Optimal Multi-Temperature Delivery Frequency for Small Format Stores

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Topic Area: Transportation, Optimization

Summary: This research compares the cost and frequency of delivery for different delivery policy options to help a large retailer identify the most suitable delivery policy for small format stores. We analyzed four delivery policies: Single Stop-Single Temperature, Single Stop-Multi Temperature, Multi Stop-Single Temperature, and Multi Stop-Multi Temperature. The analysis also considers several other scenarios, providing insights that can be extended beyond the current stores and geography. In general, it reveals that the use of Multi-Temperature trailers can provide significant cost and operational advantages for deliveries to small format stores.

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KEY INSIGHTS

1. For small format retail stores, the use of multi-temperature trailers for deliveries can provide significant cost and operational advantages over single temperature trailers.

2. The size of demand and the distance from a distribution center to stores can hugely influence delivery policies such as the number of stops, a trailer type, and delivery frequency.

3. Targeted service level also has a big impact on delivery policy selection for small format stores whose demand volume is relatively smaller because the higher service level can decrease truck utilization rate and increase transportation cost significantly.

Introduction

Distribution optimization has been playing an increasingly more important role in helping retail companies differentiate themselves against the competition in the past decade. Meanwhile, changes in demographic trends, slower growth in existing segments, and an opportunity to leverage their current presence have motivated retail companies to venture into more densely populated areas with small format stores. This requires additional skills to compete.

For this research, we worked with RetailCo, a global retailer that features in the Fortune 500. RetailCo expects a significant part of its future growth to come from small format stores which have a much greater focus on grocery products than the large format stores. However, currently grocery deliveries to the small format stores are done in exactly the same way as for the large stores. This research examines ways to make the delivery process to small format stores more efficient, thereby reducing total cost while maintaining or improving service levels.
Data and Methodology

The main purpose of the analysis is to evaluate costs between current delivery practice and new delivery strategy spanning trailer type, delivery frequency, and product mix. There are two critical variables in our model that together define the various options available to RetailCo while delivering to small format stores: 1) type of trailer: whether single temperature or multi-temperature trailer and 2) number of stops: whether single or multiple. In order to structure our analysis, we organized these options into a matrix (Figure 1), where one axis is type of trailer and the other is the number of stops. The first part of our overall analysis focuses on assessing the four different policies in this matrix by utilizing historical sales and delivery data and determining which policy is most cost-effective. The second part of our analysis is the usage of optimization modeling and simulation on the selected scenarios for further examining feasibility and developing a generic framework for delivery to small format stores.

![Figure 1: Cost Matrix](image)

We analyzed sales and shipment data during three months (March, June, and September) of 2014 for a distribution center (DC) and nine small format stores and located in Oklahoma. Building the base scenario with actual demand data, we also generated several basic assumptions for our analysis such as transportation cost per mile by trailer type, stoppage cost, annual holding cost rate, product value per pallet by product type, and required service level of minimum 4 deliveries per week with consent of RetailCo. For the analysis, we modified RetailCo’s product categorization and re-categorized products into three new categories: Ambient (A) – products requiring ambient temperature trailer, Refrigerated (R) – products requiring 32F degree temperature trailer, Frozen (F) – products requiring -20F degree temperature trailer.

1. Assessment of Four Policies

Based on the cost matrix, we built four policies as follows:

(1) Single Stop Single Temperature (SSST): A single temperature trailer delivers one category of product to only one store per trip.
(2) Single Stop Multi Temperature (SSMT): A multi temperature trailer delivers three categories of products to only one store per trip.
(3) Multi Stop Single Temperature (MSST): A single temperature trailer delivers one category of product to more than one store per trip.
(4) Multi Stop Multi Temperature (MSMT): A multi temperature trailer delivers three categories of products to more than one store per trip.

Then, we compared costs of each policy to identify the most cost efficient option. Total cost comprises cost of transportation, stop cost and inventory holding cost. Because the usage of single or multiple temperature trailers is not expected to impact the in-store labor requirement, we have not included labor cost in our analysis.

Once the cost of each policy was calculated, we also could find out truck utilization rate and delivery frequency based on pallets delivered, total delivery trips per week, and associated number of trailers. Even if any policy provides the lowest cost, it may not be selected as an optimal option depending on whether it violates RetailCo’s current operational policy such as minimum deliveries per week or not.

2. Optimization Modeling and Simulations

For the SSST and SSMT cases, this is fairly simple, as a truck delivers to just one store and the results can be computed using spreadsheet modeling. In case of MSST and MSMT options, however, this calculation is complicated due to the large number of possible routes. To identify the combination of route, delivery frequency and delivery quantity that minimizes overall cost for MSST and MSMT, we
have used an optimization model formulated and developed by Atikhun Unahalekhaka
Unahalekhaka defines the main components of the model as follows:

- **Commodity** is defined as consisting of two components: (store, product type). Each product type is characterized solely by the required temperature (Ambient, Refrigerated, Frozen).
- **A route** is defined as a sequence of stops. For example, “DC-store1-store2-DC” is an example of a route.
- **The model** considers 7 fleet types: single temperature fleet for the three temperatures (Ambient, Refrigerated, Frozen), 3 combinations of double-temperature fleet, and a triple-temperature fleet that accommodates all three temperatures.

The optimization model seeks to identify the optimal combination of commodity, route and fleet type that minimizes the overall cost. In its current form, the model incorporates constraints with respect to trailer capacity and fleet size and can additionally include constraints with respect to storage available in the stores by product type.

**Result**

We tested the base case, which was built with actual average demand and distance between the DC and the stores. Then, four other scenarios were examined to provide insights that can be extended beyond the current stores and geography.

1. **Base Scenario**

Figure 2 presents the results of the four policies for the base scenario.

Even though SSST, SSMT, and MSMT showed relatively similar level of cost per pallet, MSMT policy is favorable as its utilization rate and delivery frequency are higher than those of other policies.

2. **Sensitivity Analysis**

To better understand which factors influence the policy selection, a sensitivity analysis was conducted with different assumptions. The tested scenarios were ‘doubled demand’, ‘doubled distance between DC and stores’, ‘7-day delivery for each product category’ and ‘half demand’. Demand changes for the first scenario and the fourth scenario aimed at reflecting situations where the volume of demands is significantly different from the stores we tested. Since we examined the stores in the state of Oklahoma and RetailCo indicated that demands of those 9 stores do not represent a typical demand volume, this approach expands adoptability of our model to other regions.

The second scenario of doubled distance also reflects practice considerations. The distance between the DC and the store we tested is on average 60 miles, but some regions have longer distance. The linehaul and backhaul distances are important elements to determine total transportation costs which accounts for the biggest portion of total logistics costs. This scenario enabled us to verify how the policy changes in a practice context.

Finally, each store desires to achieve a better service level, which is determined by delivery frequency. Therefore, testing a 7-day delivery policy helps us draw connections between higher frequency and cost.

Table 1 summarizes the results of the analysis. In terms of cost per pallet, the MSMT policy provides the lowest costs for all except the doubled demand scenario. In the scenario of doubled demand, the current policy of using MSST is slightly cheaper. The SSMT is another option that seems attractive for almost all scenarios except the doubled demand case.
Table 1: Summary of Analysis by Scenario

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Policy</th>
<th>Cost per Pallet</th>
<th>Truck Utilization Rate</th>
<th>Delivery Frequency per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doubled Demand</td>
<td>SSST</td>
<td>$19</td>
<td>64%</td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td></td>
<td>SSMT</td>
<td>$16</td>
<td>90%</td>
<td>A 10 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td></td>
<td>MSST</td>
<td>$14</td>
<td>92%</td>
<td>A 4.8 / F 4.0 / R 4.3</td>
</tr>
<tr>
<td></td>
<td>MSMT</td>
<td>$15</td>
<td>96%</td>
<td>A 9.9 / F 9.9 / R 9.9</td>
</tr>
<tr>
<td>Doubled Distance</td>
<td>SSST</td>
<td>$69</td>
<td>37%</td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td></td>
<td>SSMT</td>
<td>$31</td>
<td>85%</td>
<td>A 5.2 / F 5.2 / R 5.2</td>
</tr>
<tr>
<td></td>
<td>MSST</td>
<td>$31</td>
<td>80%</td>
<td>A 4.3 / F 4.0 / R 4.4</td>
</tr>
<tr>
<td></td>
<td>MSMT</td>
<td>$29</td>
<td>99%</td>
<td>A 5.9 / F 5.9 / R 5.9</td>
</tr>
<tr>
<td>7-day Delivery</td>
<td>SSST</td>
<td>$65</td>
<td>20%</td>
<td>A 7.0 / F 7.0 / R 7.0</td>
</tr>
<tr>
<td></td>
<td>SSMT</td>
<td>$22</td>
<td>64%</td>
<td>A 7.0 / F 7.0 / R 7.0</td>
</tr>
<tr>
<td></td>
<td>MSST</td>
<td>$27</td>
<td>60%</td>
<td>A 7.0 / F 7.0 / R 7.0</td>
</tr>
<tr>
<td></td>
<td>MSMT</td>
<td>$17</td>
<td>94%</td>
<td>A 7.1 / F 7.1 / R 7.1</td>
</tr>
<tr>
<td>Half Demand</td>
<td>SSST</td>
<td>$69</td>
<td>19%</td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td></td>
<td>SSMT</td>
<td>$25</td>
<td>57%</td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td></td>
<td>MSST</td>
<td>$31</td>
<td>53%</td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td></td>
<td>MSMT</td>
<td>$18</td>
<td>93%</td>
<td>A 4.7 / F 4.7 / R 4.7</td>
</tr>
</tbody>
</table>

For truck utilization rate, we see that MSMT emerges as the option with the highest utilization for all scenarios. The reason why in some cases, a lower utilization in the single temperature delivery may still result in lower cost (as in the doubled demand case where cost per pallet for MSST is lower than MSMT) is that the trailer capacity for single temperature trailers is higher than multi temperature ones. Meanwhile, a higher delivery frequency leads to better service to the stores and is therefore preferred. Again, MSMT emerges as the most attractive scenario with the highest delivery frequency in each scenario except for the doubled demand case where SSMT provides greater number of deliveries a week.

In summary, MSMT seems to offer the lowest cost and best level of service in most cases except the doubled demand case where MSST offers better cost and SSMT offers better quality of service. What needs to be considered is whether the additional complexity of i) having multiple multi-temperature deliveries to a store and ii) a store being delivered in a single stop route and sometimes in a multiple stop route would offset some of the cost benefits over the SSMT option. The cost for MSST may be marginally higher but it also provides the advantage of using just one truck for each store.

**Demand volume:** The volume of daily demand is one of the most critical factors determining the delivery policy. As our analysis proved, daily demand could change the selection of delivery policy significantly. Demand dictates number of stops and stoppage costs change the optimal policy selection. Thus, depending on the volume of daily demand at the stores covered by the DC, the RetailCo has to implement different policies.

**Distance between DC and Stores:** The longer the distance between DC and stores, the more multi-stop is selected. As the longer distance incurs higher costs for the linehaul, our analysis models directed to have more multi-stop per delivery trip.

**Delivery Frequency or Service Level:** For small demand volume stores, higher delivery frequency or higher service level will lead to a significant decline of truck utilization rate unless MSMT policy is selected. Therefore, the promised delivery frequency with stores in a service area will become an important factor in designing delivery policy in that region.

These recommendations would apply in general as RetailCo expands beyond its current locations. To refine our analysis, future research can include constraints such as that of backroom space, incorporate different holdings costs by product category and also include the impact of using drop trailers.

**Conclusions**

Based on the results of the quantitative analysis and the industry research, we offer a few recommendations and suggestions for applying the delivery strategy.