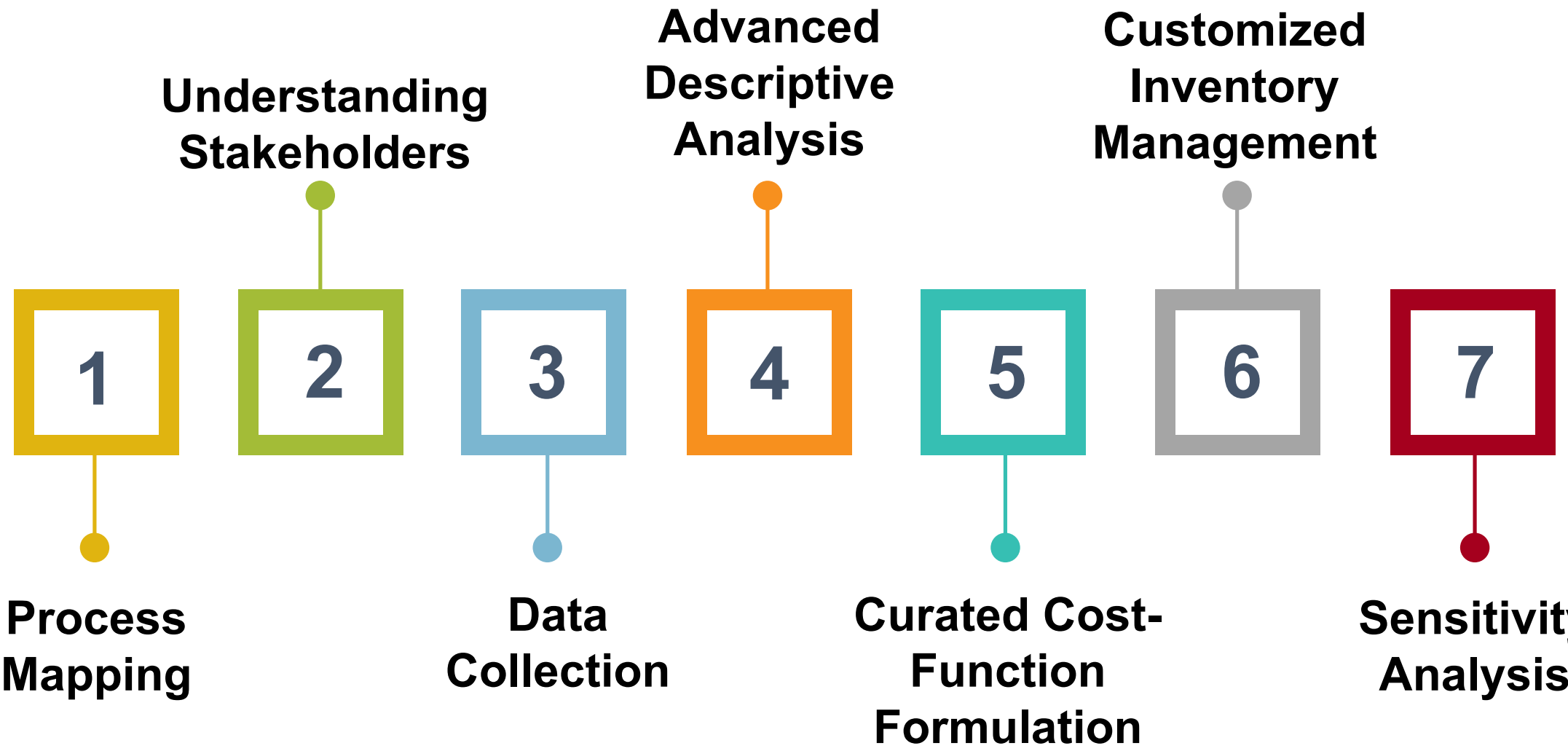
- Regulated Margin 23.08%
- Over 72 DIO
- Supplier-pushed Discounts

Network

- 50+ Store
- 1 DC
- 120+ Suppliers

DIO: Days of Inventory Outstanding

Methodology



Process Mapping

Information Flow

Purchase Order

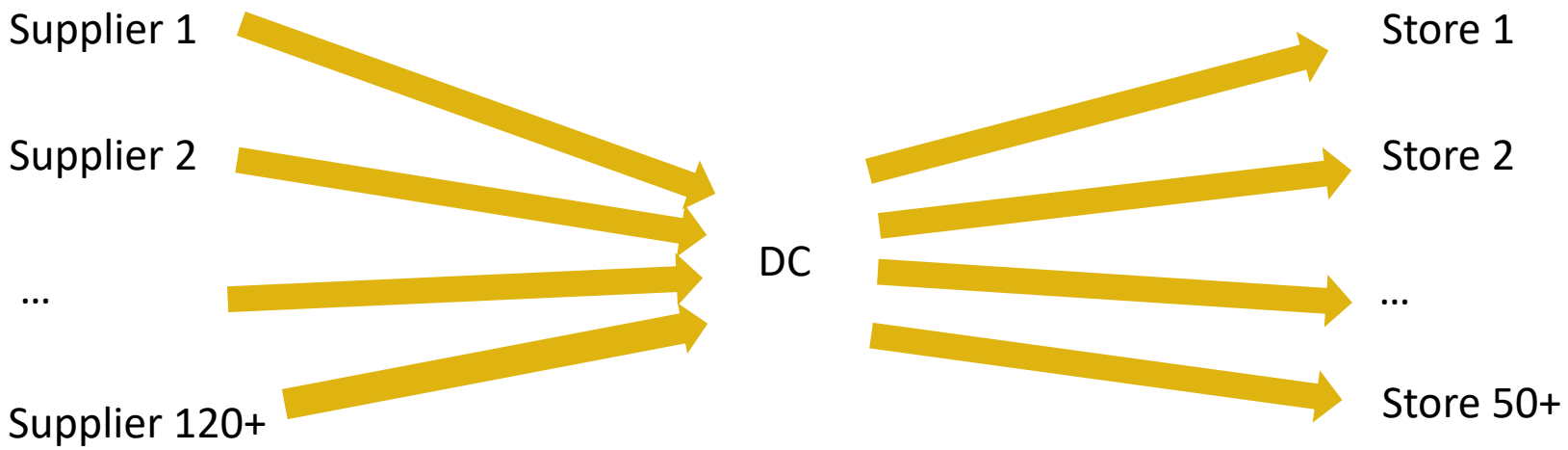
Supplier Invoice

Store Order to DC

Product Availability

Customer Order

Demand



Purchase Order

Supplier deliver to DC

DC Receives Units

DC Deliver Units

Store Receives

Deliver to Customer

Physical Flow

Data Collection & Descriptive Analysis

Data Collection

POS Data

50+ Stores

1.5+ Million records

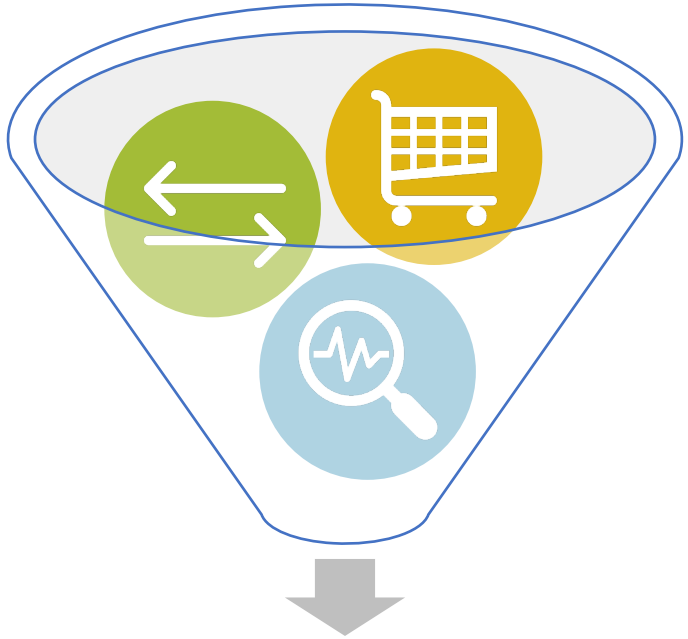
Transactional Data

1 DC, 50+ Stores

Product Selection

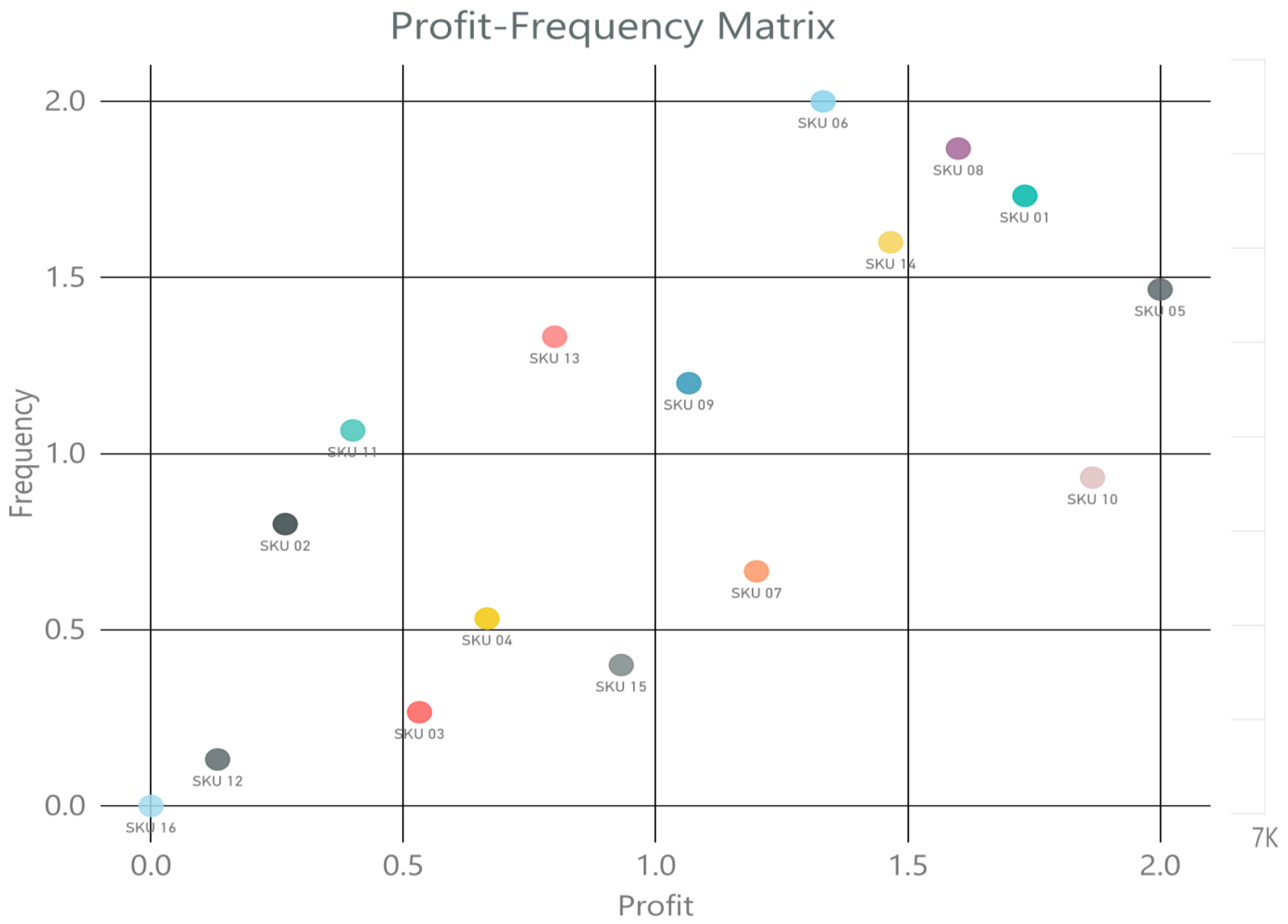
16 SKUs

Descriptive Analysis



Demand Distribution
Demand Variability
Supplier-Pushed Discounts
Stock-Outs Correlation DC vs Stores
SKU Clustering

Descriptive Analysis of SKU Demand



Profit vs Frequency Matrix

- Understand Demand Patterns on a standardized scale.
- Separate fast & slow movers.
- Separate high and low profit despite frequency.

Demand Frequency

- Understand real demand and selling frequency.
- Understand demand volume.
- Relationship between # of transactions and demand.

Demand Variability

- Understand how stable is the demand.
- Understand how stable is transaction frequency.
- Draw conclusion of potential policy.

Cost Function Components

DC

$$Ordering\ Cost = C_t * \frac{D_D}{Q_D}$$

$$DC\ Inbound\ Cost = C_{di} * \frac{D_D}{Q_D}$$

$$DC\ Outbound\ Cost = C_{do} * \sum_{s=0}^{S} \frac{D_S}{Q_S}$$

$$DC\ Stockout\ Penalty = C_{Ds} * \frac{D_D}{Q_D} * P[x > Q_D]$$

$$Product\ Cost = C_u * D_D$$

$$Holding\ Cost = C_h * (\frac{P_u}{2} + k\sigma_{DL})$$

Stores

$$Store\ Inbound\ Cost = C_{si} * \sum_{s=0}^{S} \frac{D_S}{Q_S}$$

$$Store\ Stockout\ Penalty = C_{ss} * \sum_{0}^{S} \frac{D_S}{Q_S} * P[x > Q_s]$$

Inventory Models

Periodic Review (Q, R)

- Calculated Q_D^* for the DC & Q_s^* for each store.
- Calculated $R_D = k\sigma_{DDL}$ for DC & $R_S = k\sigma_{SDL}$ for each store
- If ending inventory fall under R, Q units are ordered

Continuous Review (s, S)

- Calculated s $s_D = k\sigma_{DDL}$ for DC & $s_S = k\sigma_{SDL}$ for each store
- Calculated S $S_D = R_D + Q_D$ for DC & $S_s = R_s + Q_s$
- If ending inventory fall under s, units are ordered up to S.

The (s, S) replenishment policy accounts for current inventory while (Q, R) doesn't.

Numerical Experiments with Company's SKUs

Baseline, (Q, R) & (s, S)

Setup

- Randomized store demand based on historical distribution
- Calculated forecast based on sponsor's current forecasting technique

Consolidation

- Consolidated store demand data to form DC demand
- Calculated DC demand forecast

Run

- Calculated (Q, R) or (s, S)
- Simulated daily inventory movement

Sensitivity Analysis

1

Forecast Horizon

- Annual
- Monthly
- Biweekly
- Weekly

Determine forecast aggregation effect on the robustness of the replenishment policies

2

Stock-Out Rate

- 0x Mark up
- 2x Mark up
- 5x Mark up
- 10x Mark up

Determine the impact of customer willingness to backorder or leave to a competitor

3

Customer Service Level

- 0.99 CSL
- 0.95 CSL
- 0.90 CSL
- 0.85 CSL

Determine the impact if all SKUs are managed as equal creating excess or oscillations in replenishment.

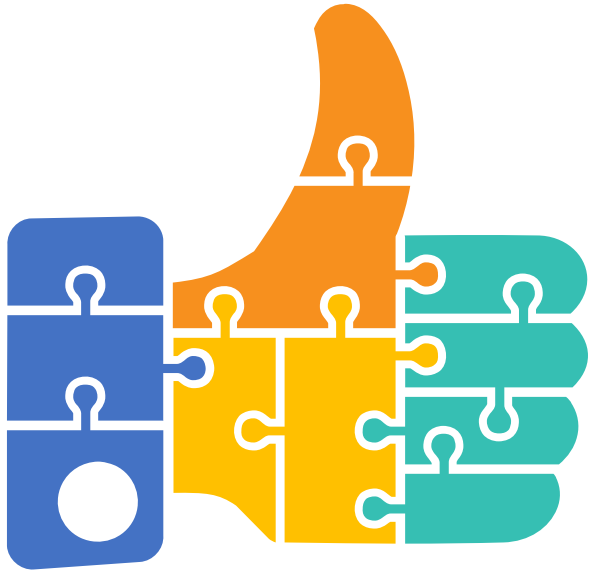
Results

IMPROVE

Significant reduction in the Total Cost Function

(Q, R) Average 33%

(s, S) Average 37%



DESIGN

SKU Differentiation

1. Profit vs Frequency 2x2 Matrix
2. Demand Variation

DEVELOPMENT

Replenishment Policies

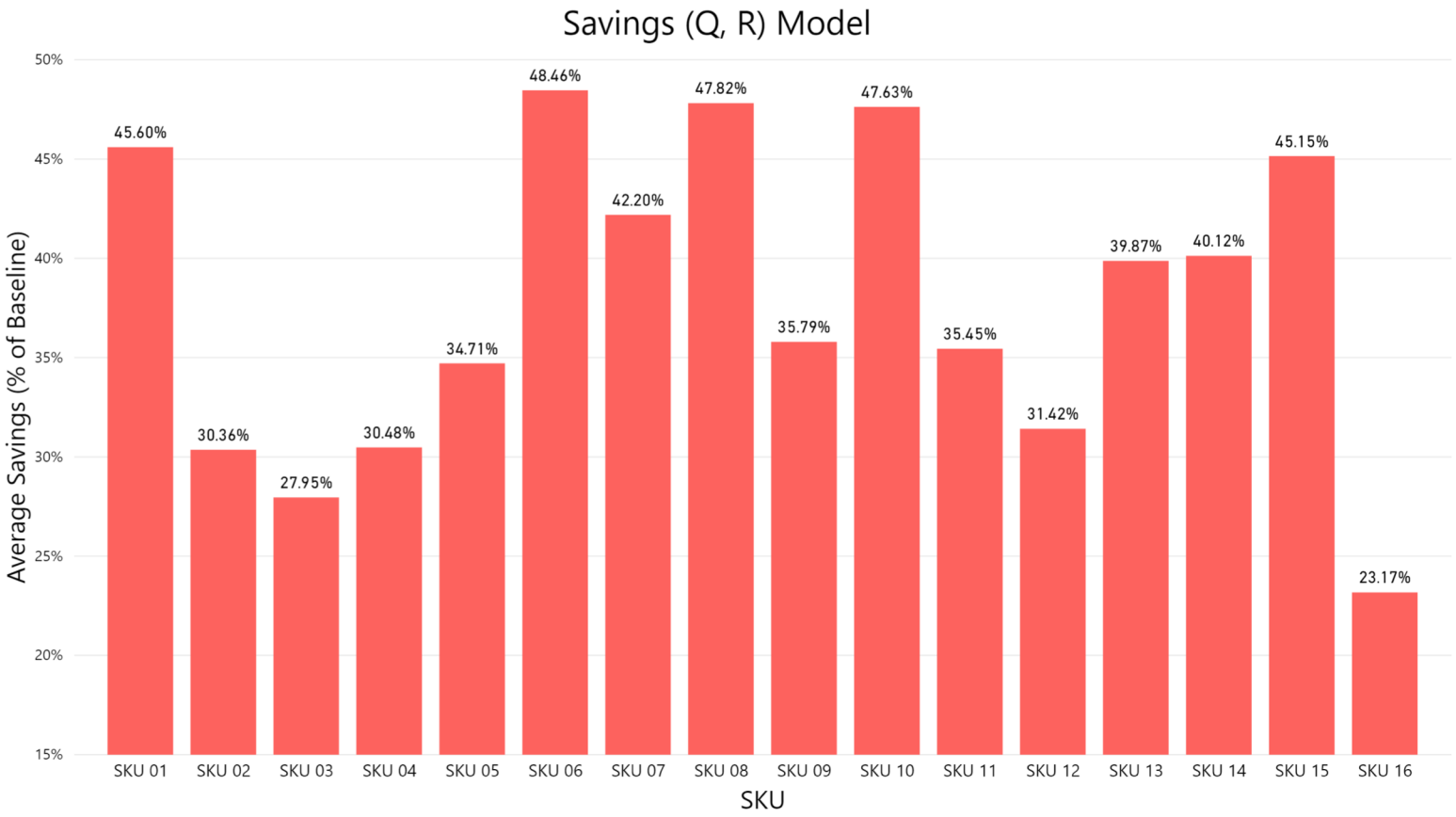
1. Baseline
2. (Q, R)
3. (s, S)

STRATEGY

Use Different Policies depending on SKU Characteristics High or Low Profit.

Periodic Review Replenishment Policy (Q, R)

Cost Savings vs Baseline



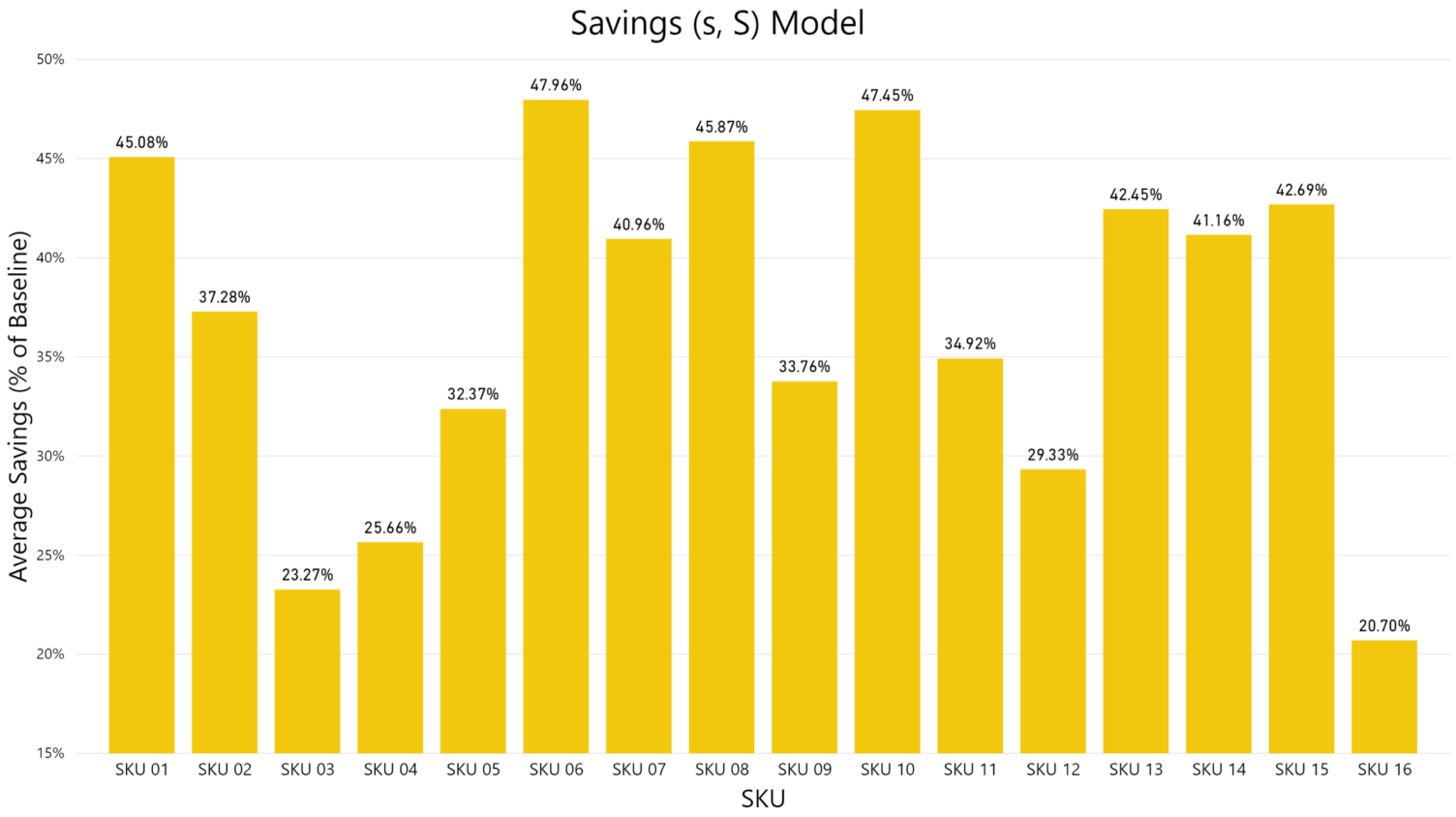
- Average Savings 33%
- Tradeoff: Lower inventory and Higher DC Holding Cost.
- Best suited for High Profit SKUs
- Higher impact on the CSL.
  - -2.53% on Average

Continuous Review Replenishment Policy (s, S)

- Average Savings 37%
- Most important cost reduction:

  Product Inventory Cost.
- Best Suited for Low Profit SKUs
- Lower impact on CSL
  - -2.09% on Average

Cost Savings vs Baseline



Supply Chain MANAGEMENT

Results Sensitivity Analysis

1

Forecast Horizon

- Annual
- Monthly
- Biweekly
- Weekly

2

Stock-Out Rate

- 0x Mark up
- 2x Mark up
- 5x Mark up
- 10x Mark up

3

Customer Service Level

- 0.99 CSL
- 0.95 CSL
- 0.90 CSL
- 0.85 CSL

@ Minimized Total Cost:

- Most Stock-outs – Biweekly Horizon
- Least Stock-outs – Annual Horizon
- Higher stock-out rate favored higher CSL

Tradeoffs Observed:

- Holding costs vs Stock-Out Penalty
- Holding costs vs Discounts leveraged

Managerial Insights & Recommendation

Use Different Replenishment Policies

- Depending on the characteristics of SKU.

Replenishment Suggestions

- (Q, R) for High Profit & Unit Cost.
- (s, S) for Low Profit & Unit Cost

Stock-Out Penalties

- High penalties lead to higher inventory.
- The company should calibrate the penalty depending on opportunity cost and possibility of losing a customer.

Forecast Horizon

- Annual for High Stock-out penalty SKUs.
- Biweekly for Low Stock-out Penalty SKUs.

Recommendation

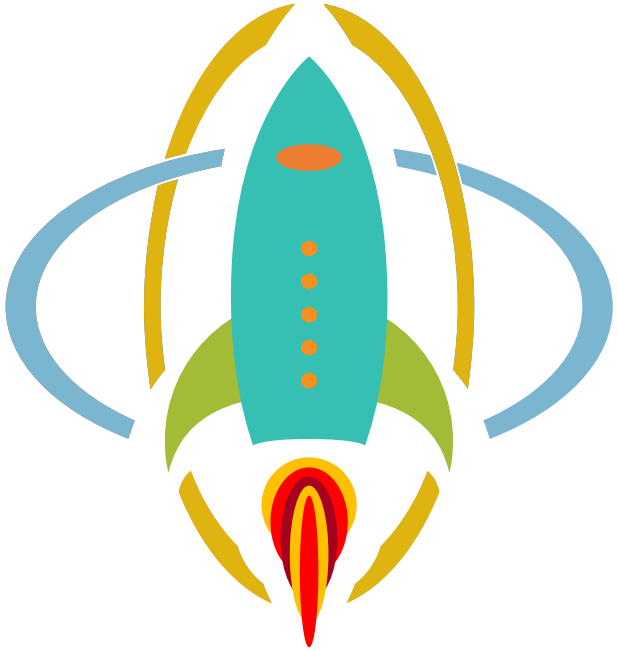
- Determine the Company priority CSL vs Total Cost.
- Determine the SKUs for each policy.
- Determine the Stock-out Penalty for each SKU and Store.

Conclusion

1

FINDINGS

- Very different SKUs Characteristics.
- (Q, R) is better for High Profit SKUs.
- (s, S) is better for Low Profit SKUs.
- Impact of Volume or variability. made no significant impact.
- Savings over 30% of the Total Cost.
- Similar Fill Rate less than 5% decrease.



DESIGN

2

- (Q, R) for DC & Stores.
- (s, S) for DC & Stores.
- Sensitivity Analysis:
  - Forecast Horizon
  - Stock-Out Penalty
  - CSL

3

FUTURE WORK

- Analyze different policies combinations for DC & Stores.
- Analyze different policies combinations for each Store.
- Determine CSL sensitivity for each SKU/Store.

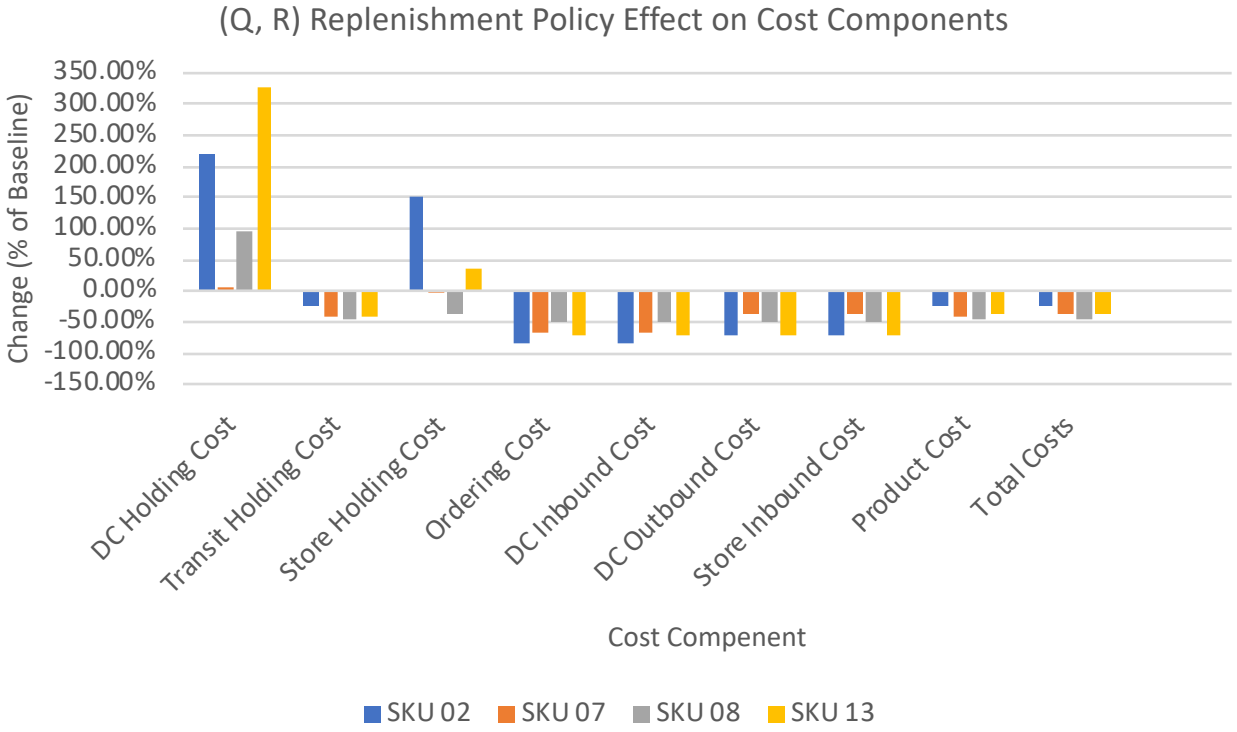
SCALABILITY & FIRST STEPS

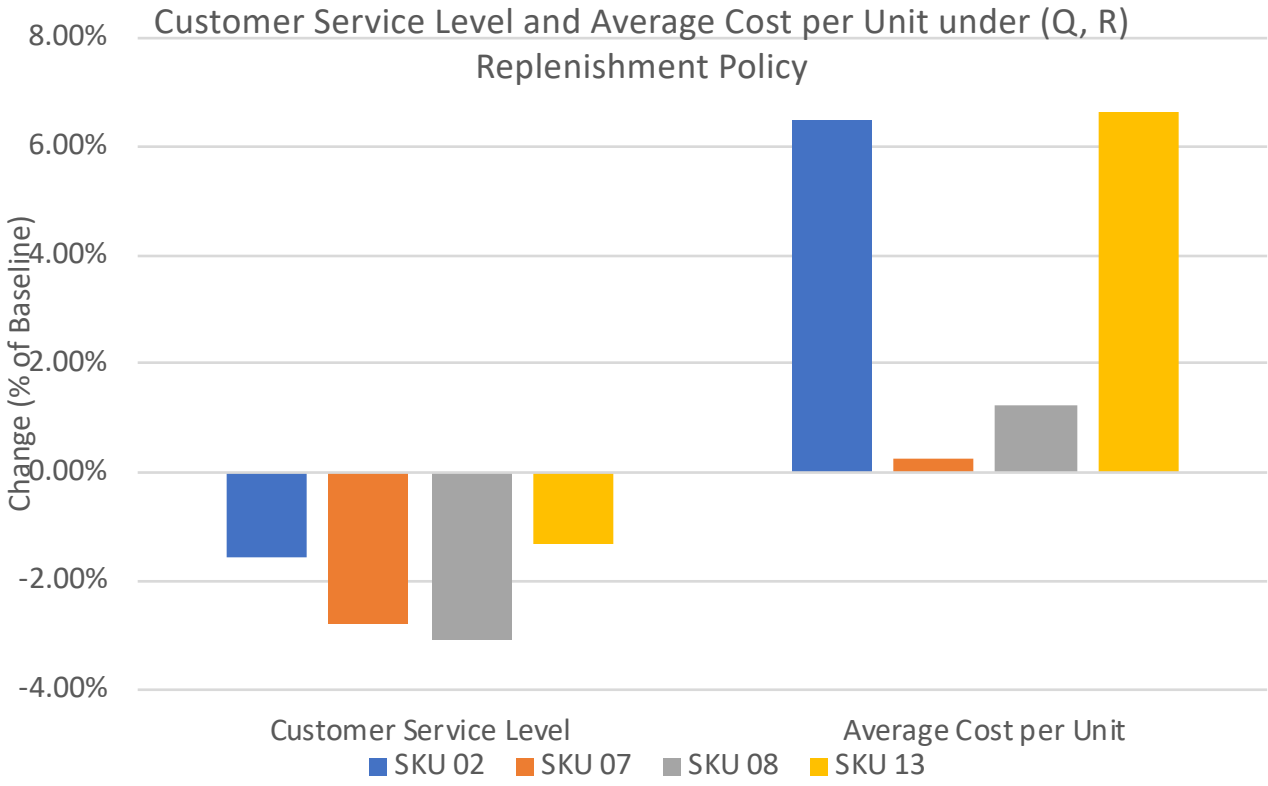
4

- All SKU demand vs frequency clustering.
- All SKU Demand variability understanding.
- Biggest $ savings in high profit & high frequency SKUs.

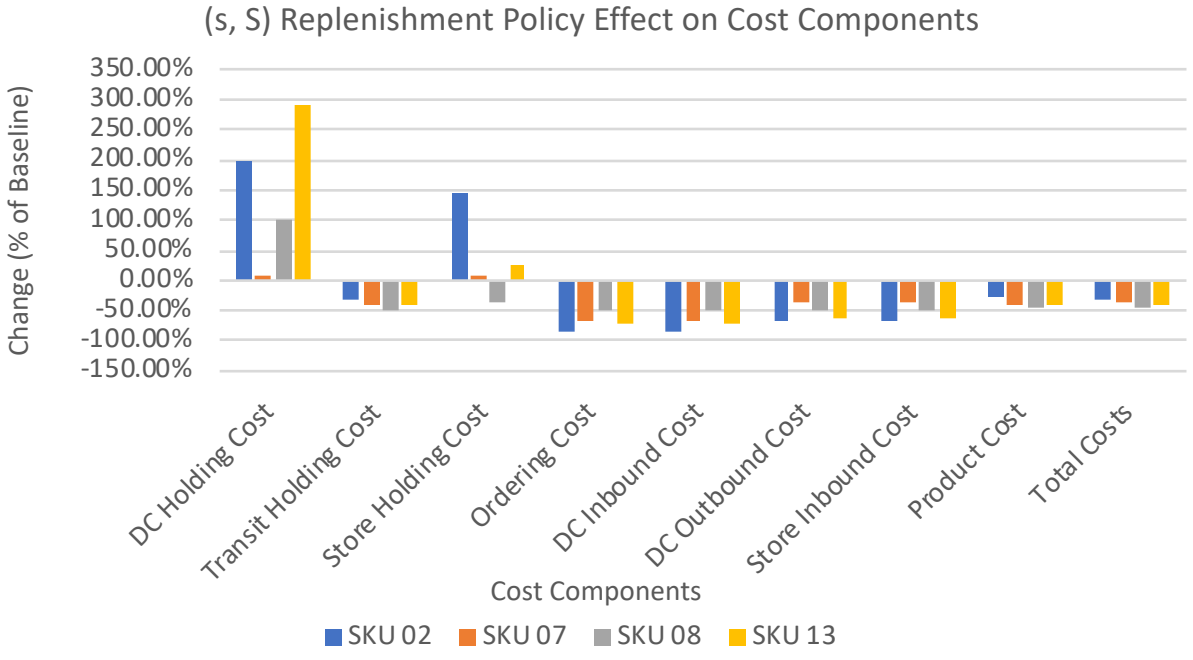
Questions?

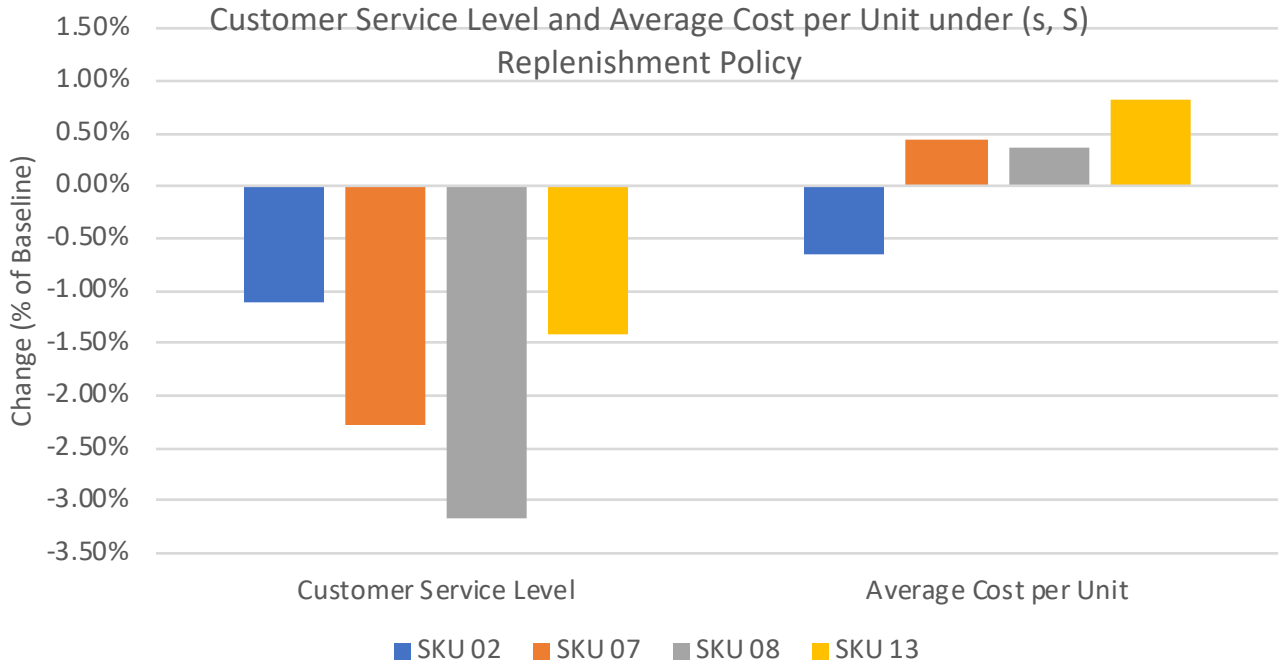
Extra (Q, R)


(Q, R) Replenishment Policy Effect on Cost Components
Change (% of Baseline)
350.00%
300.00%
250.00%
200.00%
150.00%
100.00%
50.00%
0.00%
-50.00%
-100.00%
-150.00%
DC Holding Cost
Transit Holding Cost
Store Holding Cost
Ordering Cost
DC Inbound Cost
DC Outbound Cost
Store Inbound Cost
Product Cost
Total Costs
Cost Compenent
SKU 02
SKU 07
SKU 08
SKU 13

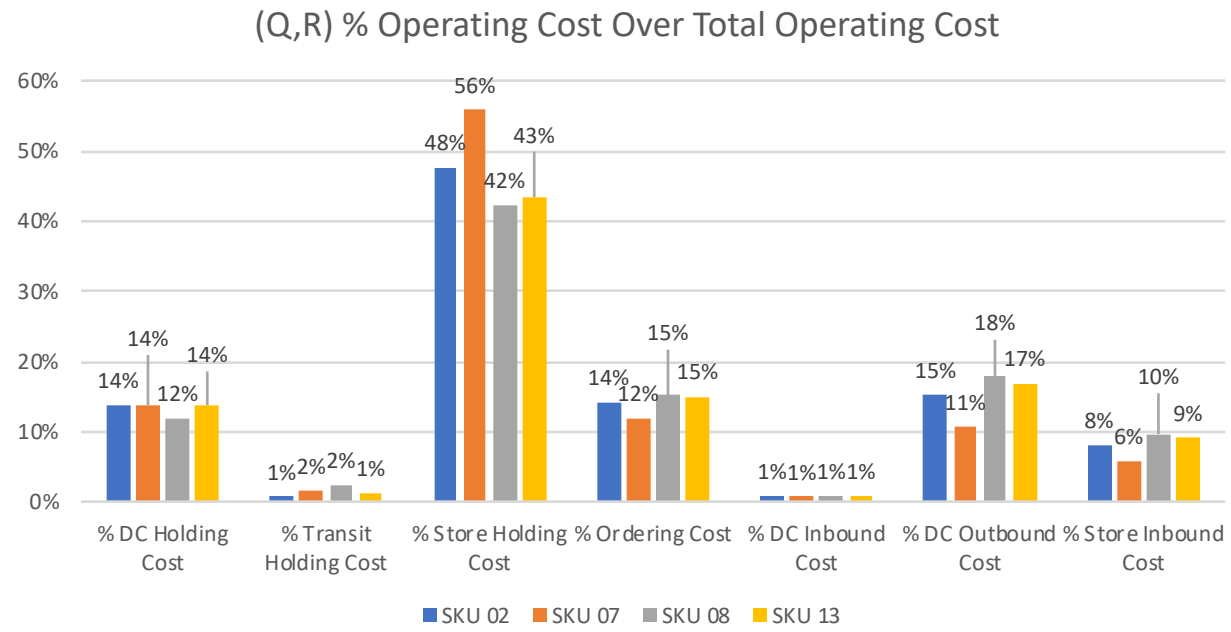

Customer Service Level and Average Cost per Unit under (Q, R) Replenishment Policy
Change (% of Baseline)
8.00%
6.00%
4.00%
2.00%
0.00%
-2.00%
-4.00%
Customer Service Level
Average Cost per Unit
SKU 02
SKU 07
SKU 08
SKU 13

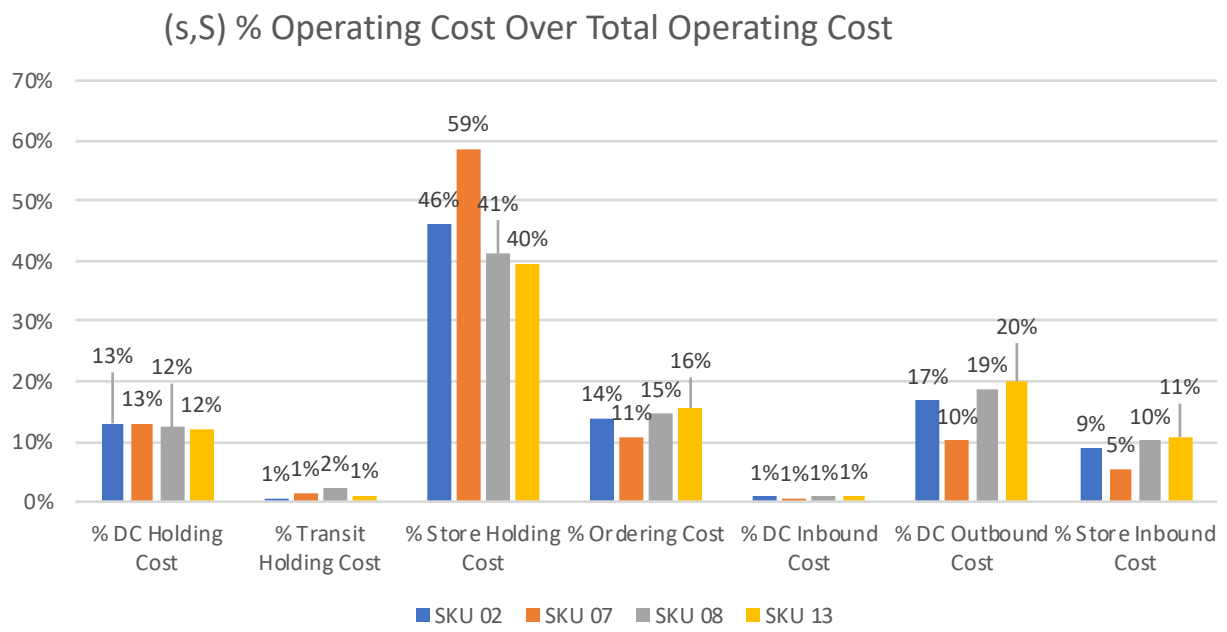
Extra (s, S)


(s, S) Replenishment Policy Effect on Cost Components
Change (% of Baseline)
350.00%
300.00%
250.00%
200.00%
150.00%
100.00%
50.00%
0.00%
-50.00%
-100.00%
-150.00%
DC Holding Cost
Transit Holding Cost
Store Holding Cost
Ordering Cost
DC Inbound Cost
DC Outbound Cost
Store Inbound Cost
Product Cost
Total Costs
Cost Components
SKU 02
SKU 07
SKU 08
SKU 13

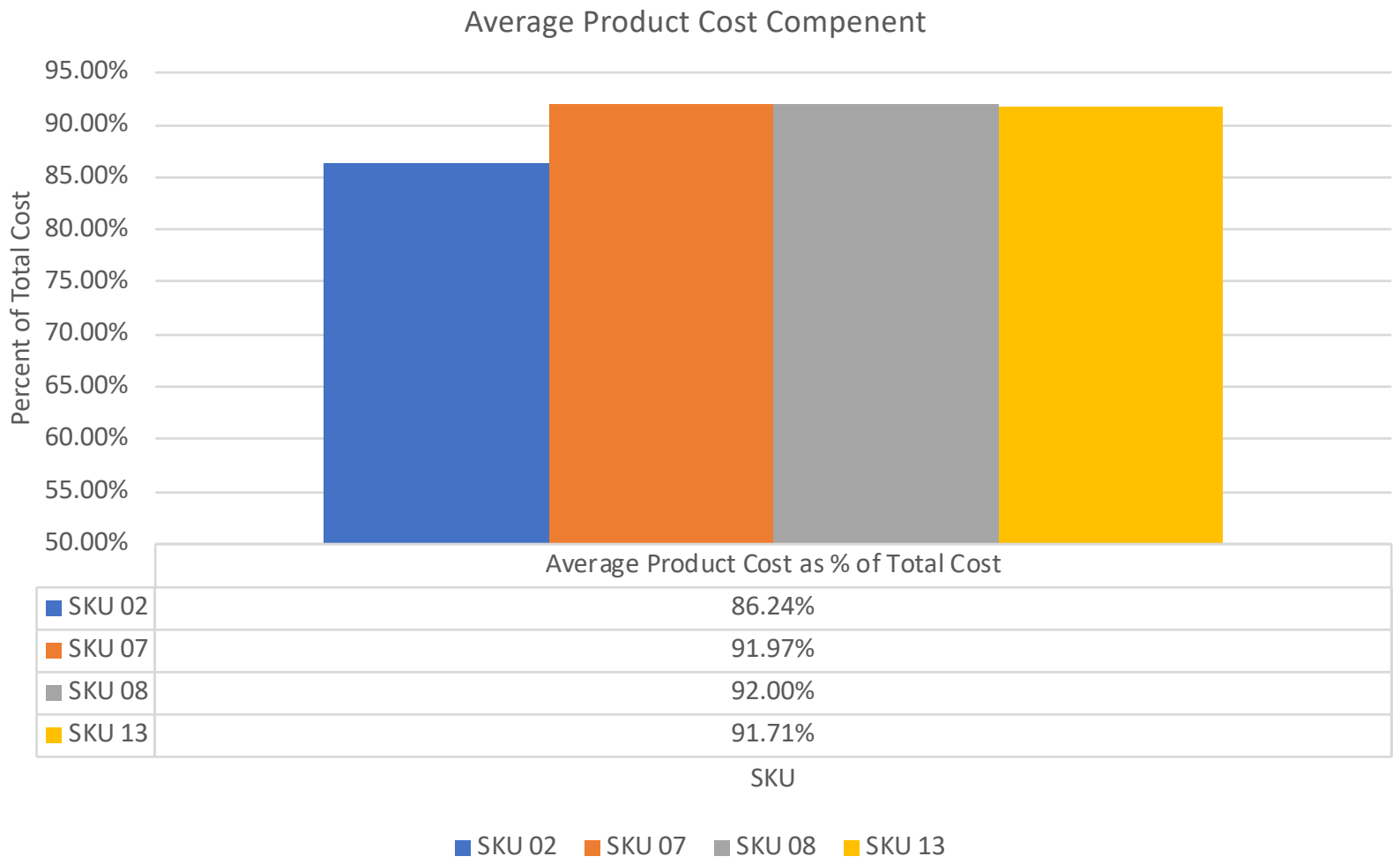

Customer Service Level and Average Cost per Unit under (s, S) Replenishment Policy
Change (% of Baseline)
1.50%
1.00%
0.50%
0.00%
-0.50%
-1.00%
-1.50%
-2.00%
-2.50%
-3.00%
-3.50%
Customer Service Level
Average Cost per Unit
SKU 02
SKU 07
SKU 08
SKU 13

Extra Operating Costs





Extra Product Cost as a % of Total Cost



Cost Function

$$Q_D = P_u + \left\lfloor \frac{P_u}{r_f} \right\rfloor * q_f$$

$$TRC_{DC} = C_h * (\frac{P_u}{2} + k\sigma_{DDL}) + \frac{D_D*(C_{di}+C_t)+(C_u*P_u)}{P_u+\frac{q_f*P_u}{r_f}} + C_{do} * \sum_0^S \frac{D_S}{Q_S} + C_{ss} * \frac{D_D}{Q_D} * P[x > Q_D]$$

$$P_u{}^* = \sqrt{\frac{2*(C_{di}+C_t)*D*r_f}{C_h*(q_f+r_f)}} * \sqrt{1 + \frac{C_{ss}*P[x>Q_D]}{C_{di}+C_t}}$$

$$TRC_S = C_{SS} * \frac{D_S}{Q_S} * P[x > Q_s] + (C_{do} + C_{si})\frac{D_S}{Q_S} + C_h * (\frac{Q_S}{2} + k\sigma_{DDL})$$

$$Q_s^* = \sqrt{\frac{2*(C_{do}+C_{si})*D_s}{C_h}} * \sqrt{1 + \frac{C_{ss}*P[x>Q_S]}{C_{do}+C_{si}}}$$

Extra Slide Assumptions

- One Distribution Center.
- Backorders are not allowed.
- All purchases are shipped to the DC.
- Supplier promotions are an extra unit in exchange of increasing orders of a SKU.
- Supplier promotions give one free unit of SKU for every r_f units ordered.
- Demand data is available, but there is some uncertainty.
- Lead times are constant from DC to Stores = 1 day from supplier to DC = 2 days.
- Replenishments from DC prioritize stores based on alphanumerical order. This can be organized depending store demand or frequency.
- The desired CSL at the store level is given depending on the SKU.

Extra Slide Conditions

- There are multiple SKUs clustered in four categories.
- All SKUs fall under one of the established SKU categories.
- One year consists of 12 months of 4 weeks of 7 days.
- The holding cost of inventory is 24% per annum and accrued daily.
- The DC processing time is included in the lead time.
- The DC processing cost is included in the DC inbound cost and the outbound cost.
- Suppliers have a 100% fill rate. Suppliers fill rate is out of scope.
- Stock-out penalty is equal to the SKU markup (30%) multiplied by a stock-out rate.