2015 SCM RESEARCH JOURNAL

Summaries of selected research projects by 2015 graduates of the MIT Master of Supply Chain Management Program

The projects included in this journal were selected from the 21 projects submitted by the SCM Class of 2015 at the Massachusetts Institute of Technology. The articles are written as executive summaries of the master’s thesis and are intended for a business rather than an academic audience. The purpose of the executive summaries is to give the reader a sense of the business problems being addressed, the methods used to analyze the problems, the relevant results and insights gained.

The articles included in this publication cover a wide selection of interests, approaches, and industries. These projects were developed in partnership with companies ranging in size from startups to the largest companies in the world. They cover industries as diverse as medical supplies, chemicals, consumer goods, railroads and trucking. They also include humanitarian logistics in Uganda, consumer goods retail promotions, price and performance in trucking, and crowdfunding for Moroccan artisans.

Each of the projects is a joint effort between a sponsoring company, one or two students, and a faculty advisor. Companies who are members of MIT CTL’s Supply Chain Exchange are eligible to submit their ideas for thesis projects in July and August and then present these proposals to the students in early September. In mid-September, the students select which projects they will work on. From September until early May, the teams conduct the research and write up the results. In late May, all sponsors, faculty, and students participate in Research Fest where all the thesis projects are presented.

The 10-month SCM program is designed for early to mid-career professionals who want a more in-depth and focused education in supply chain management, transportation, and logistics. The class size each year is limited to 40 students from around the globe and across all industries. The Master’s Thesis project gives students a hands-on opportunity to put into practice the learnings they receive in their coursework.

We hope you enjoy the articles. The rest of the master’s thesis projects are listed at the end of this journal. You can also view all of the executive summaries on the CTL website at: http://ctl.mit.edu/pubs. If you would like to learn more about the SCM Master’s Program or sponsor a thesis please contact us directly.

Happy reading!

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Optimal Multi-Temperature Delivery Frequency for Small Format Stores

By: Mayurpankhi Barooah and Seung Hwan Shin  
Thesis Advisors: Dr. Chris Caplice, Dr. Francisco Jauffred, Dr. Edgar Blanco

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.

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 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.

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.

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 if 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. For MSST and MSMT options, however, this calculation is complicated by 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 char-
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.

**Results**

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.

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 SSMT may be marginally higher but it also provides the advantage of using just one truck for each store.

### 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.

**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 back-room space, incorporate different holdings costs by product category and also include the impact of using drop trailers.

### 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><strong>Doubled Demand</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSST</td>
<td>$19</td>
<td>64%</td>
<td></td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td>SSMT</td>
<td>$16</td>
<td>90%</td>
<td></td>
<td>A 10 / F 10 / R 10</td>
</tr>
<tr>
<td>MSST</td>
<td>$14</td>
<td>92%</td>
<td></td>
<td>A 4.6 / F 4.0 / R 4.3</td>
</tr>
<tr>
<td>MSMT</td>
<td>$15</td>
<td>96%</td>
<td></td>
<td>A 9.9 / F 9.9 / R 9.9</td>
</tr>
<tr>
<td><strong>Doubled Distance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSST</td>
<td>$99</td>
<td>37%</td>
<td></td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td>SSMT</td>
<td>$31</td>
<td>85%</td>
<td></td>
<td>A 5.2 / F 5.2 / R 5.2</td>
</tr>
<tr>
<td>MSST</td>
<td>$31</td>
<td>60%</td>
<td></td>
<td>A 4.3 / F 4.0 / R 4.4</td>
</tr>
<tr>
<td>MSMT</td>
<td>$29</td>
<td>99%</td>
<td></td>
<td>A 5.9 / F 5.9 / R 5.9</td>
</tr>
<tr>
<td><strong>7-day Delivery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSST</td>
<td>$95</td>
<td>20%</td>
<td></td>
<td>A 7.0 / F 7.0 / R 7.0</td>
</tr>
<tr>
<td>SSMT</td>
<td>$22</td>
<td>64%</td>
<td></td>
<td>A 7.0 / F 7.0 / R 7.0</td>
</tr>
<tr>
<td>MSST</td>
<td>$27</td>
<td>60%</td>
<td></td>
<td>A 7.0 / F 7.0 / R 7.0</td>
</tr>
<tr>
<td>MSMT</td>
<td>$17</td>
<td>94%</td>
<td></td>
<td>A 7.1 / F 7.1 / R 7.1</td>
</tr>
<tr>
<td><strong>Half Demand</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSST</td>
<td>$99</td>
<td>19%</td>
<td></td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td>SSMT</td>
<td>$25</td>
<td>57%</td>
<td></td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td>MSST</td>
<td>$31</td>
<td>53%</td>
<td></td>
<td>A 4.0 / F 4.0 / R 4.0</td>
</tr>
<tr>
<td>MSMT</td>
<td>$18</td>
<td>93%</td>
<td></td>
<td>A 4.7 / F 4.7 / R 4.7</td>
</tr>
</tbody>
</table>
Introduction

Optimization models are a commonly used tool to identify cost efficient network flows. Complexity increases when various products move across different paths and transportation modes within one network.

To address the challenges posed by this complexity, we developed a mixed integer linear programming model for a uniform rental company. Some product families are routed through intermediary distribution centers, while others bypass these points and move directly to a regional distribution center (DC). Various simulations were run with the objective of minimizing fixed costs, warehousing, inventory and transportation expenses.

Data and Methodology

We worked with a uniform rental company that operates and distributes in the United States. We first learned about their current network structure and product families. With this information, we created a miniature model for each of the two types of network flows. The first flow, seen in Figure 1, moved directly from supplier to DC to customer region, and accounted for four of the eight product families included in the model.

The second flow, seen in Figure 2, traveled from the supplier to an intermediary distribution center (IDC) to the regional DC to the customer, and accounted for the other four product families.

Once the miniature models had been finalized, we created a larger model that incorporated both of the IDC and the non-IDC network structures.

The model was created using historical supply and demand figures from the past year. The three main categories of data required were DC costs, transportation costs, and network flow and capacity.

KEY INSIGHTS

1. Transportation rates were greatly influential. Locating closer to the supplier base yielded the highest savings.
2. As demand increased proportionately across products and customers, DCs with a combination of the lowest variable costs and the lowest transportation costs were most desirable.
3. Accurate DC cost information is vital for achieving an optimal result. High opening or closing costs that are not allocated over time may not yield the optimal solution in a single period model.

Summary: This project develops an optimization model for product families that flow through the network on various paths and use different modes of transportation. Certain rental garments products flowed through intermediary distribution centers while others bypassed this stage and moved directly to regional distribution centers. The initial model results were compared with multiple demand-related iterations to identify appropriate long-term recommendations for the company. The model scenarios tested showed that the results depended highly on demand growth and transportation rates.

Distribution Network Optimization in the Uniform Rental Industry

By: Ann-Marie Chopyak and Haotian Lee
Thesis Advisor: Dr. Bruce Arntzen

Before coming to MIT, Ann-Marie graduated in Business Administration from the Boston University School of Management. She then worked for L’Oreal USA in logistics and demand planning.

Before coming to MIT, Haotian Lee graduated in Business Administration from The University of Texas at Austin. He then worked for Deloitte Consulting for three years.
1. **DC Costs:** The company’s finance team provided detailed cost estimates for DC variable and fixed costs. They also provided the costs associated with closing and expanding current DCs and opening new DCs in various regions around the country.

2. **Transportation Costs:** The company’s transportation team worked with their largest carriers to obtain lane rate information for the new and existing lanes. All rates were based off of any corporate discounts and historical volume that would potentially move along the new lane.

3. **Network Flow and Capacity:** The company’s thesis sponsor team grouped suppliers into three main regions and customers into 17 regions. Historical volume was then calculated for each region. Additionally, the sponsor team worked with the DC managers to analyze annual flow through each DC. All of the product family flow data, for the DCs, supplier regions, and demand regions was then converted into a standard capacity unit to be able to measure the total flow with a standardized unit.
Results

We focused our analysis on how the costs and demand impacted the model’s results.

1. Costs

Many of the DC opening, and closing costs were quite high. Therefore, for the single-period model to suggest something different from the network’s current structure, it would have to find savings exceeding, in some cases, $6 million. For this reason, we allocated these expenses over a five year period. By doing so, the model did suggest shifting volume and closing some locations while opening others. This solution is more appropriate for the company as it reflects long term savings realized by the new optimized layout. Transportation costs proved just as critical to the model’s outcome. In many cases, an IDC and DC closest to the largest supplier region was opened. Though this DC’s costs were not as low as some, the transportation savings from being located right next to the largest supplier port outweighed the variable cost savings.

2. Demand

For two iterations, run off of the five year cost analysis, we increased demand across all regions and product families by 10% and 20%. The 10% increase made few changes to the network, aside from expanding one of the company’s current DCs. However, the 20% growth showed a dramatic shift in favor of lower variable costs. The model consolidated volume into fewer DCs, and heavily utilized the DC with the lowest variable cost, which it had closed in every previous iteration.

This is an extremely important takeaway that challenges the company to consider its growth projections before making any changes to its current network. What was best for 10% growth, which the company is currently achieving, is not best once it reaches an additional 10%. The model iteration results for the five year cost allocation and demand increases can be found in Table 1.

In all of the iteration results, one theme was prevalent: the importance of accurate financial and capacity figures. The model was very sensitive to the re-allocation of the opening

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Table 1: Model Results. IDC and DCs share one total volume, and volume can move ‘over the wall’ from the IDC to DC. Duplicate volume was removed from the model capacity constraint, but it is shown here.

<table>
<thead>
<tr>
<th>Location</th>
<th>IDC/DC</th>
<th>Existing, New, or Expansion</th>
<th>Capacity</th>
<th>Finance Model**</th>
<th>5 Year Costs</th>
<th>SYC 110% Demand</th>
<th>SYC 120% Demand</th>
<th>No Fixed, Open, Close, Expand Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashland</td>
<td>DC</td>
<td>Existing</td>
<td>2,550,000</td>
<td>2,550,000</td>
<td>2,205,107</td>
<td>2,481,742</td>
<td>2,560,000</td>
<td>814,092</td>
</tr>
<tr>
<td>Mason</td>
<td>DC</td>
<td>Existing</td>
<td>2,390,625</td>
<td>53,857</td>
<td>-</td>
<td>-</td>
<td>2,200,253</td>
<td>-</td>
</tr>
<tr>
<td>Scranton</td>
<td>DC</td>
<td>Existing</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
</tr>
<tr>
<td>Scranton</td>
<td>DC</td>
<td>Expansion</td>
<td>318,750</td>
<td>-</td>
<td>318,750</td>
<td>-</td>
<td>318,750</td>
<td>-</td>
</tr>
<tr>
<td>Dallas</td>
<td>DC</td>
<td>Existing</td>
<td>3,825,000</td>
<td>3,825,000</td>
<td>3,825,000</td>
<td>3,825,000</td>
<td>3,825,000</td>
<td>3,825,000</td>
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<tr>
<td>Montgomery</td>
<td>DC</td>
<td>Existing</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
</tr>
<tr>
<td>Reno</td>
<td>DC</td>
<td>Existing</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
<td>478,125</td>
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</tr>
<tr>
<td>Reno</td>
<td>DC</td>
<td>Expansion</td>
<td>318,750</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Toronto</td>
<td>DC</td>
<td>Existing</td>
<td>478,125</td>
<td>478,125</td>
<td>-</td>
<td>478,125</td>
<td>-</td>
<td>478,125</td>
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<tr>
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<td>DC</td>
<td>New</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>161,062</td>
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<td>New</td>
<td>478,125</td>
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<td>DC</td>
<td>New</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>Charlotte</td>
<td>DC</td>
<td>New</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Seattle</td>
<td>DC</td>
<td>New</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>29,837</td>
</tr>
<tr>
<td>Louisville</td>
<td>DC</td>
<td>New</td>
<td>478,125</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>355,011</td>
</tr>
<tr>
<td>Memphis</td>
<td>IDC</td>
<td>New</td>
<td>see Memphis</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>478,125</td>
<td>-</td>
</tr>
<tr>
<td>Miami</td>
<td>IDC</td>
<td>New</td>
<td>see Miami DC</td>
<td>-</td>
<td>478,125</td>
<td>478,125</td>
<td>454,110</td>
<td>478,125</td>
</tr>
<tr>
<td>Ashland</td>
<td>IDC</td>
<td>Existing</td>
<td>see Ashland</td>
<td>-</td>
<td>1,623,868</td>
<td>1,145,743</td>
<td>1,308,129</td>
<td>1,470,516</td>
</tr>
</tbody>
</table>
| **Closing costs allocated over five years**
| **The model run for the finance team assumed all DC costs were realized in year one. Thereby, the financial results cannot be compared with those run against the five year disbursements**
and closing costs, and variable costs proved critical to the network needed to support additional demand. The model is also constrained by the flow through the DCs and IDCs, so any variance could easily shift the ultimate outcome.

Conclusions

The models we developed in this research illustrate the importance of using optimization models to evaluate the best network for a company and its future growth projections. By carefully identifying costs and capacity, a company can evaluate its current network and plan for how to best support future network growth.

Our model had certain limitations due to the current company's business processes. However, removing these limitations would allow the model to generate greater savings and more optimal solutions, and should be considered if within a company's scope.

First, our network mandated that four product families move through the IDC. By removing this constraint, the model would likely bypass the IDC as it is simply incurring additional costs. The IDC could potentially generate savings if load consolidation and mode switching was permitted, which is another limitation on our model. Extensive savings could be realized by cross docking, pooling, or any form of load consolidation and mode switching.

Additional demand, supply, and growth consideration should also be taken when designing the model. If growth is projected in one region more than another, then the optimal DC location could potentially shift to a point closer to the growing region.

We believe that our approach best captured the current state of the uniform rental company's current business. It also highlighted the critical factors for consideration in supporting the future of the business. However, further cost and demand analysis is needed to allow the model to reflect the future state of the business and show the optimal model for the company moving forward.
Financing Medicine’s Last Mile in Uganda

By: Charles A. Dokmo and Nipun R. Patel
Thesis Advisor: Dr. Jarrod Goentzel

Summary: We explore how access to capital in the Ugandan private pharmaceutical supply chain affects three aspects of access to medicine—payment affordability, on-shelf availability, and geographic accessibility. We used statistical financial modeling with Monte Carlo simulation to find that retailers’ cash-hoarding behavior may contribute to lower profitability. We proposed a framework for allocating capital to improve availability and used geospatial analysis to identify Ugandan districts with insufficient accessibility to pharmacies and financial services.

Introduction

Experts estimate that more than two billion people below the international poverty line lack adequate access to medicine, challenging to the notion of health as a human right. Access to medicine plays a critical role in sustaining the health of local populations, and inability to access both financing and medicine contributes to a deeply entrenched poverty cycle.

Despite Uganda having a rapidly growing economy, access to medicine in Uganda is still a major challenge. Frequent stockouts of medicines, forecasting and ordering problems, poor inventory management, inadequate transport networks, and a lack of supply chain management expertise are common challenges. Solving these challenges is difficult because of the widespread lack of accurate data.

Compounding these challenges, lending institutions in Uganda have been unwilling to finance health institutions—including pharmaceutical companies—due to, among other things, their lack of business and financial expertise, poor financial record-keeping, and lack of collateral that can easily be reclaimed and liquidated. The Ugandan government has acknowledged that capital constraints within the pharmaceutical supply chain may be a contributing factor to shortages in pharmaceutical supplies.

Scope

The notion of access is multi-dimensional, and we chose to focus our analysis on three components of access to medicine:

1. Payment Affordability: How do customer and supplier payment terms at different levels in the supply chain affect cash flow and profitability for the business and access for the end patient?
2. On-shelf Availability: How should capital be allocated to mitigate the operational uncertainties that negatively affect on-shelf availability?
3. Geographic Accessibility: Which districts in Uganda have...
the least geographic accessibility to medicine and which districts are should be targeted for opening new pharmacy outlets?

Methodology

We researched the private sector pharmaceutical supply chain in Uganda, conducted primary field surveys in-country, analyzed publicly available data, and leveraged statistical modeling, Monte Carlo simulation, and geospatial modeling to explore each of the above components of access to medicine.

(1) Payment Affordability: Profitability-Cash Flow Analysis

Since payment affordability is reflected in customer and supplier payment terms, we modeled cash conversion cycle (CCC), a cash flow metric that includes close proxies to those terms—days payable outstanding (DSO) and days payable outstanding (DPO), against net profitability for eight businesses across three levels of the pharmaceutical supply chain in Uganda.

To calculate CCC, we used supplier payment terms as DPO, average days until a customer paid for an order as DSO, and the average number of days a business could operate without further inflow of new inventory as DIO. Next, we modeled DIO, DSO, and DPO as PERT distributions using estimates for minimum, mode, and maximum collected through primary field research. We used a Monte Carlo simulation to take random samples from each distribution and combine them according to the CCC formula, CCC = DIO + DSO – DPO.

The simulation performed 10,000 iterations of the CCC calculation and aggregated the results in a histogram for each of the eight businesses for which we had complete data sets. We calculated the mean and standard deviation from the sample of 10,000 calculations and plotted the mean and standard deviation against the profitability of each business.

(2) On-Shelf Availability: Operational Uncertainties

For on-shelf availability, we proposed applying principles from operational disruption and Six Sigma literature to address the availability challenges faced by pharmaceutical

Figure 1: Cash Conversion Cycle vs Profitability in Ugandan and US Pharmaceutical Markets
businesses in Uganda. We proposed categorizing operational uncertainties associated with demand and working capital in the Ugandan pharmaceutical supply chain into two categories: low-frequency, high-impact, and high-frequency, low-impact.

According to the literature, low-frequency, high-impact uncertainties should be addressed with a direct capital injection, whereas high-frequency, low-impact uncertainties should be addressed by funding process improvement along the lines of Six Sigma methodology. This framework should help guide decisions to allocate financing to mitigate uncertainties and improve on-shelf availability of medicine for the end patient.

(3) Geographic Accessibility: Pharmacy & Financial Service Density

Calculating ratios of people-to-pharmaceutical outlets and people-to-lending institutions may help indicate regions with lower geographic accessibility to medicine and financing. The availability of relevant geocoded data makes GIS software is ideal for this analysis.

Our analysis leverages GIS and data visualization software to approximate geographic accessibility to medicine and financing by geospatially plotting publicly available district-level pharmacy, population, and financial services data for Uganda.

The data for pharmacies only includes registered pharmacies and does not capture other drug outlets in each district. The financial data included lending services in the informal, semiformal, and formal financial sectors, which improves the robustness of this ratio as an indicator of access to finance.

Analysis

Our research revealed insights for each of the three components of access to medicine.

(1) Payment Affordability: Profitability-Cash Flow Analysis

Figure 1 (on the previous page) depicts profitability versus cash conversion cycle for 10 of the 14 businesses for which we had complete data. There is a clear demarcation in profitability and CCC between distributors, wholesalers and retailers in the Ugandan market. Retailers are conserving cash due to uncertainty in demand. As a result, they are constricting their inventory investment and likely suffering from negative operating profitability. Wholesaler and distributors are more liberal in cash flow management, with a clear correlation to positive operating profitability. Businesses in the US, by contrast, exhibit clustering, likely due to consolidated markets. US retailers also have longer cash cycles and higher net profitability than US distributors.
Although our interviews suggested that while operational disruptions were more pronounced at the retailer level of the pharmaceutical supply chain, stockouts were reported at all levels. Distributors commented that, although infrequent, supply disruptions were primarily caused by lack of supply from manufacturers, suggesting that small production changes at the manufacturer level may have a negative impact in the supply chain in Africa where inventories are not sufficient to buffer that shortage. Wholesalers and retailers commented that product stockout was predominantly caused by unexpected market demand, suggesting the need for better forecasting and/or higher inventory levels to deal with uncertainty.

To allocate financing to address these uncertainties, we propose categorizing uncertainties faced by these businesses as high-frequency/low-impact events (common cause variation) or low-frequency/high-impact events (special cause variation). Applying operational disruption literature, we found that these businesses’ low-frequency, high-impact uncertainties should be addressed with a direct capital injection, whereas their high-frequency, low-impact uncertainties should be addressed by funding process improvement along the lines of Six Sigma methodology. Our framework should help guide decisions to allocate financing to mitigate uncertainties and improve on-shelf availability of medicine for the end patient.

Figure 2 indicates severe shortages in registered pharmacies in the southwestern, central, and northeastern regions. While there are other types of pharmaceutical outlets that are not counted in these data, the dearth of registered pharmacies in these areas may indicate poor geographic accessibility to quality medicine.

Figure 3 shows lending services per person by district in Uganda. The existing network of financial services in the northeastern districts of Uganda suggests those areas may be favorable for opening new retail pharmacies to improve geographic accessibility.

Conclusion

Our analysis yielded three key insights. First, regarding payment affordability, pharmaceutical retailers have better cash positions, but their cash hoarding behavior may actually be negatively impacting their overall profitability. Supply chain training may help retailers learn to carry more inventory and extend customer payment terms in order to drive sales and increase profitability, leading to more sustainable businesses and better access for the end patient.

Secondly, for on-shelf availability, operational uncertainties may be broken into low-frequency, high-impact and
high-frequency, low impact categories. The former category should be addressed with direct capital investments, while the latter benefits most from investments in process improvement along the lines of Six Sigma methodology. This framework helps guide capital allocation decisions to improve on-shelf availability.

Finally, GIS analysis depicted districts of Uganda with inadequate access to registered pharmacies. While substantial portions of Uganda remain underserved by registered pharmacies and capital lending GIS analysis highlighted many districts of Uganda without registered pharmacies—primarily in the northeastern regions. It also revealed that many of those same districts have access to existing loan-granting financial services. While substantial portions of Uganda remain underserved by registered pharmacies, existing financial services in districts without a registered pharmacy suggests those districts are favorable areas for opening new retail pharmacies.

Our analyses provide specific insights for improving access to medicine in Uganda, and hopefully serve as a methodological basis for continued research related to private pharmaceutical supply chains in developing countries.
Relationship between Price and Performance: An Analysis of the US Trucking Market

By: Nane Amiryan and Sharmistha Bhattacharjee
Thesis Advisor: Dr. Chris Caplice

Summary: This research examines the relationship between price and performance in the US trucking market. We analyze whether better performance commands higher price by examining the impact of individual performance parameters: on time pick-up (OTP), on time delivery (OTD) and acceptance ratio (AR). Regression analysis shows that there is a relationship between price and OTD and that there is a relationship between price and shipper loyalty.

Nane Amiryan received her B.A and M.A. in Economics from Yerevan State University, Armenia. Before coming to MIT she worked in a manufacturing company and then in an auto transportation company in Pennsylvania.

Sharmistha Bhattacharjee received a B.E. in Electronics and Telecommunications Engineering and a Post Graduate Diploma in Industrial Management. Prior to the SCM program, she worked for 3 years as Supply Chain Manager with Unilever in India. Upon graduation, she will join Amazon as a Sr. Program Manager.

KEY INSIGHTS
1. Carrier rates increase with improving on time delivery performance until a threshold of 80% in OTD performance is reached after which the prices stabilize.
2. There is a relationship between shipper loyalty and carrier rates. Carrier rates decrease with loyalty on a lane. These price reductions are more prominent in short hauls (< 500 miles) and long hauls (> 1500 miles).
3. Our research could not find a direct relationship between price and AR but we saw a weak relationship between shipper loyalty and AR.

Introduction

Transportation is the lifeblood of the U.S. economy, and over-the-road transportation is its major segment. The economy depends on trucks to move about 70% of all the freight tonnage. As the economy improved in 2013 and 2014, the demand for truckload carriers increased and the shippers started competing for reliable and high performing carriers. Carriers expect to be paid fairly for the quality of their service while shippers want to reap benefits from their loyalty. The objective of our research is to analyze the performance of the carriers and to understand whether there is a correlation between performance and pricing in a shipper-carrier relationship. Our research also explores whether shipper loyalty on a lane towards a carrier inspired loyalty from a carrier towards a shipper.

Methodology

The dataset for this research included 27 months of tender and shipment records for dry-van, truck load shipments from the Transportation Management Centre (TMC), a staffed transportation management service, at C.H.Robinson (CHR), the largest third-party logistics provider in the United States. The dataset consists of tender information from 40 shippers and 963 carriers, operating within the 48 states of the United States. A total of 1,723,692 offers were made by the shippers to secure trucks for 807,662 shipments yielding an aggregate acceptance ratio of 52.8%.

We defined carrier performance using 3 parameters:

**On-Time Pick-up:**

$$\text{OTPPercent} = \frac{\text{Number of accepted loads picked up on time denoted by OTP}}{\text{Total Number of accepted loads}}$$
We conducted OLS regression with cost per load as the dependent variable and distance, geography and performance parameters as the independent variables. The table above (Table 1) summarizes the independent variables used in the different models.

Besides the above models, we defined a factor called shipper loyalty, which is defined as the consistency and volume of loads a shipper offers a carrier on a particular lane. We tested its effects on the cost per load and on the acceptance ratios. Loyalty was defined in 2 ways:

\[
\text{Loyalty}_{\text{week}} = \frac{\text{# of weeks a carrier has received loads from shipper}}{\text{# of weeks shipper has floated a load in a lane}}
\]

\[
\text{Loyalty}_{\text{vol}} = \frac{\text{# of loads a carrier has received loads from shipper}}{\text{Total # of loads shipper has floated in a lane in a year}}
\]

Table 1: List of independent variables in the models

<table>
<thead>
<tr>
<th>Model</th>
<th>Independent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Distance</td>
</tr>
<tr>
<td>2</td>
<td>Distance, Geographical binaries</td>
</tr>
<tr>
<td>3</td>
<td>Distance, Geographical binaries, OTPPercent, OTDPercent, Acceptance Ratio</td>
</tr>
<tr>
<td>4</td>
<td>Distance, Geographical binaries, All performance parameters lagged by 1 quarter</td>
</tr>
<tr>
<td>5</td>
<td>Distance, Geographical binaries, All performance Parameters lagged by 2 quarters</td>
</tr>
<tr>
<td>6</td>
<td>Distance, Geographical binaries, All performance parameters arranged in bins</td>
</tr>
</tbody>
</table>

**On-Time Delivery:**

\[
\text{OTDPercent} = \frac{\text{Number of accepted loads delivered on time denoted by OTD}}{\text{Total Number of accepted loads}}
\]

**Acceptance Ratio:**

\[
\text{Acceptance Ratio} = \frac{\text{Number of accepted loads}}{\text{Total Number of loads offered to a primary carrier}}
\]

Results and Output

OTD performance and carrier rates showed a significant amount of correlation. We concluded that while carriers are penalized for poor performance, their cost per load does not steadily increase but rather flattens after a threshold of 80% on-time delivery performance. This tendency can be seen in the output of the regression conducted in Figure 1 on the next page.

While regression did not yield a direct result between cost per load and OTP, through chi-squared test, we saw a relationship between OTP and OTD. We noticed that carriers that pick up loads late deliver them on time 80% of the times. This trend explained the apparent lack of a direct relationship between the OTP and cost per load. Transit times often include enough extra time to absorb a slightly late departure. In fact, carriers may choose to be a little late so that the driver hours and distance match more closely to the delivery schedule in an effort to boost efficiency.

We concluded from the relationship between cost per load and OTD that carrier behaviors are influenced by price. If freight is not priced right, carriers will prioritize their commitments and service.

Further, our research did not find a direct relationship between AR and cost per load. Hence, we delved into other factors like shipper loyalty on a lane to understand its effect on acceptance ratio and cost per load.

We observed that as the carrier receives more business in terms of number of weeks in a lane in a year from a shipper, the carrier offers a lower rate. The regression model suggested a subsidy of $20 per load for every 10% increase in
loyalty. This means in a year, prices decrease by $20 per load for loads offered consistently for 5 additional weeks.

From Figure 2 we can see that shippers that have loyalty_{week} in the ranges of 0-20% pay about $160-170 more than the shippers that have loyalty_{week} greater than 60%. Also, we can see that the lower pricing based on loyalty flattens out after 60%. This means that beyond 60%, there does not seem to be a correlation with lower prices and higher loyalty. Hence, a shipper may benefit from the lower pricing offered by the carriers by consistently offering a carrier loads on a lane 30 to 35 weeks in a year and may still be able to maintain a couple of carriers who can be used as contingency carriers.

Further, we noticed that lower pricing given by carriers to loyal shippers is the highest when the hauls are short (less than 500 miles or very long (greater than 1500 miles).

**Further Research**

When it comes to acceptance ratio, we were not able to find any steady relationship between performance and price. Also, while we saw an increase in acceptance ratios as the loyalty increases, the model had very limited explanatory power and seemed to suggest that while loyalty was one of the determinants of AR, there were more powerful variables that we had not considered. Two such variables are price differential that is being offered to the carrier on a particular lane from different shippers and the capacity of the carrier to haul loads compared to the general demand for TL carriers on the particular lane in a particular year. Getting price differential data and interviewing the trucking companies will further help shippers understand the acceptance patterns of the carriers.
The Impact of SKU and Network Complexity on Inventory Levels

By: Joseph McCord and David Novoa Garnica
Thesis Advisor: Dr. Bruce Arntzen

Summary: This research investigates whether observed inventory levels at a global consumer packaged goods firm are driven by two specific forms of supply chain complexity: the numbers of stock-keeping units (SKUs) in a given brand and the number of stocking locations for a given SKU. To determine the strength of this relationship we applied ordinary least squares regression and a simulation exercise. The research found that these two forms of complexity have little to no correlation with inventory levels, potentially because inventory levels appear to be set by non-forecast error-based heuristics.

Before coming to MIT, Joseph McCord graduated from the University of Maryland with Bachelor’s Degrees in SCM and International Business. He worked for five years strengthening developing country public health supply chains for the USAID | DELIVER PROJECT.

Before coming to MIT, David Novoa Garnica graduated in Robotics Engineering from University Pierre et Marie Cuire, Paris VI / Ecole Polytech’ Paris. He then worked in several companies including Saint-Gobain and Tata Group (TCS) for more than four years.

KEY INSIGHTS

1. Although it may be counter-intuitive, greater complexity does not translate into higher inventory levels.
2. Inventory quantities mirror patterns associated with simulated inventory management heuristics rather than traditional optimal inventory models.
3. Two potential measurements of complexity in the consumer packaged goods context are the number of SKUs per brand and the number of stocking locations per SKU.

Introduction

Firms that buy, produce, or sell physical goods hold inventory for several reasons. Holding stock allows these firms to meet general demands of customers and to hedge against uncertainties in supply and demand. Ideally, firms would prefer to hold the minimal amount of inventory possible while meeting their service objectives profitably.

However, the general desire to offer more distinct products to consumers means that certain forms of complexity are increasing. If firms better understood the relationship between complexity and required inventory levels they might be in a better position to weigh tradeoffs between benefits of certain forms of complexity – such as diverse product portfolios or short customer order fulfillment lead times – against an attributable increase in inventory holding cost. Any firm which aims to manage its inventory levels carefully should find value in understanding this relationship.

Data and Methodology

This research effort focused on the operations of a global consumer packaged goods firm across several regional market clusters. This firm manufactures and sells products across major product categories including personal care, hair care, deodorant, and packaged foods.

Given the nature of the consumer packaged goods industry, the research sponsor was particularly motivated to understand the role of two specific forms of complexity: product or SKU complexity – measured here as the number of SKUs in a brand – and network complexity – measured as the number of stocking locations in a market cluster for an SKU.

Based on intuition and existing literature, the working hypothesis for this research was that either form of complexity would increase observed inventory levels by the traditional square-root law. Brands that included more SKUs or SKUs that used more stocking locations would be reducing pooled variance in demand, meaning that optimal safety stocks would rise according to a power function to increases in forecast error. This problem statement is depicted in Figure 1.
Therefore, in order to measure the strength of this relationship within the operations of the research partner, the researchers applied ordinary least-squares regression between complexity and observed inventory levels against a power curve. The regression analysis was achieved by using historical data from several information systems of the research partner:

- An inventory optimization system which records average demand levels by SKU
- Records of actual inventory levels at SKU locations
- Sales history records (to support effective removal of obsolete SKUs from the analysis).

For each iteration of the analysis, the researchers calculated two measurements of complexity and inventory levels of brands and SKUs expressed as days of stock. Each measurement of complexity was then compared to the associated inventory levels within a scatterplot. The researchers used basic spreadsheet software to measure the correlation between complexity and inventory levels against a power curve line of best fit.

This approach was repeated for multiple product categories within two market clusters (geographic regional markets) across multiple points in time to determine the applicability of the results within the firm's operating environment. Where possible, inventory levels were averaged across several close points in time to reduce the likelihood of results being driven by arbitrary sampling within the products' review periods.

To complement this regression methodology and help explain results, the research also included a simulation exercise. Using an artificial database of products constructed to have similar properties to the actual datasets, anticipated inventory levels were calculated using several variants of common inventory control rules.

For example, one simulation applied a base stock policy in which safety stocks were calculated assuming that forecast error was solely driven by SKU complexity within brands. Another simulation assumed that inventory levels were not set by demand variance at all, but according to the common “ABC” heuristic. This approach assumes faster moving (higher sales) products can be managed with lower inventory levels while the long tail of slow moving “C” products have a higher target inventory level. The researchers conducted this exercise to compare hypothetical results with actual observed scatterplots from the regression analyses.

Results

Initial summary analytics of the categories analyzed showed a common “long tail” of slow moving SKUs when demand per SKU was observed. For one cluster, approximately 10% of the 4,000+ SKUs had daily demand of 500 units or more, while more than half of the SKUs had an average demand of 25 units or less per day. This result illustrates one aspect of the significant complexity within the research firm's product portfolios.

The distribution of network sizes per SKU varied between market clusters, with some showing a fairly even balance across a range of one to eight stocking locations per SKU and others with an average network size of two and a range of one to eleven locations.
Based on four iterations of the analysis, SKU complexity did not prove to have a correlation with inventory levels. Instead, the scatterplots showed a consistent pattern: a wide variation in inventory levels for brands with fewer SKUs and fairly stable and lower inventory levels for brands with more SKUs. In general this pattern, seen in Figure 2, had the opposite trend to the hypothesized relationship. All scatterplots had an R-squared value of between 0.04 and 0.06 for the linear regression.

This pattern occurred because many brands had a small number of SKUs with average daily demand close to zero units. This demand level meant that even with low inventory quantities the brand would have a high weighted days of stock. Brands with more SKUs tended to balance these slow moving SKUs with products with higher demand.

The analyses of network complexity produced a similarly confounding result. Inventory levels appeared to vary more within network sizes than between them, giving a similar low correlation. The simulation exercise potentially helps to explain these results.

As expected, when the simulated inventory levels were obtained from a safety stock equation which derived all of its forecast error from variance driven by the number of SKUs in a brand, inventory levels followed a power curve almost exactly. When additional sources of forecast error were introduced, the inventory levels began to drift from the line of best fit, but still displayed some correlation. However, when inventory levels were driven by relative demand and not forecast error, as in the "ABC" method, inventory levels displayed a similar pattern to the observed scatterplots of the analysis on historical data. This observation held true for both SKU and network complexity. Figure 3 shows the scatterplots produced through the simulation exercise.

**Conclusions**

The overall aim of this research effort was to answer the question of whether SKU or network complexity drives observable inventory levels. Based on ordinary least squares regression analysis using calculated measures of complexity, the research found no observable changes in days of stock from changes in SKU or network complexity.

The simulation exercise offers some insight into why. While the research partner firm maintains an inventory optimization software to recommend optimal inventory levels, planning staff do not always adhere to its recommendations. Instead they might be applying simpler methods such as "ABC." The visual similarity between the simulated "ABC" inventory levels and the scatterplots based on historical data indicate that this could be the case. Instead of
adhering to inventory targets calculated by an inventory optimization module, staff may prefer to respond to the complexity of managing hundreds of distinct products by applying non-safety stock-based approaches such as the “ABC” method.

Other firms in this industry or any other which manage large numbers of SKUs should consider the actual decision-making of planning staff when looking at the impact of complexity on inventory levels. As this research only looked at the experience of one firm, however, other settings may see different results if they operate under more centralized inventory control processes. Additionally, further research could look into the role of other sources of complexity such as sourcing lead time variance, frequency of product mix changes, and overall variance of demand within brands.
New Crowdfunding Distribution Channel for Moroccan Artisans

By: Zyad El Jebbari  
Thesis Advisors: Dr. Edgar Blanco and Dr. Tauhid Zaman

Summary: This thesis provides a model for a new distribution channel for Moroccan artisans to improve the efficiency of the value chain linking them to the American consumer. We identified the three models that are currently used to bring the artisans' crafts to the end consumer in developed markets: the classic retail distribution model, the marketplace, and the crowdfunding model. We assess the benefits of all the models by developing a new framework allowing us to score each of them. We also determine the optimal social media strategy to market this platform and more efficiently engage potential customers.

Introduction

The handicraft sector in Morocco represents more than 9% of the nation’s GDP and employs over two million people. However, despite their talent and expertise, Morocco’s artisans are struggling to reach markets other than local regional or national markets. Total exports account for only 8% of the revenue generated by the sector and the United States became the primary market for exports with around $10 million of revenue generated in 2013 (Figure 1).

Data and Methodology

1. Artisans’ platforms scoring framework

The first step in our methodology was to analyze the features of each model: the classic retail distribution model, the marketplace model, and the crowdfunding model. We then evaluated and scored them using 6 criteria, taking both the artisan and the customer perspectives:

1. On the artisan’s side: we assessed access to funding, profit margins, and access for artists in developing countries. These 3 issues were identified as the top three challenges for artisans to get access to international markets.

2. On the customer’s side: we evaluated shipping and logistics management, emotional link and trust, and...
lead time. We conducted a national customer survey with potential American buyers and these issues were mentioned several times as the top three criteria for a client to buy crafts.

Depending on the model, data was collected through different means. First, we interviewed the purchasing director of a Fair-Trade retail store to get a sense of the different tradeoffs between trust, lead time, supply chain control and profit margins for a fair trade retailer.

Second, we relied on the existing literature and print sources from customer surveys, such as the one published on Etsy’s website, to gather additional data on the dynamics of the marketplace and crowdfunding models such as Kickstarter.

2. Hybrid platform building and proof-of-concept

After we scored the different models, we developed a new model that will solve the issues of the current models to import/export artisans’ crafts. This hybrid model is a crowdfunding platform that displays existing and new features to help artisans access international markets. The platform reduces the inventory and financing risks, and increases the artisan’s profit margins. A pilot test of the model has also been conducted on Kickstarter, and we collected data concerning the market segments (gender, income, degree of study), conversion rate and cost of acquisition to target them more efficiently on social networks.

3. Social network experiments

Once the right audience was identified in the prototype phase, we developed the platform and tried to build the community around the project. To do so, we used experiments on social networks and especially Twitter and Instagram. Twitter is an online social media platform where users can post 140-character segments of text to share with friends.

There are a few ways to engage with fellow users on Twitter:

1. When one follows another user, the followed user, or the friend, gets displayed on his homepage.
2. When a user wants to endorse another user’s post, he can re-tweet the original status.
3. A user can also reference a fellow user in his post by directly replying to a post.

In this experiment we investigated the efficacy of three different strategies: following, retweeting and replying, and measured the incremental benefits of combining two strategies (following and retweeting, following and replying).

Evaluating the performance of the hybrid crowdfunding platform

Based on the interviews and the pilot test we ran for 3 months, each model received a score of:

- 0 (no sign): no access to free loans, no reasonable

![Figure 1: Moroccan Crafts exports to the United States (Source: Moroccan Ministry of Handicraft)](image)
margin for the artisan, no access for African artists, no emotional link and trust for the customer, no reliable shipping and logistics management by the platform, long lead time to the customer.

- 1 (one X): adequate access to working capital, relatively good margin for the artisan, relatively good access for African artists, adequate emotional link and trust for the customer, relatively reliable shipping and logistics management by the platform, relatively short lead time to the customer.

- 2 (two X): good access to free loans, reasonable margin for the artisan, good access for African artists, good emotional link and trust for the customer, reliable shipping and logistics management by the platform, short lead time to the customer.

Figure 2 sums up the findings. The retail model has been split between the classic online retail model and the fair trade retail model.

It appears that the Hybrid model we called “MoroCrafts” achieved the highest scores based on the six criteria we set up. The main disadvantage of this model is the lead time that can take up to two months based on the proof-of-concept we implemented on Kickstarter. The e-Commerce and retail Fair Trade model developed by Ten Thousand Villages arrives second with only a weakness in margins given to artisans (due to additional inventory held in warehouses) and emotional link conveyed through the online e-Commerce platform (less time spent on the website to know the culture and artisans story). The regular crowdfunding model arrives third with a lack of access for African artists, lack of control in the supply chain and longer lead times. The marketplace model is ranked fourth at the same place as regular e-Commerce platforms such as Amazon. While e-Commerce mainly focuses on the satisfaction of the customer, the Marketplace focuses more on the supplier: they do not focus on both sides of the supply chain.

Designing an efficient marketing strategy on social networks for social engagement

Based on the number of followers we attracted, the best single strategy was clearly identified as being the follow strategy. It outperforms the reply strategy by 20 more followers and the retweet strategy by 16 more followers (with almost the same number of actions performed: 20% more or less). The benefit of adding a retweet or reply action does not add more followers: this may be attributed to some noise since the sample is not big enough. This might also be attributed to the lead time not taken into account in the compilation of results since people react later to a friend request.

However, worth noting is the reply strategy engages people much more than the retweet one since the messages posted by the artisan have been retweeted and mentioned 50% times more.

The results of the logistic regression from Table 1 indicate the user’s friend count, the user’s follower count, and the actions of replying and following are significant, with the user’s friend count and the user’s follower count being the most significant. The follow probability is increasing in the number of friends of the user and decreasing in the number of followers of the user. This makes sense intuitively, as we would suspect less “popular” users on Twitter to follow more readily than “popular” users. The coefficient associated with
the action of following illustrates the idea that a user is more likely to follow back if followed. The coefficient for the action of replying also indicates what we described earlier in that replying is not the strongest tactic to gain followers and thus decreases the likelihood that a user will follow back. It only allows people to engage you in a different manner through mentions. Although the follower and the friend counts of the bot are deemed insignificant, we suspect that this is due to an experimental shortcoming of not being able to significantly change the bots’ follower and friend counts during our period of experimentation. We plan to see how the significance of these features might change by more drastically changing friend and follower counts of the bots in subsequent experiments.

There is definitely more value combining the reply and follow strategy as we can attract both more followers and engage more people in the conversation. We might have to test the marginal/incremental benefit of performing 3 actions at the same time in a future experiment: follow, reply and retweet.

The second gender experiment suggests that followers are equally likely to follow back a female or male artisan using the follow and reply strategy. Overall we could not draw a real causal effect between the artisan gender and the customer engagement on social networks. This does not confirm the hypothesis that women who represent the main part of our customer base are more likely to engage with similar female artisans.

### Conclusion

The results of this research directly enhance the distribution models used to export art and craft items in the context of a global supply chain. When the prepayment of items through a crowdfunding platform is combined with an efficient internal supply chain, both artisans and consumers will be more satisfied. A straightforward framework can be applied to score and assess the performance of the different distribution models in place. Then, social media strategies can be used within this new model to target and engage the right audience. Using the tools developed for this platform on Twitter to spread the word and build a linked community, the model and strategies can be expanded to other social network tools such as Facebook, Tumblr, or Pinterest. The scoring framework we developed during our research can be applied to assess the efficiency of distribution channels for all sorts of items that countries would like to export to international markets (e.g. traditional cosmetics, accessories, authentic home décor).

Further opportunities exist to test, extend and improve the methodology applied in this thesis, especially if we can incorporate inventory holding cost for lower value items in the context of the hybrid platform. In addition to that, we also added the social network aspect that is extremely important nowadays to build a strong community of followers around the platform. Further opportunities exist to extend the experiment to other social network such as Instagram or Pinterest and tailor the experiment to other e-Commerce retail channels in order to engage potential customers on social media and increase revenues without having to spend extra money on marketing campaigns.

### Table 1: Logistics regression analysis

<table>
<thead>
<tr>
<th>Feature</th>
<th>β</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-10.9644***</td>
<td>1.31e-08</td>
</tr>
<tr>
<td>log(User Friend Count)</td>
<td>3.4066***</td>
<td>6.28e-10</td>
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<tr>
<td>Follow</td>
<td>1.6365*</td>
<td>0.0211</td>
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<tr>
<td>log(User Follower Count)</td>
<td>-1.9575***</td>
<td>1.03e-05</td>
</tr>
<tr>
<td>log(Bot Follower Count)</td>
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<td>0.2883</td>
</tr>
<tr>
<td>Retweet</td>
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<td>0.1096</td>
</tr>
<tr>
<td>log(Bot Friend Count)</td>
<td>0.2954</td>
<td>0.7634</td>
</tr>
<tr>
<td>Reply</td>
<td>-0.9330*</td>
<td>0.0238</td>
</tr>
</tbody>
</table>

Table 1: Logistics regression analysis
Measurement and Evaluation of Retail Promotions

By: Asen Kalenderski and Satya Sanivarapu
Thesis Advisor: Dr. Chris Caplice

Summary: Promotions involve a complicated interplay of factors and are a result of a synchronized sequence of activities between manufacturers and retailers. The outcome of promotions pivot on several elements beyond the control of any one party in the supply chain. ‘How’ a promotion performed has a more straight forward answer than ‘Why’ a promotion performed a certain way. This research attempts to define a quantitative methodology to measure performance of promotions and reveal insights to consumer product manufacturers and retailers that will help answer the ‘How’ and the ‘Why’ of promotions. The measures used are simple, but the combination of analysis creates a complex structure of many dimensions that reveals intricate insights into the functioning of the supply chain, the most important asset in executing promotions. We present to you a three dimensional framework termed the ‘Promotion Performance Cuboid’ with structural elements consisting of three foundational supply chain measures, inventory, stock-outs, and performance of sales against target forecasts. The measures when viewed together through the Promotion Performance Cuboid, tell a revealing story of the underlying dynamics of promotions and the elements that actually control promotional performance become lucid.

Introduction

Promotions were a brilliant solution for CPG manufacturers to increase demand and push their merchandize at discounted prices onto retail shelves. However, with CPG manufacturers and retailers increasing the frequency of promotions as well as the discounts offered, promotions are becoming harder to manage and profit from. Today, promotion spending accounts for one of the highest line items on the profit and loss statement for CPG manufacturers, only second to cost of goods sold. Promotion spend by CPG manufacturers is increasing at a stupendous rate, sometimes, even faster than sales. This gives good reason for CPG manufacturers to invest in methods to improve promotions through accurate measurement and evaluation to gain insights into promotions behavior. Measuring and evaluating promotions allows isolating characteristics that cause promotions to be successful. These characteristics may then be transferred to improve the performance of under-performing promotions.

The main scope of this research is to understand promotions and develop a methodology to measure and effectively evaluate promotion performance. What important factors should be considered when evaluating promotions? What is the effect promotions have on stores? Are there some SKUs, stores or promotions that weigh down the overall revenue or profit potential of promotions? These are some of the questions that the thesis addresses. The measurement of promotions is based on three foundational measures, end
of promotion store inventory levels, stock-outs, and sales performance against promotion forecasts.

Methodology

The methodology pivots around three primary dimensions to measure and classify promotions. Levels of inventory by the end of promotions, stock-outs during promotions, and sales performance against promotion forecasts. The analysis can further be sliced from three perspectives. Analysis of promotions by SKUs may reveal the assortment of SKUs that perform and those that don’t. Analysis of promotions by stores may reveal the stores that are able to execute promotions well and those that don’t. Analysis by promotions may reveal the promotions that do well across all stores and those that don’t perform as well. The three perspectives put together along the dimensions of measures reveal insights into ‘How’ promotions performed and ‘Why’ they performed in the way they did. The ‘Why’ is a more difficult question to answer than the ‘How’?

Promotions impose stress on supply chain operations due to sudden spikes in demand. A promotion may hit a store and leave it with insufficient inventory during the post-promotion period. Conversely, a promotion may leave a store with excess inventory during the post-promotion period. Figure 1 is an example of a typical promotion and is a composite graph that captures the impact on unit sales, average price, and end-of-day inventory for a promoted SKU. The data for the SKU is aggregated nationally across all stores in the supply chain. On the X-axis is time (days). On the Y-axis for the first graph is total units sold across all stores by day. The second graph shows the average price of the SKU across all stores by day. The third shows the end-of-day inventory for the SKU across stores. The SKU is promoted through a price reduction from Jul 26th to Aug 2nd. The price reduction results in a tremendous spike in sales. Also interesting to note is the ramp up of inventory in the week preceding the promotion across stores. Inventory depletes rapidly during the promotion period as a result of increased sales. The increase in inventory levels depicted by the third graph reveal that retail distribution centers replenish stores during the promotion. In this example, it appears that the promotion results in stores across the supply chain holding higher inventory levels than during the average non-promotion period.

- **First dimension:** Since stores vary in size and demographics plays a role in the rate of sales at a store, the levels of inventory by the end of a promotion are of little help in judging the impact that a promotion had on a store in terms excess or depleted inventory. However, the Days of Supply (DoS) measure is a better indicator in revealing inventory levels by the end of a promotion. To determine whether inventory for a SKU is in excess or not by the end of a promotion, the difference in end of promotion DoS to the average non-promotion DoS is computed.

- **Second dimension:** The stock-out rate reveals how prepared a store was during a promotion. A low stock-out rate is usually preferred than a high one. However, a high stock-out rate is not necessarily detrimental because it may be caused by abnormally high sales.

- **Third dimension:** The forecast for a promotion is the
target that the supply chain gears for. The sales as compared to the forecast reveal how a promotion performed. Thus, this metric is the cornerstone in answering the ‘How’ of promotion performance. A positive difference between sales and forecast indicates that sales exceeded forecast. A negative difference indicates that sales fell short of forecast. The point that sales equals forecast is when the target is hit. Sales exceeding forecast during a promotion is not necessarily preferred because this may result in increased stock-outs and lower sales during the post-promotion period, which may not be desirable.

Thus, the methodology for measuring and evaluating promotions rests on the three pillars as defined by the three dimensions above. This thesis proposes a method to analyze promotions along the three classified dimensions and suggests corresponding implications on promotion operations in terms of replenishment frequencies and sizes, store and DC inventory levels, and SKU sales.

Figure 2 represents the framework for measuring and evaluating performance of promotions. The Promotion Performance Cuboid framework is made up of 18 different cubes, each of which represents one possible combination of the dimensions. In turn, each cube also reveals insights into the ‘Why’ of the promotion, revealing what may have truly happened during the promotion that led to the final outcome. The X-axis represents the excess supply at stores by the end of promotions and is classified into ‘High’, ‘Green Zone’, and ‘Low’ categories. The ‘High’ represents excess supply, the ‘Green Zone’ represents an acceptable level of supply, and the ‘Low’ represents less than average levels of supply of a SKU across stores by the end of a promotion. The Y-axis represents the performance of sales against forecast and is referred to as the forecast error. The ‘Negative’ implies sales is below forecast, ‘Positive’ implies sales exceeds forecast, and sales = forecast is self-explanatory. The Z-axis represents the stock-out rate and is classified into ‘High’ and ‘Low’. If the stock-out rate is above the average non-promotion stock-out rate (1.11% computed from this dataset), it is classified as ‘High’ and otherwise as ‘Low’.

Results

The dataset analyzed spans the point-of-sale data for product category P across BoxCo’s 1820 retail stores over the period September 1st, 2013 to August 31st, 2014. There are 937 SKU-promotions during this period and the level of granularity of the data is SKU-Store-Promotion. For analysis purposes, promotions in the dataset were categorized by discount class, based on the dollar value of the gift card offered during the promotion. The most popular promotion category with the largest amount of data was the $10 gift card promotion ($10GC). SKU, Store, and Promotion level analyses were conducted by applying the previously described Promotion Performance Cuboid framework on the $10GC promotions. The dataset consisted of 1.5 million records representing SKU-Store-Promotions.

Each cube of in Figures 3 and 4 represents the distribution of the $10GC SKU-Store-Promotion dataset against the cubes in the Promotion Performance Cuboid. The percentages displayed in a cube represent the number of SKU-Store-Promotions with the combination of DoS Diff %, Stock-outs, and sales performance against forecast, represented by the cube. Figure 3 displays the distribution of data across cubes in the ‘Low’ stock-out rate zone and Figure 4 displays the same for the ‘High’ stock-out zone. Thus, each cube also reveals a story of the possible implications regarding replenishments, inventory levels at stores and distribution centers, and SKU sales.

For example, in Figure 3 (‘Low’ stock-outs), SKU-store-pro-
motions that falls into the cube represented by low DoS Diff %, and ‘Positive’ Forecast error (sales exceeding forecast) account for around 13% of $10GC SKU-store-promotions. This cube reveals that end of promotion inventory levels were low, the promoted SKU sold beyond forecast expectations, and that stock-outs for the SKU were low across stores. The high sales and the low stock-outs may reveal that stores held high inventory levels. The high sales and low end of promotion inventory levels reveal that the SKU may have sold well. The low end of promotion inventory levels and the low stock-outs reveal that replenishments from DCs to stores may have been on time and of the right size. Additionally, since sales exceed forecast and the DC was able to meet the demand, the retailer DC may have been holding high levels of inventory for the SKU, beyond those recommended by the forecast. Using these insights, the retailer may revise the forecast for the SKU and make necessary adjustments to DC inventory levels to and achieve higher profits with a similar sales success.

Similar analysis and insights may be derived for the remaining 17 cubes in the Promotion Performance Cuboid. The thesis analyzes the top 4 cubes in-depth, accounting for the highest distribution of data, and arrives at possible implications for the respective cubes.

Conclusion

The Promotion Performance Cuboid is a powerful tool to measure and evaluate performance of promotions. Measuring promotions along the dimensions defined by the Promotion Performance Cuboid helps isolate characteristics that are common to successful promotions. The successful characteristics may then be transferred and applied to promotions performing below par with an objective to improve their performance. Overall, this is expected to enhance the performance of promotion events leading to an increase of revenues and the profit potential.
**Additional 2015 SCM Theses**

**Improving Supply Chain Agility of a Medical Device Manufacturer**  
By Xinye Bai and Yaniv Rosenberg  
This research identifies a strategy to increase supply chain agility for DeCo's instruments. A qualitative analysis of historical data and supply chain processes shows the current bottleneck at DeCo. This thesis provides guidelines and suggestions for the redesign of the supply chain to achieve shorter lead time, lower inventory levels, and higher level of service.

**The Logistics of Creativity**  
By Collin Brady and Joseph H. Williams, Jr.  
This research explores the logistics problems experienced by a luxury apparel retailer for decorative items used in its stores. We identified many symptomatic issues, such as overcapacity facilities and inefficient – at times even unsafe - behaviors in the logistics operations. Underneath these problems lies a disconnect of the company's creative design team from the requirements of safe and efficient logistics operations, and a logistics team with little to no relative power to exert any positive change.

**Factors Influencing Tier 2 Supply Chain Risk Data Collection**  
By Stephanie Buscher and Angel Poyato Ayuso  
With 39% of supply disruptions occurring at indirect suppliers, companies can no longer ignore their supply networks when determining supply chain risk. Measuring the risk of a network requires collaboration amongst all players. Through a series of conversations held with suppliers, the research conducted here identifies the internal and external factors that determine success in supply chain risk data collection.

**An analytical model to approach consolidation processes in air freight transportation**  
By Niklas Blomberg and Ramon Gras  
This thesis proposes an analytical model to guide air freight forwarders' decision-making when addressing their commercial strategy for air cargo tenders. Using the model, we designed a series of meaningful metrics and visualization tools to depict air density usage efficiency and profitability. The model was used to assess the attractiveness of incoming bids under consideration after estimating their consolidation potential with the current business.

**Improving Automotive Battery Sales Forecast**  
By Vinod Bulusu and Haekyun Kim  
This research evaluates causal factor analysis to determine how the sales forecast accuracy can be improved. We focused on understanding the relationship between temperature and automotive battery sales. Using Point of Sales (POS) data analysis and regression modelling, we found that temperature is an important variable in battery failure and hence impacts sales. We validated the model by using comparing the actual and predicted sales for various geographies and periods.

**A Supply Network Resiliency Assessment Framework**  
By Jaspar Siu and Santosh Stephen  
Although companies are aware of the importance of resiliency in their supply chains, due to the inability to quantify resiliency, mitigation planning is often based on "gut feelings" and intuition. We developed a framework to quantitatively assess the resiliency at each supplier, facility, and location in a supply chain. The "expected business impact of disruptions" metric can be used to identify the entities bearing the highest risk, evaluate the best mitigation options, and make a business case for the extent of investment in resiliency improvement.

**SKU Clustering for Supply Chain Planning Efficiency**  
By Axel Barbará and Tomás Dominguez Molet  
This research proposes an optimized SKU segmentation for a global CPG food retailer to use in inventory management and operational design. Clustering techniques were used to identify a more cost-effective clustering strategy. Disconnects between theoretical and actual costs were calculated and targeted for improvement. Our research created new insights into the comparable cost of under-forecasting and over-forecasting on safety stock and customer service level.
Data-driven Risk Assessment for Truckload Service Providers
By Sriram Kishore Chittella and Marcos Machado Teixeira
This research proposes a methodology for truckload service providers to better understand the risk and volatility patterns when dealing with the trucking spot market across the different geographies and time periods. This allows them to reduce their risk when setting long-term contracts with shippers. Using three different measures of volatility (coefficient of variation, beta, and month over month percentage change) we developed a framework to assess the company’s risk profile. We used this framework to distinguish regions and lanes from a risk perspective, arising with insights to improve 3PL companies’ business.

Operationalizing Demand Forecasts in the Warehouse
By Dan Li and Kyung (KD) Kim
This research evaluates the plausibility of leveraging the SKU level forecast to predict equivalent operational activities in the warehouse. We analyze rolling base forecasts of outbound shipments with actual picking data from the warehouse. The thesis concludes with results of the evaluation regarding the rolling base forecast and the potential areas to improve the accuracy. This work will help warehouse managers to understand the potential of utilizing demand forecasts to plan warehouse activities.

Quantifying the Impact of Deployment Practices on Interplant Freight Volatility
By Kurn Ma and Manish Kumar
This thesis looks at the variability that a shipper passes on to its carrier in terms of number of truckloads requested. We developed a deployment model to replicate real-life deployment practices to evaluate the impact of various exogenous and endogenous variables on transportation variability. The results show that changing the frequency of deployment review impacts the variability. It is also observed that if a company delays dispatches and evenly distributes replenishment loads over a week, it can achieve high level of stability in its shipment volume while maintaining customer service levels.

Roadmap for Commodity Sourcing Strategy
By Wenzheng Chong and Yuwen Lai
This research proposes a methodology to forecast, design and develop the future state of the company’s next generation supply base. Utilizing the machined parts commodity group as a use case, we developed a tool that is able to quantify, balance and combine the competing procurement drivers so as to determine the overall alignment to the company’s procurement and sourcing strategy. Additionally, this tool seeks to predict the near to mid-term global competitiveness of oilfield services equipment manufacturing by country.

Towards a Consumer-Oriented Supply Chain
By Panagiotis Andrianopoulos and Hector Rafael Perez Wario
A retailer and a vendor, sponsors of this project, asked how a consumer (not customer) oriented supply chain is defined and what techniques can they use to effectively implement one? Our methodology to define one consists of interviews with key stakeholders/industry experts, literature research, value stream mapping and data analysis of historical sales and shipments between the sponsors. We define the consumer-oriented supply chain and propose a roadmap with short-term and long-term steps towards it.

E-Commerce Cold Chain Fulfilment
By Mounir Yakzan and Jordan Nelson
This research focuses on four segments of cold chain fulfillments: package routing and delivery, consolidated returns, competitive research, and packaging technologies. The different categories were considered based on three key performance indicators (KPIs): speed, quality, and cost. Each fulfillment segment offers tradeoffs in the KPIs through use of new technology or efficient design. A holistic approach looking at all four segments will allow managers to focus on the KPI that is most important for their product.