Inventory Management in the Washington State Tree Fruit Industry

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Sponsoring Company: N/A
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Washington State Fruit Growing Regions

Source: http://treefruit.yakima.wsu.edu/graphics
Agenda

1. Overview of the Tree Fruit Supply Chain

2. Problem #1: Too Much On-hand Inventory
   - The ‘Big Pile, Small Pile’ Problem
   - How costly is the problem?
     • 5-12% of Revenue

3. Problem #2: Too Little On-hand Inventory
   - The ‘Sourcing’ Problem
   - How costly is the problem?
     • 1% of Revenue
1. Tree Fruit Supply Chain

Growers → Storage and Packers → Distributors → Retailers → You

(Sales and Marketers)

Raw Material Storage → Finished Goods Storage

Grower

Packing Facility

Processing Facility

Retailer

You
1. Tree Fruit Supply Chain

(Sales and Marketers)

Growers → Storage and Packers → Distributors → Retailers → You

- Raw Material Storage
- Finished Goods Storage
- Packing Facility
- Processing Facility
- Grower
- Retailer
- You
2. The Big Pile, Small Pile Problem

1. Fruit is not sorted by SKU while in storage.
2. Retailers seek SKU uniformity, and prefer the ‘Big Pile.’
## Multivariate Regression Results

<table>
<thead>
<tr>
<th></th>
<th>Apple Model</th>
<th>Pearson Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusted R²</td>
<td>0.692</td>
<td>0.766</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Significance</th>
<th>Coefficient</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Price</td>
<td>$17.74</td>
<td>0.000</td>
<td>$21.05</td>
<td>0.000</td>
</tr>
<tr>
<td>Fruit Age</td>
<td>($0.04)</td>
<td>0.000</td>
<td>($0.01)</td>
<td>0.000</td>
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<tr>
<td>Shipment Size</td>
<td>($0.00)</td>
<td>0.000</td>
<td>($0.00)</td>
<td>0.000</td>
</tr>
<tr>
<td>Destination</td>
<td>($1.50)</td>
<td>0.000</td>
<td>($1.51)</td>
<td>0.000</td>
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<tr>
<td>Large Customer</td>
<td>($0.05)</td>
<td>0.005</td>
<td>$0.94</td>
<td>0.000</td>
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<tr>
<td>Medium Customer</td>
<td>$1.20</td>
<td>0.000</td>
<td>$1.20</td>
<td>0.000</td>
</tr>
<tr>
<td>Quarter 1</td>
<td>($0.80)</td>
<td>0.000</td>
<td>$0.10</td>
<td>0.032</td>
</tr>
<tr>
<td>Quarter 2</td>
<td>$0.83</td>
<td>0.000</td>
<td>($0.31)</td>
<td>0.000</td>
</tr>
<tr>
<td>Quarter 3</td>
<td>$2.64</td>
<td>0.000</td>
<td>$1.48</td>
<td>0.000</td>
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<tr>
<td>2006</td>
<td>$2.06</td>
<td>0.000</td>
<td>$2.63</td>
<td>0.000</td>
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<td>2007</td>
<td>$2.68</td>
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<td>$1.85</td>
<td>0.000</td>
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<td>2008</td>
<td>$4.28</td>
<td>0.000</td>
<td>$2.01</td>
<td>0.000</td>
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<tr>
<td>Size Small</td>
<td>($5.05)</td>
<td>0.000</td>
<td>($5.85)</td>
<td>0.000</td>
</tr>
<tr>
<td>Size Large</td>
<td>$2.38</td>
<td>0.000</td>
<td>$2.17</td>
<td>0.000</td>
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<tr>
<td>Size XL</td>
<td>$2.51</td>
<td>0.000</td>
<td>$5.49</td>
<td>0.000</td>
</tr>
<tr>
<td>Size Specialty</td>
<td>$10.59</td>
<td>0.000</td>
<td>$12.09</td>
<td>0.000</td>
</tr>
<tr>
<td>Grade (20)</td>
<td>-10 to +17</td>
<td>0.000</td>
<td>-9 to +6</td>
<td>0.000</td>
</tr>
<tr>
<td>Variety (99)</td>
<td>-6 to +43</td>
<td>0.000</td>
<td>-8 to +30</td>
<td>0.000</td>
</tr>
</tbody>
</table>
2a. How Costly is the Problem?

Expected Revenue and Costs

\[ y = -0.04x + 17.74 \]

- **Expected Sale Price**
- **Expected Cost of Repack**
- **Expected Cost of Rejection**
2a. How Costly is the Problem?

Industry Efficiency = \frac{\text{Adjusted Revenue}^* \times \text{Percentage of Boxes Sold}}{\text{Full Revenue}^* \times \text{Percentage of Boxes Sold}} = 88-95%
2b. It’s a Big Problem, So Now What?

Four Ways to Improve the Shrinkage Problem

1. Improve Visibility of Packing
   • Pre-sort Inventory
   • Reduce the number of Stock-keeping units (SKUs) available

2. Improve Visibility of Demand
   • Use point-of-sales (POS) data from retailer to improve forecasting
   • Establish vendor-managed inventory (VMI) relationship

3. Improve visibility of on-hand inventory to Buyers
   • Establish an e-Commerce platform

4. Shape Customer Demand through Pricing
   • Use Adjusted Revenue Curve
3. The Sourcing Problem

• In the event of a stock-out, Sales Managers have four possible decisions:

1. Move: Intra-shed Transfer
2. Buy: Inter-shed Purchase
3. Make: Emergency Production
4. Reject: Cancel Order
3a. Managing Stock-outs

- How often do Stock-outs occur?
- What choices do manager currently make?
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- How often do Stock-outs occur?
- What choices do manager currently make?

**Average Stock-out Rate = 7.5%**
1. Define Decision Variables
   - What SKU?
   - How many boxes?
   - From where should I source?
   - Where do I consolidate?
   - What mode should I use?

2. Define Objective Function
   - Cost of Intra-Shed Transfer = Transportation + Labor + Inventory Costs
   - Minimize $\sum a_{ijk}(b_{ijk}-c_i d_{ijk}) + e_j f_j + g_k h_k + I_{ijk} m_{ijk} + n_{ijk} o_{ijk}$

3. Define Constraints
   - Demand- How many boxes are needed?
   - Capacity- How many trucks/trailers are available?
   - Inventory- What is on-hand inventory at each warehouse?
Minimize: $\sum_{ijk} a_{ijk}(b_{ijk} - c_i d_{ijk}) + e_j f_j + g_k h_k + l_{ijk} m_{ijk} + n_{ijk} o_{ijk} + \varepsilon$

Subject to the following constraints:

- $\sum\sum_{ijk} a_{ijk} = q_i$
- $\sum_{ijk} a_{ijk} \leq r_{ij}$ for all $j$
- $\sum_{ijk} a_{ijk} - p_1 e_j \leq 0$ for all $j$
- $\sum_{ijk} a_{ijk} - p_2 y_{ik} \leq 0$ for all $k$
- $\sum g_k \leq 1$
- $\sum l_{ijk} \leq s_{ijk}$ for all $j$
- $\sum n_{ijk} \leq t_{ijk}$ for all $j$
- $\sum_{ijk} a_{ijk} - p_3 l_{ijk} - p_4 n_{ijk} \leq 0$ for all $j$

$b, c, f, h, m, o =$ continuous

$e, g =$ binary

$a, d, i, j, k, l, n, q, r, s, t =$ integer

Where: $a$ through $z \geq 0$

Average cost per box = $0.75 - 1.00$
3c. It’s a Small Problem, So Now What?

![Graph showing percentages of all sales for different types of transactions.](image)

- **Intra-Shed Transfer**: Average Transfer Cost = 4-6% of Full Value
- **Inter-Shed Purchase**: Average Purchase Premium = 8% of Full Value

- **Emergency Production**
- **Cancel Order**
### Sales Organization Interface

<table>
<thead>
<tr>
<th>Stock Keeping Unit (i.e. P.ORA.WFC.042.X2AL.CP.K.X.X.X.83916)</th>
<th>P.ORA.WFC.042.X2AL.CP.K.X.X.X.83916</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Boxes Ordered</strong> (i.e. 30 or 131 or 1070)</td>
<td>399</td>
</tr>
<tr>
<td><strong>Maximum Pickup Locations Allowed</strong> (i.e. 1 or 2 or 3)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Diesel Price ($/gallon)</strong> (i.e. 2.14)</td>
<td>2.25</td>
</tr>
<tr>
<td><strong>Total Cost of this Transfer</strong> (don’t enter anything here, cost will be entered for you)</td>
<td>$604.05</td>
</tr>
</tbody>
</table>

### Instructions

Move **250** boxes from **Apple-House** to **Silverstone** using **1** trailer.

Move **29** boxes from **Greenlake** to **Silverstone** using **1** trailer.

**Silverstone** has **120** boxes of inventory on-hand.

The retailer pickup location is **Silverstone**.
Recommendations and Expected Results

1. Implement Policies to Reduce On-hand Inventory
   - Pre-sorting of Raw Material Inventory, SKU Reduction
   - Establish VMI relationship or get POS data from buyer
   - Establish e-Commerce model and shape demand via pricing

2. Use optimization model to find low-cost sourcing decision
   - No major firms in the industry use optimization software

The tree fruit industry in Washington State has revenues of over $2 billion. The current costs of shrinkage and stock-outs range from 6-13% of revenue, or $120 – 260 million.