Replenishment Policies for Retail Pharmacies in Emerging Markets

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Sponsor: Retail Pharmacy Chain in Emerging Market

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

Replenishment Policies

- Stock-outs
- Inventory Levels
- Sustainable Operations
- Discounts

Optimize Tradeoffs
Global Pharmaceutical Industry

- Pharmaceutical Annual Global Healthcare Expenditure: $600B (Source: Plunkett Research Group)
- Prescription Drugs and Over-The-Counter Annual Global Expenditure: $768B (Source: Evaluate)

Hospital

Retail Pharmacies
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

- **Understanding Stakeholders**
  - 1. Process Mapping

- **Advanced Descriptive Analysis**
  - 2. Data Collection
  - 3. Curated Cost-Function Formulation

- **Customized Inventory Management**
  - 4. Advanced Descriptive Analysis
  - 5. Curated Cost-Function Formulation
  - 6. Customized Inventory Management
  - 7. Sensitivity Analysis
Process Mapping

Information Flow

Purchase Order | Supplier Invoice
---|---
Store Order to DC | Product Availability

Supplier 1 → DC → Store 1
Supplier 2 → DC → Store 2
...
Supplier 120+ → DC → Store 50+

Customer Order | Demand

Deliver to Customer

Physical Flow

Purchase Order | Supplier deliver to DC | DC Receives Units | DC Deliver Units | Store Receives | Deliver to Customer
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 = $C_t \cdot \frac{D_D}{Q_D}$

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

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

DC Stockout Penalty

= $C_{Ds} \cdot \frac{D_D}{Q_D} \cdot P[x > Q_D]$

**Stores**

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

Store Stockout Penalty

= $C_{ss} \cdot \sum_{s=0}^{S} \frac{D_S}{Q_S} \cdot P[x > Q_S]$

Product Cost = $C_u \cdot D_D$

Holding Cost = $C_h \cdot \left(\frac{P_u}{2} + k\sigma_{DL}\right)$
Inventory Models

Periodic Review
(Q, R)

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

Continuous Review
(s, S)

- Calculated $s_D = k\sigma_{DDL}$ for DC and $s_S = k\sigma_{SDL}$ for each store.
- Calculated $S_D = R_D + Q_D$ for DC and $S_S = R_S + Q_S$.
- If ending inventory falls 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%

**DEVELOPMENT**
Replenishment Policies
1. Baseline
2. (Q, R)
3. (s, S)

**DESIGN**
SKU Differentiation
1. Profit vs Frequency 2x2 Matrix
2. Demand Variation

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

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
Results

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
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

1. Use Different Replenishment Policies
   - Depending on the characteristics of SKU.

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

3. 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.

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

5. 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

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.

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

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

SCALABILITY & FIRST STEPS
- 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

Customer Service Level and Average Cost per Unit under (Q, R) Replenishment Policy
Extra $(s, S)$

$(s, S)$ Replenishment Policy Effect on Cost Components

Customer Service Level and Average Cost per Unit under $(s, S)$ Replenishment Policy
Extra Operating Costs

(Q,R) % Operating Cost Over Total Operating Cost

(s,S) % Operating Cost Over Total Operating Cost
Extra Product Cost as a % of Total Cost

<table>
<thead>
<tr>
<th>SKU</th>
<th>Average Product Cost as % of Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>02</td>
<td>86.24%</td>
</tr>
<tr>
<td>07</td>
<td>91.97%</td>
</tr>
<tr>
<td>08</td>
<td>92.00%</td>
</tr>
<tr>
<td>13</td>
<td>91.71%</td>
</tr>
</tbody>
</table>
Cost Function

\[ Q_D = P_u + \left( \frac{P_u}{r_f} \right) q_f \]

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

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

\[ TRC_S = C_{ss} \ast \frac{D_S}{Q_S} \ast P [x > Q_S] + (C_{do} + C_{si}) \frac{D_S}{Q_S} + C_h \ast \left( \frac{Q_S}{2} + k \sigma_{DDL} \right) \]

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