KPI-driven Supply Chain Optimization

Cost Optimization Model for an Online Grocery Retailer

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Status Quo
In online retail there are two types of orders along the supply chain
Those two orders are connected through a path of supply chain steps.

- Order
- Arrival
- Replenishment
- Picking
- Delivery
The Challenge
High availability is a major aim for online grocery retailers...
Concurrently they have to keep an eye on the stock level
Online grocery retailers need to balance between two opposite trends:

- **High availability of products** (Overstocking)
  - High storage level

- **Short storage time & little spoilage** (Understocking)
  - Low storage level

High storage level implies overstocking, while low storage level implies understocking.
The demand forecast can be a helpful tool in this dilemma
Mathematical Problem
The situation can be mathematically described in a convex cost function

\[ C(q) = c_U \cdot \mathbb{E} \left( \max(D - q, 0) \right) + c_O \cdot \mathbb{E} \left( \max(q - D, 0) \right) \]

- Understocking
- Overstocking

\( D \): stochastic demand
\( q \): order quantity/stock quantity
For symmetric cost factors the demand forecast matches the optimal solution...
... but for asymmetric cost factors, the demand distribution is required.

Continuous distribution:

\[ q^* = F^{-1}\left(\frac{c_u}{c_u + c_o}\right) \]

Discrete distribution:

\[ F(q^*) \geq \frac{c_u}{c_u + c_o} \]
The Model
The order quantity depends on both the lead time and the delivery period.
There are many parameters that affect the stock order

<table>
<thead>
<tr>
<th>Cost Parameters</th>
<th>Delivery Parameters</th>
<th>Product Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Overstocking costs</td>
<td>• Length of delivery period</td>
<td>• Stocking unit</td>
</tr>
<tr>
<td>• Understocking costs</td>
<td>• Duration of lead time</td>
<td>• Best before date</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Initial stock</td>
</tr>
</tbody>
</table>
We feed our model with parameters and obtain results which can be evaluated with KPIs.
We measure the quality of our model with contrary KPIs representing the two opposite trends.

<table>
<thead>
<tr>
<th>Understocking</th>
<th>Overstocking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-availability rate</td>
<td></td>
</tr>
</tbody>
</table>
| NAR = \[
\frac{\text{# not available items}}{\text{# demanded items}}
\] |
| Spoilage rate |
| SR = \[
\frac{\text{# spoiled items}}{\text{# stocked items}}
\] |
Optimization of Cost Parameters
The exact values of the cost factors are often unknown or can only be approximated...

\[ c_U = 5 \]
\[ c_O = 2 \]

\[ c_U = \text{price} \]
\[ c_O = \frac{\text{price}}{\text{expiry date}} \]
... but it’s often easier to define a relation of the costs parameters
Taking a closer look on the interaction of the KPIs can help to define the optimal KPI relation.

Non-availability versus spoilage rate

Overstocking costs
Results
Both the non-availability rate and the spoilage rate end up below one percent.
Outlook
This model can be applied to all problems which can be explained in a convex cost function

\[ C(q) = c_U \cdot \mathbb{E} \left( \max(D - q, 0) \right) + c_O \cdot \mathbb{E} \left( \max(q - D, 0) \right) \]
Another example could be pricing where the vendor wants to find the optimal price to offer considering what the customer is willing to pay.

- If the offered price is lower than what the customer is willing to pay, the vendor loses the difference.
- If the offered price is higher than what the customer is willing to pay, the customer might refuse and the vendor earns nothing.
Model Extension
Sometimes unavailable items can be substituted by a similar product.
Substitution introduces an additional cost parameter to the cost function

\[
C(q_1, q_2) = c_1^U * \mathbb{E} \left[ (D_1 - (q_1 + (D_2 - q_2)))^+ \right] \\
+ c_1^\ddagger * \mathbb{E} \left[ (q_1 - (D_1 + (q_2 - D_2)))^+ \right] \\
+ c_2^U * \mathbb{E} \left[ (D_2 - (q_2 + (D_1 - q_1)))^+ \right] \\
+ c_2^\ddagger * \mathbb{E} \left[ (q_2 - (D_2 + (q_1 - D_1)))^+ \right] \\
+ c_{12}^S * \mathbb{E} \left( (\min(D_1 - q_1, q_2 - D_2))^+ \right) \\
+ c_{21}^S * \mathbb{E} \left( (\min(q_1 - D_1, D_2 - q_2))^+ \right)
\]
This phenomenon increases the complexity of the cost function a lot.
The parameter optimization approach can also be applied in extensions of our cost optimization model.
Further Research
The parameter optimization approach could also be generalized to other scenarios where parameters are unknown or need to be optimized.
Vielen Dank

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