Modeling Order Guidelines to Improve Truckload Utilization

Authors: Jaya Banik & Kyle Rinehart
Advisor: Dr. Jarrod Goentzel

MIT SCM ResearchFest
May 24-25, 2011

Agenda

Motivation, background, & research focus

Findings:
• Critique of floor position as a viable metric
• How to mix trucks better with linear programming
• How to mix better with SKU categorization
Motivation

Overall freight vehicle efficiency: 43%

Source: World Economic Forum 2009

Background

Areas that impact truckload efficiency

**Volume Efficiency**
- Formula design
- Packaging

**Fill Optimization**
- Cube efficiency
- Weight efficiency

**Transport**
- Route
- Vehicle type
- Driving efficiency
Research Focus

Order Fulfillment Process

Order Promising
- Check product availability
- Schedule delivery

Warehousing
- Pick items
- Assemble items
- Package items

Transportation
- Ship products
- Deliver orders
- Customer pickup

Source: An and Srethapakdi, 2006

Floor position: chi-square independence test

- **Null hypothesis**: independence

<table>
<thead>
<tr>
<th>Expected Counts</th>
<th>Does not hit FP</th>
<th>Hits FP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does not hit volume</td>
<td>383</td>
<td>568</td>
</tr>
<tr>
<td>Hits volume</td>
<td>413</td>
<td>614</td>
</tr>
</tbody>
</table>

- **Reality**

<table>
<thead>
<tr>
<th>Actual Counts</th>
<th>Does not hit FP</th>
<th>Hits FP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does not hit volume</td>
<td>761</td>
<td>190</td>
</tr>
<tr>
<td>Hits volume</td>
<td>35</td>
<td>992</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Volume</th>
<th>FP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt; 98%</td>
<td>&lt;= 29</td>
</tr>
<tr>
<td>1</td>
<td>&gt;= 98%</td>
<td>&gt; 29</td>
</tr>
</tbody>
</table>
Floor position: test results

- **Further evidence**: .69 correlation

- **Results**: p-value of < 0.0001
  - Investigate further and examine anomalies

How to mix trucks: an example

- **Example**: 4 shipments from location A to location B

- **Objective**: to sequentially maximize weight
  - $4 \times Weight_{truck_1} + 3 \times Weight_{truck_2} + \cdots$

- **Variables**:
  - where to place each line/SKU on each truck

- **Constraints**:
  - 45,000 lbs/truck
  - 3750 vol./truck
  - Each order line placed in only one truck
How to mix trucks: results

• Actual shipment:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>85%</td>
<td>35%</td>
<td>35%</td>
<td>99%</td>
</tr>
<tr>
<td>Volume</td>
<td>100%</td>
<td>99%</td>
<td>18%</td>
<td>81%</td>
</tr>
<tr>
<td>Floor position</td>
<td>100%</td>
<td>99%</td>
<td>18%</td>
<td>81%</td>
</tr>
</tbody>
</table>

• Our model:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>100%</td>
<td>85%</td>
<td>69%</td>
<td>0%</td>
</tr>
<tr>
<td>Volume</td>
<td>98%</td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Floor position</td>
<td>98%</td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
</tr>
</tbody>
</table>

SKU categorization

Pallet density spread around the optimal density
SKU categorization: utilization statistics

Average truck utilization for different types of SKUs

SKU categorization: mixing guidelines

- Mix cube-constrained with weight-constrained
- Mix neutral SKUs with same category and weight-constrained

<table>
<thead>
<tr>
<th>Primary category ordered</th>
<th>Mixing category</th>
<th>Density Utilization</th>
<th>Deviation from Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cube-constrained 4.85 30</td>
<td>Weight-constrained 24.85 20</td>
<td>10.71</td>
<td>-0.24</td>
</tr>
<tr>
<td>Neutral 10.8 30</td>
<td>Neutral 10.8 30</td>
<td>10.80</td>
<td>-0.14</td>
</tr>
<tr>
<td>Neutral 10.8 30</td>
<td>Weight-constrained 24.85 13</td>
<td>10.78</td>
<td>-0.16</td>
</tr>
<tr>
<td>Weight-constrained 24.85 20</td>
<td>Cube-constrained 4.85 30</td>
<td>10.71</td>
<td>-0.24</td>
</tr>
<tr>
<td>Weight-constrained 24.85 20</td>
<td>Neutral 10.8 14</td>
<td>10.80</td>
<td>-0.14</td>
</tr>
</tbody>
</table>
SKU categorization: recommendations

- Profile customers’ annual demand patterns and look for opportunities to mix better with categorization
- Combine small SKU set customers with other customers, geographically, to fill in utilization gaps

Modeling Order Guidelines to Improve Truckload Utilization

Authors: Jaya Banik & Kyle Rinehart
Advisor: Dr. Jarrod Goentzel