Summaries of Select Research Projects by 2008 graduates of the MIT Master of Engineering in Logistics (MLOG) Program

Introduction

Impact of Lead Time on Truckload Transportation Rates

This project developed a model to quantify the impact of business policy decisions, such as tender lead time, on truckload transportation costs. This model demonstrates that business policies have a substantial impact on companies' overall transportation spend, and these policies can be quickly modified to reduce cost with little risk or capital investment. This paper was awarded the Outstanding MLOG Thesis prize for 2008.

100% Container Scanning: Security Policy Implications for Global Supply Chains

In August 2007, the US government passed the 9/11 Act, requiring all US-bound containerized cargo to be scanned using radiation and non-intrusive imaging equipment at foreign seaports prior to vessel loading by July 2012. This project creates a quantitative framework to assist importers in analyzing the financial costs and delay concerns associated with 100% container scanning.

Determination of Drivers of Stock-Out Performance of Retail Stores using Data Mining Techniques

This project utilizes data mining techniques to determine the drivers of stock-out performance. Best performing and worst performing clusters of stores were identified using data clustering techniques. Furthermore, logistic regression and multiple ordinary-least-squares regression were used to gain further insights and quantify the drivers of stock-outs.

An Engineering Approach to Improving Hospital Supply Chains

Utilizing supply chain best practices from industries outside of healthcare; a supply chain has been designed and modeled that reduces hospital supply chain costs. The supply chain is centered on patient-specific kits delivered from an offsite warehouse to hospital bedsides. Effective implementation requires that each individual hospital segment their products to determine which items are appropriate for the supply chain.

Leveraging Risk Management in the Sales and Operations Planning Process

In order to incorporate risk management into the Sales and Operations Planning (S&OP) process, companies must segment their products and customers based on business importance, demand forecast, and order lead time. After completing these segmentation steps, companies can then apply appropriate risk management tactics to mitigate uncertainty in demand and supply.

Inventory Optimization in a Retail Multi-Echelon Environment

This project developed an inventory model to find the optimal inventory distribution in a retail three-echelon network that enables high target service level at the stores. Using a multi-echelon approach, the optimal network inventory cost can be achieved by low inventory and service level at the intermediate echelon. The study shows the interrelations between echelons that should be considered when developing each echelon's inventory policy.

Transport Mode and Network Architecture: Carbon Footprint as a New Decision Metric

Climate change and its political, social and economic implications are pushing companies to find ways to reduce the carbon footprint of their supply chains. This project examines tradeoffs between carbon footprint, cost, time and risk across three case studies of United States’ perishable and consumer packaged goods firms and their transportation partners.

The Impact and Dynamics of Centralization in Supply Chain Decision-Making

This thesis examines the relationship between centralization in the supply chain organization of companies, cost structure and the factors prompting companies to either centralize or decentralize their supply chain organization.

Complete List of MLOG 2008 Theses

www.mit.edu/mlog/research
Introduction

Welcome to the 2008 Master of Engineering in Logistics (MLOG) Research Journal!

The eight papers included in this journal were selected from the several dozen theses submitted by the MLOG Class of 2008 at the Massachusetts Institute of Technology. The articles are written as executive summaries and are intended for a business, rather than academic, audience. The purpose of the executive summaries is to give the reader a sense of the business problem being addressed, the methods used to analyze the problem, and the relevant results, conclusions, and insights gained. The complete theses are, of course, much more detailed. We’ve also included a complete list of this year’s MLOG theses with short descriptions at the end of this journal.

The articles included in this publication cover a wide selection of interests, approaches, and industries. The articles explore how companies should quantify the impact of business policies on transportation pricing; prepare for 100% scanning of inbound containers; deploy inventory in a multi-echelon network; make trade-offs between costs, risks, time, and the carbon footprint of transportation operations; use their sales information to understand causes of stock-outs; and incorporate risk into their Sales and Operations planning (S&OP) process. Other articles discuss how hospitals can improve their supply chains as well as the factors that drive firms to centralize or decentralize their supply chains. This variety of topics illustrates one of the hallmarks of the MIT-MLOG program: the ability for students to focus their course work and research on the topics that most interest them.

The MLOG program is designed for early to mid-career supply chain professionals who want a more in-depth and focused education in supply chain management, transportation, and logistics. The class size is limited each year to 30-40 students from around the globe and across all industries. The projects highlighted in this journal reflect the variety of MLOG student interests. Most of the projects are conducted in conjunction with a sponsoring company through the Supply Chain Education Partners Program at the MIT Center for Transportation & Logistics (CTL).

I hope you enjoy the articles. If you want access to the entire thesis, just let me know and I can make it available to you. Also, if you wish to discuss any other aspect of the MLOG program or wish to find out how your company can interact with MLOG students, please do not hesitate to contact me directly.

Happy reading!

Dr. Chris Caplice
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Impact of Lead Time on Truckload Transportation Rates

By Erik Caldwell and Bryan Fisher
Thesis Advisor: Dr. Chris Caplice

Summary: This project developed a model to quantify the impact of business policy decisions, such as tender lead time, on truckload transportation costs. This model demonstrated that business policies have a substantial impact on companies’ overall transportation spend and these policies can be quickly modified to reduce cost with little risk or capital investment.

**KEY INSIGHTS**

1. Routing guide depth (the number of carriers to which a shipper tenders a load before it is accepted) drives transportation costs.
2. Business policy decisions, such as tender lead time, affect the likelihood preferred carriers will accept a tender.
3. Companies can modify business policies to increase carrier tender acceptance rates and therefore reduce transportation costs.

Introduction

Since companies in the United States spend over $150B annually on transportation, even slight improvements in pricing efficiencies can lead to substantial cost savings. This research analyzed over one million truckload transactions in partnership with C. H. Robinson’s Transportation Management Center and determined that it is possible for shippers to modify their business processes to improve the likelihood tenders will be accepted by their preferred carriers at a lower cost. These business policy factors include tender lead time, tender and pick up day of the week, and carrier size preference.

Many companies seeking to reduce transportation costs concentrate on network design and carrier negotiation, which have both been well researched. Conversely, the transportation pricing impact of business policies, such as lead time, has been less explored. As a result, companies likely fail to appreciate the impact their processes have on transportation costs. This research resolves this shortcoming by using statistical modeling to estimate the impact of each transportation factor and provide management insights to help companies improve business policies.

Routing Guide Depth

Since the price each carrier charges to haul a load is contractually fixed, the driving force in transportation cost is related to how deep a shipper must tender in their routing guide until a carrier accepts their load. A routing guide is unique to each transportation corridor and lists all the potential carriers on that corridor. Generally the least expensive carriers are at the top and have the first opportunity to accept the tender. The first carrier in the routing guide will on average accept 78% of tenders. The acceptance rate generally drops with each subsequent position in the routing guide, with tenders offered to the fifth carrier in the routing guide being accepted only 40% of the time.

The average routing guide depths for each day of lead time represented in Figure 1, show that the more time a carrier
has between the tender and pick up day the more likely the first carriers in the routing guide are to accept the load.

The decrease in routing guide depth then corresponds to a decrease in the cost per mile a shipper pays when providing longer lead times, as shown in Figure 2. From this observation one can conclude that the impact of business policy is actually measured by the effect it has on the likelihood a tender will be accepted, since multiple rejections result in increased cost.

A critical point to note is that the worst loads (those with multiple tender rejections) have the greatest affect on the average rate paid by a shipper. Figure 3 shows the average number of times a load had to be tendered compared to the average for the lane on which the load was traveling. From this graph, one can see that the 90th percentile of loads required 1.8 times the number of tenders compared to the average for the lane when lead time was zero. This helps demonstrate that even the small percentage of loads that are rejected repeatedly force the shipper much deeper into their routing guide and cause proportionately higher costs.

For loads with six or more days of lead time, the impact of the worst percentile of loads is mitigated, helping explain the improvement in cost per mile after five days of lead time in Figure 2.

**Transportation Model Results**

Using multiple linear regression it was possible to quantify the impact of the different factors in a transportation model. All factors in Table 1 (shown on page 4) except mileage are binary and result in either a cost bonus or penalty for the predicted cost of each load. Distance cost is calculated by multiplying the mileage of the load by the per mile charge.

The origin and destination were represented with a variable for each state. Corridor volume reflects economies of scale with the number of annual loads travelling between a pair of 3-digit origin and destination zip codes. Carrier size was derived using industry rankings.

**Lead Time Impact**

Although they all used the same tendering platform, average lead time for the nine customers included in the study ranged from less than one day to over five days, as shown in Figure 4.

This four-day difference in average lead time results in the customer with the shortest lead time paying an expected cost penalty of $42 per load, or 4.2% of that customer’s annual transportation spend. It is likely that these costs could have been reduced if the customer had been able to provide carriers additional lead time.

**Carrier Availability Impact on Lead Time**

The research also reviewed how different periods of carrier
availability would impact the transportation factors. The Morgan Stanley Freight Index compares the demand for trucks against the availability of trucks in a given week. A higher index number indicates tight capacity and a lower index number indicates looser capacity. The graph below shows a strong correlation between the freight index and the average routing guide depth.

After isolating the dataset for periods of tight and loose capacity (loads tendered when the freight index was above 2.20 and below 1.20), the transportation model was rebuilt to better understand the macroeconomic effects. The models have adjusted R2 values of .910 and .904 respectively. In the tight-capacity variation of the model, the impact of short lead time became more sensitive and carrier size became less important. The penalty for short lead time increased 40% and the penalty for using larger carriers decreased 50% compared to the original model. In the loose-capacity model, the short lead time penalty dropped 50% and the larger carrier penalty increased 40%.

These changes make sense with smaller carriers being more sensitive to idle tractors in the times of reduced demand and either discounting rates or increasing their acceptance frequency, while the larger carriers are more prone to maintain the status quo. This would explain the widening gap between the different sized carriers as large carriers become even more expensive in relation to the smaller carriers in times of reduced demand and excess capacity.

Day of the Week Activity

The results of the model highlight that tendering at the end of the week becomes slightly more expensive. Tender and pick up activity on the weekends incurs an average cost penalty of over $23 per load.

Management Insights

We expect that increasing average lead time to five or more days will markedly reduce transportation costs. Companies can increase lead time by contacting carriers when shipments are planned before actual loading or even forecasting future transportation needs with carriers well in advance.

The average corridor volume was 350 loads per year and the highest volume corridors were substantially above the median. This creates a situation where it is possible to forecast fixed transportation requirements weeks in advance to allow carriers time to better plan their capacity and increase the tender acceptance rate. Any additional loads can then be secured for the variable portion of the corridor volume closer to the pick up date.

Companies can also improve their transportation costs by focusing on loads responsible for the most expensive cost variances. By maintaining a private fleet capable of handling 10% of the volume, it would provide the strategic ability for managers to handle loads with multiple rejections with fixed cost assets.

Human behavior tends to be impacted by metrics and deadlines. When companies use a Monday-Friday schedule they unwittingly cause an increase in more costly end of week activity and weekend penalties. By changing the work week metrics to a Wednesday-Tuesday schedule companies can avoid these impacts by changing their volume patterns. This also provides three days following the modified “end of week” in order to handle exceptions before the more expensive weekend.

Finally, the research shows that cost savings do not end with network design and carrier negotiation. Shippers can significantly reduce their transportation costs by optimizing their business policies with regard to the factors discussed in this research.

Table 1: Transportation Model Details

<table>
<thead>
<tr>
<th>Variable</th>
<th>Criteria</th>
<th>Impact</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>per load $</td>
<td>149.56</td>
<td>0.000</td>
</tr>
<tr>
<td>Distance</td>
<td>per mile (6 per load)</td>
<td>1.17</td>
<td>0.000</td>
</tr>
<tr>
<td>Origin</td>
<td>Origin State (6 per load)</td>
<td>Various</td>
<td></td>
</tr>
<tr>
<td>Destination</td>
<td>Destination State (6 per load)</td>
<td>Various</td>
<td></td>
</tr>
<tr>
<td>Corridor Volume (per year)</td>
<td>150 loads ($ per load)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrier Size</td>
<td>Large (6 per load)</td>
<td>22.12</td>
<td>0.000</td>
</tr>
<tr>
<td>Tender Day</td>
<td>Monday (6 per load)</td>
<td>10.28</td>
<td>0.000</td>
</tr>
<tr>
<td>Pick Up Day</td>
<td>Wednesday (6 per load)</td>
<td>12.07</td>
<td>0.000</td>
</tr>
<tr>
<td>Lead Time</td>
<td>June 6-8 hours (6 per load)</td>
<td>24.26</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>June 16 hours (6 per load)</td>
<td>17.48</td>
<td>0.007</td>
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<tr>
<td></td>
<td>June 24 hours (6 per load)</td>
<td>22.94</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>June 9-11 days (6 per load)</td>
<td>33.52</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>June 12 or more days (6 per load)</td>
<td>47.10</td>
<td>0.000</td>
</tr>
</tbody>
</table>

| Adjusted R² Goodness of Fit| 0.905 |

Figure 5: Freight index and average tender sequence number
100% Container Scanning: Security Policy Implications for Global Supply Chains

By Allison C Bennett and Yi Zhuan Chin
Thesis Advisor: James B Rice, Jr.

Summary: In August 2007 the US government passed the 9/11 Act, requiring all US-bound containerized cargo to be scanned using radiation and non-intrusive imaging equipment at foreign seaports prior to vessel loading by July 2012. This project creates a quantitative framework to assist importers in analyzing the financial costs and delay concerns associated with 100% container scanning.

KEY INSIGHTS:
1. Cost and delay implications of 100% export US-bound container scanning may be less severe than industry anticipated.
2. Supply chain disruptions due to scanning is best mitigated through earlier container dispatch, increased safety stock or increased scanning infrastructure and personnel at ports.
3. It is not economically feasible to scan only US-bound containers at half of the 600 ports with direct connections to the US.

Introduction

Economic vitality hinges upon global trade. Over 90% of the economic value of global commerce is transported through the maritime domain via containerized cargo. In the post-9/11 trade environment, the global reach of terrorist organizations lends credence that terrorists or states of proliferation concern may exploit containerized cargo. Utilizing maritime shipping networks, terrorists could launch an attack using special nuclear or other radioactive materials in a weapon of mass destruction or radiological dispersal device. The anonymity of containerization requires containers to be opened or examined with special-}

ized equipment to determine contents with any level of certainty.

Based on the threat imposed by seaborne containers, the United States government used regulatory measures to increase maritime security by extending the inspection frontier by requiring the scanning of US-bound containers abroad. On August 3, 2007, President George W. Bush signed into law HR1 (referred to as the 9/11 Act), the “Implementing Recommendations of the 9/11 Commission Act of 2007,” requiring that all US-bound containers be scanned with non-intrusive inspection (NII) equipment to examine cargo density, as well as radiation portal monitors (RPMs) to detect the presence of gamma and neutron radiation.

The 9/11 Act was met with industry criticism over how the legislation would potentially cause delays in supply chains.
and increase logistics costs. Critics also contended that current technology is insufficient to scan the 11.5 million US-bound containers at foreign ports. Some feared that the 9/11 Act would result in container bottlenecks and place tremendous burdens on ports with limited space or capital for scanning equipment installation. Even though many parties provided estimates for the delays and costs associated with the 9/11 Act, we found no officially released approaches to quantify these assertions.

Our goal was to provide a framework to assist stakeholders in:

1. identifying elements of costs and delays along the entire supply chain; and
2. quantifying the trade-offs between costs and delays.

**Taxonomy**

Our case studies led us to develop a “Supply Chain Control – Consumer / Beneficiary Reach” matrix that provides a framework to correlate a business or NGO’s supply chain strengths to the optimum type of contribution they can make in a disaster relief effort (Figure 1). It classifies corporations and NGOs into four quadrants of different roles they play and the different levels of effectiveness they have in disaster relief. The quadrants range from organizations with a limited ability to provide sustainable or immediate aid for disaster relief, to organizations that can be termed “1st Responders” and are highly effective and autonomous in providing large-scale relief.

Interviews with maritime and import stakeholders revealed 2 primary industry concerns:

1. How is the 9/11 Act going to affect supply chains and operations?
2. Who will pay for the implementation and how much will it cost?

Integrating opinions from interviews with our own analysis, a framework was developed to present the potential delays and costs along the end-to-end global supply chain, as shown in Figure 2.

Our research focuses on the impacts of scanning exports at the port of departure. Cost and delay analyses are based on 2 prototypical ports:

1. a small/low-volume export port (referencing Puerto Cortes, Honduras)
2. a large/high-volume export port (referencing Antwerp, Belgium)

**Cost Analysis**

Cost analysis was performed for a consolidated (port authority) level and a segmented (terminal operator) level equipment installation. Scanning at individual terminal operators requires separate primary and redundancy equipment to be installed at each individual terminal operator, as opposed to scanning containers at centralized locations.

Cost estimates were created for initialization and operational costs, with consideration to the entities that may bear these expenses. Initialization costs are defined as equipment procurement, installation, operational testing, civil engineering works, training and communication package costs. Operational costs include ongoing expenses associated with the container scanning equipment, with significant contributions from wages, data transfer and equipment maintenance costs.

Costs are then assessed based on past domestic installations within the US, along with estimates provided by vendors and international seaports. These costs are then broken down to an expected per box fee, assuming that 100% of costs are passed directly to importers.

Cost analysis showed that port authority level implementation of the 9/11 Act results in a lower per box cost than terminal operator level implementation due to greater economies of scale. This highlights the importance of governments and port authorities in taking jurisdictional control of implementation, or at minimum encouraging terminal operators to share scanning resources.
For ports shipping less than 100 TEUs to the US a year, the per box cost of scanning only US-bound containers can amount to tens of thousands of dollars, making it financially unjustifiable to pass all costs to US importers. These ports will need to consider government subsidies, scanning and charging fees across a larger percentage of container volume, or no longer being the last port of loading for US-bound containers. This could add additional costs and transit time to US imports arriving from approximately 300 ports that fall into this category.

### Delays – Truck Congestion

A queuing model was developed to analyze the impact of scanning on truck congestion. Analysis results revealed that queuing delays due to scanning at small-volume ports are trivial. This allows US-bound export scanning to be accomplished with 2 sets of scanning equipment regardless of the US-bound volume, without taking physical lay-out constraints into consideration.

For a high-volume port, the heartening finding is that even for a large port exporting 2.4 million containers annually with as high as 30% US-bound cargo, only a minimum of 3 sets of scanning equipment is needed to ensure minimal congestion.

This result allays industry concerns that high volume ports will require a proportionally large number of scanners to maintain efficiency. It is prudent to note, however, that the congestion analysis performed did not consider space constraints, infrastructural layout issues and the ports’ ability to separate US-bound from non-US-bound cargo, which might also contribute to congestion.

The combination of both cost and congestion analyses reveals the trade-off between cost per container and scanning delays. Amortizing scanning costs over the total export volume results in a lower per box cost but may incur greater scanning queues and truck congestion.

In low-volume export ports, scanning of all exports is likely to be achieved without additional equipment investment and delays; however, at high-volume ports, this effort may require a higher number of scanning systems.

Results from a high-volume port case study show that if the port chooses to scan all its exports without purchasing additional equipment, the per container cost may drop from $45 to $4 but congestion delays will increase to more than 6 hours.

### Table 4

<table>
<thead>
<tr>
<th>Scanning Regime</th>
<th>Exports Scanned</th>
<th>Scanners</th>
<th>Scanning Cost</th>
<th>Queue Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>US-bound</td>
<td>10%</td>
<td>4</td>
<td>$45</td>
<td>0:00:00</td>
</tr>
<tr>
<td>All-Export</td>
<td>100%</td>
<td>4</td>
<td>$4</td>
<td>6:02:23</td>
</tr>
</tbody>
</table>

However, if the port decides to purchase 10 scanners to scan all exports, per box cost will still decrease from $45 to $10 but congestion will also be minimized.
in safety stock since the high demand variability already dominates the variability in lead-time. Products with relatively constant demand (CV less than 0.1) will require a higher percentage increase in inventory.

Conclusion

1. Currently, importers do not have the necessary tools to assess the impacts of the 9/11 Act along their supply chain. Our research clearly identifies cost and delay issues, which cascade beyond the port of departure. In addition, generic quantitative modeling approaches are developed to allow importers to estimate costs and delays at ports of departure. The estimates can then be used to weigh the risks and costs associated with the legislation and formulate contingency plans.

2. Our analyses indicate that the delay and cost impacts of export scanning for the 9/11 Act appears to be less severe than anticipated. Nonetheless, it is prudent for businesses to begin analyzing the impact of the legislation on their supply chains and develop contingency plans to mitigate risks in the future.

As such, it may be more economical for ports to install additional equipment to scan all exports instead of deploying fewer sets of equipment to scan only US-bound containers. This result, however, may be unique only to the particular port studied. Thus, high-volume ports need to examine the trade-offs between scanning costs and delays before determining which subset of container traffic should be scanned. Additionally, information and traffic constraints may increase the difficulty in parsing US-bound from other traffic.

Delays – Secondary Inspections

A Monte-Carlo simulation was developed to estimate the probability of containers missing vessel sailings as a result of secondary inspection delays. Results revealed that the probability of a container missing its vessel could potentially increase up to around 1.5%. Sensitivity analysis of importer inventory shows that the increased risk of containers missing their vessels only requires an additional 0.5% to 3% increase in inventory. The percentage required depends on the coefficient of variation of the product under consideration. Products with high coefficients of variation will require a lower percentage increase

<table>
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<th>Queue Time</th>
</tr>
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<tbody>
<tr>
<td>US-bound</td>
<td>10%</td>
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<td>$4</td>
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</tr>
<tr>
<td></td>
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<td>5</td>
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<td>3:19:30</td>
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<td></td>
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<td>All-Export</td>
<td>100%</td>
<td>10</td>
<td>$10</td>
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</table>

Table 5
Determination of Drivers of Stock-Out Performance of Retail Stores using Datamining Techniques

By Khalid Usman
Thesis Advisor: Dr. Chris Caplice

Summary: This project utilizes data mining techniques to determine the drivers of stock-out performance. Best performing and worst performing clusters of stores were identified using data clustering techniques. Furthermore, logistic regression and multiple ordinary-least-squares regression were used to gain further insights and quantify the drivers of stock-outs.

KEY INSIGHTS:

1. The number of years a retail store has been in operation is an important driver of stock-out performance. Newer stores tend to have higher stock-outs.

2. Greater distance from distribution center to retail stores causes higher stock-outs.

3. Income of the area in which stores are located impacts stock-out performance. Retail stores in high-income areas tend to have lower stock-outs.

Introduction

A stock-out for a retailer is defined as an event where a retailer experiences a demand for an item that is not available on-shelf. Stock-out situations are detrimental for both manufacturers and the retailers. According to a research study conducted by Guen, Corsten and Bharadwaj (2002), in case of stock-out situations retailers incur lost sales 41% of the time, while suppliers lose sales 28% of the time. Recent studies show that the worldwide average for stock-outs is 8.3%, while for the United States it stands at 7.9%.

Stock-outs can be due to business practices or inefficiencies in store operations, distribution center, retailer headquarters or suppliers. According to Gruen, et. al.(2002), the leading causes of stock-out are store ordering (34 percent), store forecasting (13 percent), store shelving (25 percent), distribution center (10 percent) and retailer headquarters (14 percent). Based on this, about 70 to 75 percent of stock-outs are a direct result of retail store practices, which include forecasting, store ordering and shelving.

In this research, three data mining techniques were used to determine the drivers of stock-outs: Multiple-ordinary-least-squares (OLS) Regression, Logistic Regression and Data Clustering. The project was done in collaboration with Unilever and one of its vendor managed inventory (VMI) partners, RetailerCo.1

Analysis and Results

Data clustering technique, utilizing k-means algorithm, was used to group stores in similar clusters. These clusters were formed based on numerous attributes of the stores such as stock-out performance, inventory levels, income of the areas, demographic variables, store delivery day from distribution center, size of stores, distance of stores from distribution center, store layout and the number of years the stores have been in operation. A clustering scheme of 10 clusters was selected and out of these clusters of retail stores, best and worst performing stores were identified, and their characteristics were analyzed.

The two worst performing store clusters were 'Low-income, Newer' stores and 'Newer, Further from DC' stores. The three best performing clusters were ‘High-Income, High-Inventory’ stores, ‘Closer to DC, Older’ stores and ‘High-Income, Smaller’ stores.

Using multiple ordinary-least-squares (OLS) and logistic regression techniques, the following insights were obtained:

Number of years store has been in operation: Newer stores tend to have higher stock-outs. If a retail store has been in operation for less than a year, the probability of

1 Name has been disguised for confidentiality purposes.
stock-out will be 5.2 times higher than if the store has been in operation for more than 5 years. For stores that have been in operation for 1-2 years and 2-5 years, the probability of stock-out is 1.210 and 1.089 times more than stores in operation for more than 5 years, respectively.

Distance of Store from Distribution Center: If the retail store is more than 200 miles from the distribution center, it will experience more challenges vis-à-vis replenishment and stock-outs will be higher. For stores more than 200 miles from distribution center, the probability of stock-out will be 1.229 times (or 22.9 percent) higher than if the store was less than 200 miles from the distribution center.

Income of the area: Income of the area in which a store is located impacts the stock-out performance. If a store is located in a low income area, it has 2.37 more stock-outs per week (for the 8 high moving SKUs) than a store in a high income area. Similarly, a store located in a medium income area on average has 1.63 stock-outs per week more than a store in a high income area.

Store Size: Logistic regression model pointed out that the store size also affects stock-out performance of stores; and smaller stores tend to have lesser stock-outs. If a store has low square-footage, the probability of stock-out is 0.951 times (or 4.9 percent) less than the probability, if the store had a high square-footage. Similarly, if a store has medium square-footage, the probability of stock-out is 0.966 times (or 3.4 percent) less than the probability, if the store had a high square-footage.

Demographic variables (African-American area): None of the stores for RetailerCo were located in predominantly Latin or Asian population areas, so only the impact of African-American population could be modeled. The model predicts that the probability of a stock-out will increase by 14 percent, if the store is in an African-American neighborhood. A high correlation (0.28) between low-income areas and African-American neighborhoods could be one of the underlying reasons.

Average Inventory-on-Hand (IOH): For every one unit increase in the average inventory-on-hand, the probability of stock-out becomes 0.958 (or a 4.2 percent) reduction of the prior probability. More inventory-on-hand will provide a higher safety stock but there are cost implications of raising the inventory in the supply chain as well.

Store Layouts: Store layout was not a significant explanatory variable across different modeling approaches. However, the logistic regression predicted that if a store has Racetrack layout, the probability of stock-out is 0.696 (or 30.4%) times less than the probability, if it was traditional, front-to-back or flipped layout. This could be due to the ease of shelf-replenishment in the race-track layout where the aisles are visible to store staff. Similarly, if the store has a market layout, the probability of stock-out is 0.73 times (or 27%) less than the probability of stock-out, if it was traditional, front-to-back (FTB) or flipped layout.

Delivery day from Distribution Center: The data clustering approach showed that Thursday or Friday store delivery from the distribution center might have some benefits to it in terms of lower stock-out performance of stores, as the replenishment gets done before the weekend rush.

Impact of Stock-outs at the Distribution Center

Other than the insights regarding drivers of stock-out performance, multiple OLS regression analysis was carried out to determine the relationship between the stock-outs at the distribution center and downstream impact at the store level. The models gave the insight that stock-outs at the distribution center level have an adverse impact on sales at the store level. The model developed at the ag-

Figure 1: Stock-out performance of all stores vs. clusters of stores.
Aggregate level across different categories of products predicts a loss of sale of 9.9 cents for every one dollar Xout (Unit Price x Number of items out-of-stock) at the distribution center level. Though, there is a negative implication of stock-outs at the DC level but this is a trade-off decision between the lost of sales at stores versus the extra inventory holding costs at DC.

**Conclusions**

Data clustering technique, utilizing k-means algorithm, was used to group stores in similar clusters. These clusters were formed based on the numerous attributes of the stores such as stock-out performance, inventory levels, income of the areas, demographic variables, store delivery day from distribution center, size of stores, distance of stores from distribution center, store layout and the number of years the stores have been in operation. A clustering scheme of 10 clusters was selected and out of these clusters of retail stores, best and worst performing stores were identified and their characteristics were analyzed.

Based on the insights developed in the previous section, the management of Unilever and RetailerCo should focus on the following aspects:

*Focus on performance of new stores:* New stores have consistently shown bad stock-out performance. A best practices study should be conducted among the older, established stores, and a 'Store Operations Manual' focusing on shelving practices, inventory counts and backroom organization should be developed and used to train the staff and management of newer stores. Stores which have been open for less than a year have the highest incidence of stock-outs and should be the prime focus of training and standardization program.

*Training programs for stores in Low-Income/African-American areas:* Stores in low-income areas, or stores in pre-dominantly African-American neighborhoods, have shown worse stock-out performance as well. RetailerCo should focus on training and standardization programs for the management and staff of these. It should also conduct Failure Mode and Effects Analysis (FMEA) to isolate and determine the main causes of stock-outs in these stores.

*Distance of stores from Distribution center:* Whenever possible, retail stores should be located within 200 miles of the distribution center. This should guide future network design for the distribution centers and stores.

*Store Layout:* Though all types of store layouts do not always correspond to better or worse stock-out performance, some of the insights gained from data-mining point out that Racetrack layout and Market layout have better on average stock-out performance. If there are no significant cost implications, these layouts should be adopted.

**Cited Sources:**

Leveraging Risk Management in the Sales and Operations Planning Process

By Yanika Daniels and Timothy Kenny
Thesis Advisor: Dr. Larry Lapide

Summary: In order to incorporate risk management into the Sales and Operations Planning (S&OP) process, companies must segment their products and customers based on business importance, demand forecast, and order lead time. After completing these segmentation steps, companies can then apply appropriate risk management tactics to mitigate uncertainty in demand and supply.

KEY INSIGHTS:

1. In order to understand how risk can affect sales and operations planning, a company must be aligned on which products and/or customers are most important to the growth and sustainability of the business.

2. A company must know how to identify, assess, and mitigate uncertainty in order to balance supply with demand.

3. Different risks are associated with different product types and customers.

Introduction

Sales and Operations Planning (S&OP) is a process companies use to continually align their supply and demand. The goal is to increase communication between the sales and marketing teams, the operations team, and the finance team so that future sales estimates are in line with production schedules and overall company financial goals. The S&OP process allows top management to arrive at a single number forecast that can be used company wide and to control business operations, integrating long-term strategy into short-term business operations. The S&OP process has been widely used over the last twenty years to open lines of communication and align a company’s supply and demand; however, the use of risk management techniques to mitigate uncertainties in supply and demand has not been widely implemented in the S&OP process. Our research methods included interviewing and surveying S&OP industry practitioners as well as visiting SemiCo, a global semiconductor manufacturer, to observe their S&OP process firsthand. These research methods allowed us to explore how companies can incorporate uncertainty into their S&OP process and to develop our S&OP risk mitigation framework, as shown in Figure 1.

Step 1: Business Importance Scorecard by Product and/or Customer
Step 2: Business Importance vs. Forecastability and/or Order Lead Time segmentation
Decision Making: Implement Tactics

Figure 1: Risk Management Framework
Risk Management Step 1: Developing Business Importance Scorecards

Based on the data generated from our research, the most important step companies can do to mitigate uncertainty in their supply and demand is to segment their products and/or customers based on business importance to ensure the most important elements of a company’s top and bottom line performance are a priority. The first step to incorporating risk management into the Sales and Operations Planning process is to segment a company’s products and customers based on business importance characteristics through a scorecard.

Developing a product and customer scorecard can help a company understand which products and customers are essential to their growth. The scorecard also helps management communicate which products and customers are the top priorities on which employees should focus. For some industries, such as defense and aerospace, segmenting by customer does not provide significant value because there are very few customers, and therefore companies in this industry should focus on segmenting out the most important products. In other industries, such as packaged goods, segmenting business importance on both products and customers makes sense because there are numerous products and customers in this industry. Based on insight gained from our expert interviews, we recommend five key attributes on which companies can measure product and customer business importance. Figure 2 provides an example scorecard for both product and customer segmentation; however, the most important attributes will vary depending on the industry.

The output from Step 1 should be a break down of products and customers into an “ABC” product analysis and/or a “Tier 1/2/3” customer analysis. “A” products are high impact items that require lots of the management teams’ time and resources. “A products” and “Tier 1 Customers” usually follow the 80/20 rule, accounting for only 20% of the product mix or customer portfolio, but providing 80% of company revenue. Thus, these products and customers have a high business importance rating. “B” and “C” level customers usually provide less impact to a company’s revenue and growth. The business importance scorecard will provide an understanding of how customers or products should be segmented. Therefore, the output of Step 1 will be a determination of which products are A, B, or C level and which customers are Tier 1, 2, or 3 level.

Risk Management Step 2: Segmenting For Tactical Decision Making

Once a company has completed the product and/or customer segmentation, the second step is to take each product and customer and assign them to one of the quadrants of a matrix based on their “ABC” score (from the company’s appropriate step 1 scorecard) and either the ability to forecast demand or order lead time, respectively. In Figures 3 and 4, we have developed a matrix for both products and customers.

Products with a variable demand pattern present different risks as compared to those with a stable demand pattern. Low demand patterns also present different challenges and require different plans of attack in balancing the supply and demand. In addition, a company must look at the order lead time requirements of each of their “Tier 1, 2, or 3” customers in order to determine the service levels required for each level of customer importance. Therefore, based on the results of risk management step one (segmentation) and step two (forecastability/order lead time determination) a product or customer is placed into one of the six quadrants on the two matrices shown in Figure 3 and Figure 4.

### Step 2 – Risk Management Tactics: Product

<table>
<thead>
<tr>
<th>Customer Business Importance Scorecard</th>
<th>Score</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Revenue Contribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length of Relationship</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strategic Importance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential for Sales Growth</td>
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<tr>
<td></td>
<td></td>
<td>Portfolio Expansion</td>
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<tr>
<td>Total</td>
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</table>

<table>
<thead>
<tr>
<th>Product Business Importance Scorecard</th>
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<th>Attribute</th>
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<tr>
<td></td>
<td></td>
<td>Revenue and Margin Contribution</td>
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<td>Stage in Product Lifecycle</td>
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<td></td>
<td>Lead Time</td>
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<tr>
<td></td>
<td></td>
<td>Growth Potential</td>
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<td></td>
<td></td>
<td>Product Type</td>
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<td>Total</td>
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Figure 2: Product and Customer Business Importance Scorecards

<table>
<thead>
<tr>
<th>Business Importance</th>
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<th>B-Level</th>
<th>C-Level</th>
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<tr>
<td></td>
<td>Capacity/Inventory/Time Tactics:</td>
<td>Capacity/Inventory/Time Tactics:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.) Range Planning; Produce to Low Demand and Confidence Levels, Maintain Flexible Production Capacity for High Demand and Confidence Levels.</td>
<td>1.) Use Inventory as the Main Mitigation Strategy, as Inventory Write-offs are Low Probability.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.) Postponement of Production Steps</td>
<td>2.) Maintain Excess Production Capacity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capacity/Inventory/Time Tactics:</td>
<td>Capacity/Inventory/Time Tactics:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.) Inventory Buffer</td>
<td>1.) Pre-Build Inventory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.) Multi-sourcing supply contracts</td>
<td>2.) Component Commonality</td>
<td></td>
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</table>

Figure 3: Risk Management Tactics Matrix - Customer

<table>
<thead>
<tr>
<th>Forecastability</th>
<th>High</th>
</tr>
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<tbody>
<tr>
<td>Low</td>
<td></td>
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</table>

- 13 -
**Step 2 - Risk Management Tactics: Customer**

<table>
<thead>
<tr>
<th>Tier 1</th>
<th>Capacity/Inventory/Time Tactics:</th>
<th>Capacity/Inventory/Time Tactics:</th>
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<tbody>
<tr>
<td></td>
<td>1) Reserve Capacity</td>
<td>1) Reserve Capacity</td>
</tr>
<tr>
<td></td>
<td>2) Decentralized Inventory close to customer</td>
<td>2) Decentralized Inventory close to customer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier 2</th>
<th>Capacity/Inventory/Time Tactics:</th>
<th>Capacity/Inventory/Time Tactics:</th>
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<tbody>
<tr>
<td></td>
<td>1) Demand Shaping</td>
<td>1) Demand Shaping</td>
</tr>
<tr>
<td></td>
<td>2) Mix Centralized / Decentralized Inventory</td>
<td>2) Mix Centralized / Decentralized Inventory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier 3</th>
<th>Capacity/Inventory/Time Tactics:</th>
<th>Capacity/Inventory/Time Tactics:</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1) Widen (Pad) Delivery Window</td>
<td>1) Widen (Pad) Delivery Window</td>
</tr>
<tr>
<td></td>
<td>2) Centralized Inventory</td>
<td>2) Centralized Inventory</td>
</tr>
</tbody>
</table>

**Order Lead Time**

Figure 4: Risk Management Tactics Matrix - Customer

Based on which quadrant a certain product or customer is placed into in Figure 3 and Figure 4, we have provided actionable tactics that can be used to mitigate the uncertainty of supply and demand for that product or customer. Figure 5 lists the risk management techniques we identified during our research according to whether the tactic primarily applies to demand or supply side risk and whether it is used to mitigate capacity, inventory or time risk, or all three.

**Putting It All Together: Incorporating Risk Management into the S&OP Process**

In general, the five-step S&OP process, as shown in Figure 6, begins with a data gathering step in which sales, production, and inventory data from last month are pooled along with marketing and sales input. Step-two consists of demand planning, where the information gathered in step one is used by the marketing and sales organization to establish an unconstrained demand forecast. Then, in step three, the operations team analyzes the unconstrained demand plan from step two and makes any restrictions or adjustments to that plan based on production capacity and constraints.

Step-four, the pre-executive meeting, provides an opportunity for middle-managers to iron out issues and problems in matching the demand plan and supply plan from steps two and three, as well as to condense and summarize all unresolved issues so that the executive meeting is productive and makes good use of upper management’s valuable time. Finally in step-five, the executive meeting, the heads of operations, marketing, sales, finance, logistics, and hopefully the CEO, meet to discuss the recommendations established during step four as well as to make final decisions on any unresolved issues from step four in terms of matching supply and demand.

Figure 7 presents a visual example of how our risk management framework can be implemented into each of the five steps of the S&OP process described above. The first step in our risk management framework, the business importance segmentation scorecard, can be done during the data gathering phase of the S&OP process. Then, during the demand planning portion of the S&OP process, a company can place their products and/or customers into the matrices provided in Figure 3 and Figure 4 based on forecastability and order lead time, respectively. In the third stage, called the operations planning phase, the S&OP team can implement the tactics in the product or customer matrices that are most appropriate for mitigating risk. During step four of the S&OP process, the pre-executive meeting team can analyze any gaps in supply and demand and decide which additional risk mitigation tactics are needed to close these gaps. Finally, during the executive meeting, top management can determine the overall company risk management strategy.

**Conclusion**

As supply chains become more complex due to outsourcing, longer lead times, and customization, companies...
have tried to address the balance between demand and supply through S&OP processes that align sales and marketing with operations and finance. While S&OP processes lead to greater alignment with both sides looking at demand, supply, capacity, production and finance for better business results, uncertainty in the demand and supply can lead to stock-outs and mark-downs causing revenue loss for companies. Companies have fallen short in implementing risk management into the S&OP process.

Companies are under pressure to cut costs, optimize through efficient means, and never run out of product. Therefore, there is a need for a mechanism to balance a company’s financial commitments to Wall Street and service commitments to customers, while mitigating any risks that will affect those commitments. A two-fold approach of incorporating risk management into the S&OP process will help companies mitigate uncertainties in supply and demand that might otherwise have impaired their ability to meet business commitments.

Figure 7: Risk Management Framework in S&OP Process
An Engineering Approach to Improving Hospital Supply Chains

By Scott Hsiang-Jen Cheng and Graham Whittemore
Thesis Advisor: Dr. Mahender Singh

Summary: Utilizing supply chain best practices from industries outside of healthcare, a supply chain has been designed and modeled that reduces hospital supply chain costs. The supply chain is centered on patient-specific kits delivered from an offsite warehouse to hospital bedsides. Effective implementation requires that each individual hospital segment their products to determine which items are appropriate for the supply chain.

KEY INSIGHTS:
1. Delivery of patient specific customized kits picked at an offsite warehouse and delivered directly to a hospital bedside will reduce healthcare supply chain costs.
2. Products must be segmented in order to determine which items are appropriately held in the offsite warehouse.
3. Successful implementation of the next generation supply chain is heavily dependent upon change management practices.

Introduction
Over the past decade, most hospitals have been facing the challenges of rising costs. For over seven years, the cost of healthcare has been increasing at a much faster rate than inflation. From the year 2000 through 2005, inflation has risen by 18%, while healthcare premiums increased by 87%. Supply chain management practices account for some of the problems driving these continually increasing costs.

It can be argued that as hospitals in the US look to improve margins through revenue enhancement and cost containment, they regard enhancing the hospital’s procurement and logistical supply chain as an opportunity to control cost, improve patient safety, and optimize staff time. Hospitals are seeking ways to optimize how they both procure and then move medications and medical supplies through their hospitals in the safest, most cost effective manner. Many hospitals, having for years relied on manual processes, are looking to cutting edge technologies and processes both in and outside of the healthcare arena to choose the best strategy to move forward.

Practices such as hording, over-ordering, and leaving inventory management up to nurses within hospitals are some of the factors that have contributed to the current problems. Nurses horde because of the relationship that exists between the doctors and nurses within hospitals; nurses are often reprimanded when there are stock outs. Over-ordering occurs because many of the systems hospitals use to track inventory are manual and outdated. In order to reduce holding costs and stock out occurrences, hospitals may need to update their inventory policies to benefit from the advances made over the past decade in other industries.

The Distributor and Hospitals
In order to probe into the hospital practices, the authors worked closely with HCD, a fortune 500 medical wholesaler/distributor. HCD has developed several long-term
collaborative pharmaceutical and medical/surgical sourcing relationships with hospitals in the United States. HCD provides a vendor managed inventory (VMI) service and stockless inventory arrangement for the pharmaceutical and medical/surgical items they sell. HCD also assists in managing the inpatient pharmacy of these hospitals and installs automatic point of use (APU) systems to manage the local supply of medication and medical surgical products. A key objective of implementation of these systems is to enhance the hospital's procurement and logistical supply chain. The relationship between the hospitals and HCD is viewed by both parties as an opportunity to control cost, improve patient safety, and optimize staff time.

Segmentation

In simple terms, segmentation is to discriminate items into several groups. The homogeneity of the segmented groups allows the standardization of supply chain techniques and reduces the processing costs. Segmentation also helps map the demand and supply channel in a systematic way and lays the foundation for further supply chain optimization.

In order to design supply chains in industries outside of healthcare, a segmentation approach has been successfully taken. Indeed, the complexity and sensitiveness of hospitals would not allow application of these successful approaches directly. To this end, potential segmentation variables are discussed that facilitate applicability to hospitals. Furthermore, the segmentation approach for every hospital may vary and leverage different variables. The following 5 variables are discussed: Criticality, Unit Price, Demand Level, Demand Frequency, and Demand Dispersion.

Five Segmentation Variables

Criticality - Criticality can be expressed with three attributes: Danger of Loss of Life, Quality of Treatment, and Replacement with Other Treatments. The weights and the grading of these three attributes should be obtained via interviews with medical staff at each individual hospital. Among the hospitals included in this research, the weights are different from one hospital to another. This observation coincides with the need for customized supply chain policies for each hospital. Similarly, the expected service level can be customized to each ward and hospital. Stock-outs for high criticality items should either be measured separately or weighted differently in an aggregate analysis.

Unit Price - Unit price is defined as the value of a drug or medical/surgical item per package. However, the packaging method may vary for items that have different uses and may be used in different frequencies among hospitals. Therefore, packages that have different quantities of the same item are treated as different Store-Keeping-Units (SKUs).

Demand Level - In the hospital, medication demand and medical/surgical-item demand are relatively slow-moving. Figure 1 shows the distribution of demand level. The weekly demands of these items vary drastically, from 5,200 units per week to zero demand during the observation period. Specifically, some of the items have zero-demand but the hospitals must still hold safety stock in order to make sure they are ready for emergency situations. In Figure 1, the high-demand items lie only in quadrant 2. The high-demand items are all relatively low value.

Demand Frequency - Demand frequency is the number of transactions over a unit period. A transaction is defined as the action of a nurse or a pharmacist going to the point of use system and attempting to access the items he/she wants, even if the items are not in stock. Figure 2 shows the average weekly number of transactions versus the total average weekly demand of each item. It is clear that there is a group of items with high demand frequencies and with a high demand level. Among these items, the average demand frequencies are above 140 units per week, namely 20 units per day. Relative to other slow-moving items, these items are moving much faster in the hospital. The demand behaviors of these items are similar to fast moving consumer goods and can be compared to make an analogy to develop a specific supply chain strategy.

Demand Dispersion - Demand dispersion is interpreted as the number of locations where demand occurs; the larger the number of locations, the higher the demand dispersion. In a hospital, some of the common medications or medical/surgical items are widely used in many wards of the hospital, while some other items are only intensively used in a few specific wards. Whether the demand is
fragmented or not can also affect the decision-making process in the supply chain network.

**Next Generation Hospital Supply Chain Next Generation Hospital Supply Chain**

Once the correct product mix has been determined using appropriate segmentation variables, our model suggests that these items be stored in an offsite warehouse known as a revolver. As many of the different SKUs from each hospital as possible will be stored in the revolver, critical items must be stored within the hospital wards so that the healthcare professionals have immediate access to these items. Items will be transported from the revolver to the hospital in totes at 20 minute intervals.

The revolutionary idea in the proposed model is that these totes will be filled with product specific to a bed. Nurses and doctors will use electronic handheld devices to place orders that are immediately transmitted to the revolver. The orders will indicate the items that are needed and the bed that the items are for. These items will be processed in the revolver and delivered directly to each bed. The proposed system will reduce the value of inventory hospitals must have on hand, reduce hospital real estate dedicated to inventory storage, reduce the amount of time nurses dedicate to managing inventory and increase revenues derived from hospital beds. Benefits of the next generation hospital supply chain are quantified in table 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Savings/(Loss)</th>
<th>Duration of savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventory Value Savings</td>
<td>$858,564</td>
<td>One-time</td>
</tr>
<tr>
<td>Space Savings</td>
<td>$216,000</td>
<td>One-time</td>
</tr>
<tr>
<td>Revenue from Additional Beds</td>
<td>$250,000</td>
<td>Continuous</td>
</tr>
<tr>
<td>Nurse’s Time Savings</td>
<td>$2,651,740</td>
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</tr>
<tr>
<td>Transportation</td>
<td>($559,000)</td>
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</tr>
<tr>
<td><strong>Total Annual Savings</strong></td>
<td><strong>$3,417,304</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Annual Cost Savings at NEH upon Implementation of Personalized Kit Supply Chain

**Conclusion**

This research concludes that implementation of an offsite warehouse in which inventory is pooled would result in savings for hospital supply chains. The savings would be achieved as a result of a dramatic reduction in inventory holding costs, and also a dramatic reduction in on hand inventory. On hand inventory would be reduced because there would be one stocking location instead of multiple locations throughout the hospital. Benefits of the offsite pooled inventory warehouse would be even greater if several hospitals jointly pooled their inventory in the same offsite warehouse.
Inventory Optimization in a Retail Multi-Echelon Environment

By Rintiya Arkaresvimun
Thesis Advisor: Dr. Larry Lapide

Summary: This project developed an inventory model to find the optimal inventory distribution in a retail three-echelon network that enables high target service level at the stores. Using a multi-echelon approach, the optimal network inventory cost can be achieved by low inventory and service level at the intermediate echelon. The study shows the interrelations between echelons that should be considered when developing each echelon’s inventory policy.

KEY INSIGHTS:
1. A multi-echelon approach can offer optimal inventory distribution, in which the network inventory cost is lower than that of a single-echelon approach. Increasing delivery frequency tends to provide the most significant customer inventory savings for products with high demand variability.
2. The optimal network inventory cost can be achieved by low inventory and service level at the intermediate echelon.
3. There exist interrelations between echelons in the network that should be considered when developing an echelon’s inventory policy to achieve optimal cost and protect against network service failure.

Introduction

Today’s retail market is highly competitive. Having out-of-stock at the retail stores can lead to lost sales or customers. Therefore, it is a retailer’s focus to maintain high product availability on the shelf. Thus high target service level is always set as a retailer’s performance objective. However, focusing only on the service level can confine the drive for operation efficiency, resulting in high inventory carrying cost. As such it is important to effectively allocate inventory in the network to obtain the optimal network inventory carrying cost, while still allowing a high target service level to be achieved at the retail stores.

The focus of this study is to find the optimal inventory distribution in a retail multi-echelon network that offers the lowest network carrying cost while still enabling the retailer to achieve a high target service level. A multi-echelon approach is used due to its benefits over a single-echelon approach. In a single-echelon approach, each echelon sets its own inventory policies, regardless of those of the others. Once the lower echelons determine their policies, the result of their policies are combined and passed up to the upper echelon to be used as input demand to develop its own policy using its performance objective. In a multi-echelon approach, the echelons’ inventory policies are determined simultaneously with a single performance objective by considering the interrelation between the echelons. Using a single-echelon approach in a multi-echelon situation can lead to three serious flaws. First, infinite supply, which is difficult to achieve in reality, from the upper echelons is assumed in a single echelon approach. Second, a single-echelon approach ignores the cost implications of one echelon’s policy on the other echelons. Third, the approach fails to reduce the bullwhip effect, leading to high inventory in the network. Using a multi-echelon approach, these flaws can be eliminated.

Industry Case

The study is based on a case study of RetailCo, a leading pharmacy and convenience store chain in the United States, and SupplierCo, a big manufacturer of private-label products. Three echelons are included in the scope: SupplierCo’s warehouse, RetailCo’s distribution center (DC), and one hundred RetailCo stores. The DC and stores are currently using a periodic, order-up-to-level (OUTL) inventory policy, in which review periods are agreed upon between the involved parties, while the OUTLs are determined by an echelon’s own inventory model.
system based on its performance objectives and criteria. The supplier uses a daily review, OUTL inventory policy, in which a single OUTL is agreed upon by SupplierCo and RetailCo and is applied to all SKUs. Different target service levels are set for each echelon. In this study, a store’s target service level is determined by the number of days without an out-of-stock, while the service level of the DC and the supplier are determined by ability to fulfill demand.

Inventory Model

The echelons’ inventory policies are replicated in the inventory model. Minimizing network inventory carrying cost is set as the objective function; store target service level and minimum OUTLs, determined by the shelf-facing quantities, are set as constraints; and the echelons’ OUTLs are set as decision variables. A heuristic approach combining a simulation and an optimization is used to find the optimal combination of the echelons’ OUTLs.

Results and Analysis

The results show that we can achieve the optimal carrying cost by having low inventory and service level at the DC, while inventory and service levels at the supplier and the stores vary, depending on many factors such as production lead time and minimum OUTLs set at the stores (Refer to Figure 1 and Table 1). The comparison between the optimal and current inventory policies shows the benefit of a multi-echelon over a single-echelon approach currently used in the network by offering 53% lower inventory carrying cost. Highest savings of 67% shown at the supplier highlights the drawback of applying a single inventory policy to all SKUs with different demand characteristics (i.e. high and low demand).

The sensitivity analyses conducted in this study show the interrelations between echelons by estimating the impact of the echelon’s deviation from the optimal inventory policy, the echelon’s performance objective, and the echelon’s service disruption on the other echelons. Three main conclusions are obtained.

The first study was conducted to estimate the impact of DC’s deviation from the optimal OUTL on the other echelons. Results of the DC’s deviation from the optimal inventory policy are shown in Figure 2. Results reveal that reducing the DC’s OUTL, though saving inventory carrying cost, can compromise the network service level. Moving below optimal OUTL, service levels at the stores cannot meet target service level constraints. On the other hand, increasing OUTL does not always improve the lower echelon’s service level. At an OUTL above 110 units, the increase in OUTL only increases DC’s service level, while the store’s service level remains constant. In addition, the study also shows that deviation from the optimal OUTL has more impact on the lower echelons. Supplier’s deviations result in a similar trend.

Second, the target service level set as a constraint at the stores influences inventory distribution and other echelons’ service levels in the network, especially at the downstream echelon. With higher target service levels, the stores and the DC need to maintain much higher inventory level and the DC needs to significantly increase its service level.
from 85% at store target service level of 95% to 92% at store target service level of 99.5%. High inventory at the downstream echelon allows the supplier to relax its service level. The supplier’s service level drops from 99% when store target service level is at 97.5% to 98% when store target service level is at 98.5%. The impact of the changes in store target service level on the echelons’ optimal inventory policies is shown in Figure 3.

Third, analysis shows that supplier’s service disruption resulted from quality failure at the production ending stage marginally reduces its service level but significantly reduces the service levels of the DC and the stores. From Figure 4, only 1% probability of service disruption can result in service levels at the stores dropping below target service level. Considering the substantial impact from the supplier’s service disruption, additional inventory on top of the suggested optimal inventory policies may be needed in the network to protect against the possibility of network service failure.

**Conclusion**

A heuristic multi-echelon approach is used to find the optimal inventory distribution in the network. The study shows the benefit of a multi-echelon over a single-echelon approach by offering lower network inventory carrying cost. To achieve multi-echelon optimal inventory carrying cost, we need collaboration between the echelons to set up inventory policies, integration of demand and inventory information to offer demand visibility, and sophisticated optimization tool to find the optimal inventory policies for the network. The study shows that in a multi-echelon approach, optimal carrying cost can be achieved by having low inventory and service level at the DC and there are interrelations between the echelons’ inventory policies and performances that should be considered when setting up an echelon’s inventory policy to achieve optimal network carrying cost.
Transport Mode and Network Architecture: Carbon Footprint as a New Decision Metric

By Nelly Andrieu & Lee Weiss
Thesis Advisor: Dr. Edgar Blanco

Summary: Climate change and its political, social and economic implications are pushing companies to find ways to reduce the carbon footprint of their supply chains. This project examines tradeoffs between carbon footprint, cost, time and risk across three case studies of United States’ perishable and consumer packaged goods firms and their transportation partners.

KEY INSIGHTS:

1. Transport mode changes and distribution network redesign are opportunities for CO2 reduction. When making these alterations, CO2 reduction often goes along with cost savings. The tradeoffs are risk and time-to-market.

2. Use of partnerships and reference standards —such as GHG Protocol and EPA SmartWay—are found useful for companies seeking to reduce CO2 emissions across the supply chain.

3. Capacity utilization affects CO2 emissions. However, capacity utilization is often ignored in commonly used calculation methods.

Introduction

Carbon dioxide (CO2) and other greenhouse gases including methane and nitrous oxide, are believed to be the most damaging to the environment. The total amount of these gasses emitted directly or indirectly by an entity sum to a firm’s carbon footprint. This research explores the cost, time and risks involved with altering a supply chain using carbon footprint as the impetus for redesign. Our research focuses upon the United States’ perishable and consumer packaged goods (CPG) industry, and examines companies across the supply chain.

Using a survey of 100+ supply chain industry professionals and three case studies based on three different CPG and perishable goods companies and their transportation partners, we provide further insight into the following questions: How much CO2 reduction can be achieved by altering the distribution network and/or switch for different transport mode? What are the tradeoffs in the supply chain for these companies in terms of costs, time-to-market, risks, and carbon footprint?

Below, we present three cases we conducted, and introduce our findings, analyzing the similarities and differences between them.

Case Studies: Three Initiatives to Reduce Carbon Footprint

Our first case study examines SpeedyRailCo, an expedited rail shipper of perishable and other consumer packaged goods, and their relationship with one of the world’s largest retailer, BigRetailCo, for whom SpeedyRailCo ships apples and other produce goods from Washington for distribution to BigRetailCo stores throughout the Northeast. The lead company for our analysis of this relationship was SpeedyRailCo. Before allowing SpeedyRailCo...
to consolidate and ship produce via expedited rail, Big-RetailCo used trucking to carry produce cross-country. Switching to SpeedyRailCo, in 2006, BigRetailCo’s produce shipments were 2% of SpeedyRailCo’s total. This has grown to 5% of total SpeedyRailCo shipments as of 2008. SpeedyRailCo has not yet taken a complete inventory of their carbon footprint, nor do they have a process or methodology in place to do so; however, the expedited rail service is an EPA Smartway Partner. In the second case study we examined the strategic partnership between a large organic yogurt producer, YogurtCo, and its trucking transportation partner, TruckCarrierCo. The lead company for our analysis of this relationship was YogurtCo. With the assistance of data and strategic planning from TruckCarrierCo, YogurtCo explored the possibility to modify its distribution network, moving from a single distribution center (DC) to a 4 DC system, adding 3 additional DCs strategically placed to minimize transportation distances. With TruckCarrierCo’s assistance, YogurtCo was able to use EPA Smartway as a reference standard to define a baseline in 2006, and begin implementation in 2007. WaterCo, the focal firm for our third case study, does not have a single transportation partner; the bottled water firm which ships all of its goods from overseas to the United States, uses an assortment of container vessel carriers and third-party logistics firms for its trucking and warehousing needs. Since announcing a broad initiative to become carbon negative, one of WaterCo’s approaches to minimizing carbon output has been to add additional shipping routes from its production location to the U.S. States. Where previously, all shipping containers were entering the United States through a unique port of entry, since the 4th Quarter of 2007, some of WaterCo’s shipments are now routed to a second port of entry. By maximizing shipping time, more carbon-intensive trucking time is reduced, thus reducing the firm’s carbon footprint. To conduct a baseline measurement, WaterCo used the GHG Protocol, calculating the carbon footprint for the firm from raw material sourcing to bottled water consumption. To certify carbon inventory, WaterCo works with an energy and environmental consulting firm to review and verify carbon inventory, advise them on climate strategy, and increase volume shipped closer to customers. Key information on the context and changes analyzed in our case studies are presented in Table 1. 

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1 EPA SmartWay is an initiative of the U.S. Environmental Protection Agency that offers both detailed calculation tools to companies looking to estimate their carbon footprint, and a partnership program to certify carriers that meet defined environmental thresholds.

2 GHG Protocol was issued jointly by the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD). The GHG Protocol Initiative developed industry-specific calculation tools for companies to conduct GHG inventory.

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### Analysis of the Cases

As our case studies examined only three companies in depth, we hesitate to draw overarching conclusions. Still, there are similarities and differences in our findings on SpeedyRailCo, YogurtCo, and WaterCo.

**Similarities:**

It is impossible to redesign an entire supply chain in one go. In the cases of BigRetailCo with SpeedyRailCo, and WaterCo with its shipping partners, only part of all the goods they ship were transferred to an alternative route—for BigRetailCo, from truck to expedited train, and for WaterCo—from a single shipping route to a dual shipping routes. In the case of YogurtCo, changes have been consistent and incremental as well, including their latest shifts from 1 DC to 4 DCs. Each company involved in our case study looks at both individual network design changes, and how they impact the transport mode, and vice versa. Network design and transport mode must be evaluated simultaneously, because each affects the other. In all three case studies, CO2 reduction and cost-saving created a win-win situation; that is, by decreasing CO2 output, costs decreased as well; reduction in transportation costs and in carbon output were reduced by 11% and 61% respectively for BigRetailCo, 47% and 47% for YogurtCo, 42% and 33% for WaterCo. The tradeoff for Big-RetailCo and WaterCo deliveries is increased time-to-market. Risk is another tradeoff, and YogurtCo and WaterCo are affected, as rail and vessel make their supply chains more vulnerable. From our findings, perhaps because there is so much redundancy in the U.S. road network, trucking is the most reliable way to transport goods from point-to-point. In switching to rail or vessel, risk management should go hand-in-hand with network redesign. Another risk, and consequence of increased time-to-market is an increase in inventory stock level. Forecasting and stock management thus require more attention.

All three firms in our case study decided to approach either EPA Smartway or GHG Protocol as a reference standard to calculate carbon footprint.

**Differences:**

Although these companies have the same objective, reduction of the carbon footprint of their distribution network, none of them adopted the same approach: two companies decided to look first at change in transport mode; the other one selected network redesign as the primary objective.

The approaches of these companies differ not only on a tactical level, but also on a strategic level. YogurtCo and WaterCo appear to be driven primarily by the positive publicity their efforts can generate, while for BigRetailCo cost and convenience were looked at in parallel with environmental impact. Table 1 summarizes the key results discussed above.
### Table 1: Context and Summary of Results – Impacts on Cost, Time, Risk, and Carbon Emission

<table>
<thead>
<tr>
<th>Context</th>
<th>SpeedyRailCo and BigRetailCo</th>
<th>YogurtCo and TruckCarrierCo</th>
<th>WaterCo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Partner</td>
<td>BigRetailCo</td>
<td>YogurtCo</td>
<td>WaterCo</td>
</tr>
<tr>
<td>Product</td>
<td>Apples and other Produce</td>
<td>Organic Yogurt</td>
<td>Bottled Water</td>
</tr>
<tr>
<td>Transportation Partner</td>
<td>SpeedyRailCo</td>
<td>TruckCarrierCo</td>
<td>Multiple Partners</td>
</tr>
<tr>
<td>Transport Mode</td>
<td>Expedited Rail</td>
<td>Trucking</td>
<td>Container Vessel and Trucking</td>
</tr>
<tr>
<td>Leading Company for Case Study</td>
<td>SpeedyRailCo</td>
<td>YogurtCo</td>
<td>WaterCo</td>
</tr>
<tr>
<td>Change Introduced</td>
<td>Switch to SpeedyRailCo instead of Truck</td>
<td>Modify Distribution Network to Move from 1 DC to 4 DCs Strategically Placed Across the US</td>
<td>Maximize Length of Shipping Route to Minimize Trucking Distance</td>
</tr>
<tr>
<td>Tactics</td>
<td>Date of Change Implementation</td>
<td>2006- 2% of SpeedyRailCo Transportation; by 2008, 5% of SpeedyRailCo Shipments</td>
<td>2006- Definition of a Baseline; 2007- Beginning of Implementation</td>
</tr>
<tr>
<td>Reference Standard</td>
<td>N/A, although SpeedyRailCo is an EPA Smartway Partner</td>
<td>EPA Smartway</td>
<td>GHG Protocol</td>
</tr>
<tr>
<td>Partnerships with Carriers</td>
<td>Customer-Supplier Relationship</td>
<td>Strategic Partnership</td>
<td>No Long-Term Partnerships; Selection of Carrier based on Costs</td>
</tr>
<tr>
<td>Partnerships with Consultancies</td>
<td>No Specific Partnership</td>
<td>Close Partnership with the EPA SmartWay.</td>
<td>An Energy and environmental consulting firm reviews and verifies carbon inventory; advice on climate strategy</td>
</tr>
<tr>
<td>Scope of Change</td>
<td>Dollar Value of the Good Shipped Impacted by the Change (in $)</td>
<td>$19 Millions</td>
<td>$290 Millions</td>
</tr>
<tr>
<td></td>
<td>Transportation Cost prior to the Change (in $)</td>
<td>$6.1 Millions</td>
<td>$13.4 Millions</td>
</tr>
<tr>
<td></td>
<td>Transportation Carbon Footprint prior to the Change (in metric tonne of CO2)</td>
<td>5,300</td>
<td>13,600</td>
</tr>
<tr>
<td>Impact</td>
<td>Transportation Cost Savings (in $)</td>
<td>$0.7 Millions (I.e. -11%)</td>
<td>$5.8 Millions (I.e. -47%)</td>
</tr>
<tr>
<td></td>
<td>Transportation Emission Reduction (in metric tonne of CO2)</td>
<td>2,600 (I.e. -61%)</td>
<td>6,500 (I.e. -47%)</td>
</tr>
<tr>
<td></td>
<td>Transportation Cost Savings per Emission Reduction (in $/metric tonnes)</td>
<td>$270</td>
<td>$900</td>
</tr>
<tr>
<td>Time-to-Market</td>
<td>Cross-country transportation: 5 days with SpeedyRailCo vs. 3 days by truck</td>
<td>Push inventory closer to customer. Might reduce delivery time by 4 days for delivery to farther customers.</td>
<td>The new route takes 4 to 6 weeks vs. 2 to 4 weeks for the previous route.</td>
</tr>
<tr>
<td>Risk</td>
<td>Risk is minimal and high consistency. As of January 2008, the most a SpeedyRailCo train has ever been late is 6 hours (three late deliveries out of 70 total train runs).</td>
<td>A decentralized network will be more complex for YogurtCo to put in place and maintain. A move towards a A decentralized network will necessarily drive inventory up.</td>
<td>Switch to the new route pushes WaterCo to increase inventory. The increase of the inventory level without deep analyses might result in the degradation of service level and to the augmentation of the occurrence of stock-out.</td>
</tr>
</tbody>
</table>

### Conclusion

We have found that there is no single objective for firms trying to cut carbon emissions. There is also no single solution to limit CO2 and equivalent emissions. According to our findings from 100+ supply-chain professionals, the primary drivers for companies planning to engage in greener supply chain practices are (in order): (1) reputation, (2) to cut costs, and (3) anticipation of government regulation. In terms of implementation, although we focused only on the dispatch of products from the grower/ manufacturing facility to the customer’s distribution center, we can already see how a partial change to the supply chain can dramatically decrease transportation costs and CO2 emissions. However in our analysis, inventory costs are never taken into account; neither is the effect of capacity utilization on carbon footprint. From our findings, inventory costs and effect of capacity utilization are of tremendous importance; we recommend continued analysis of this area for further study.

However, these limitations should not affect our main strategic recommendations. We recommend partnership between transport and perishable/CPG firms as a strategic advantage for firms looking to reduce CO2 emissions across a supply chain. Partnering allows exchange of information, and helps companies gain confidence in a new and unregulated arena. Also, we recommend adoption of a reference standard such as GHG Protocol or EPA SmartWay. Reference standards allow for transparency, easier partnership, comparison within and between firms, and broader recognition for CO2 reduction efforts.
The Impact and Dynamics of Centralization in Supply Chain Decision-Making

By Guruprakash Rangavittal and Tae-Hee Sohn
Thesis Advisor: Dr. Chris Caplice

Summary: This thesis examines the relationship between centralization in the supply chain organization of companies, cost structure and the factors prompting companies to either centralize or decentralize their supply chain organization.

KEY INSIGHTS:

1. Strategic functions are centralized and operational functions are decentralized, while tactical functions tend to be centralized or decentralized depending on the business context.

2. The two most important factors for centralizing or decentralizing in any function across industries were customer requirements and cost considerations. Strategic functions were centralized for cost considerations and operational functions were influenced by customer requirements.

3. Companies that have a hybrid structure, where strategic functions were centralized and operational functions were decentralized, were able to achieve the lowest cost.

Introduction

Companies adopt different structures for their supply chain organization. While one company might retain supply chain decision making at the corporate level, another might delegate supply chain decision making to the business units. Since supply chain organizations are critical to corporate success, it is important to understand the dynamics that shape supply chain organizational structure.

Centralization and Strategic Importance of Functions

For our research, we categorized supply chain functions into three broad groups – strategic, tactical and operational as defined in Table 1. Such a categorization will enable us to explore centralization in the supply chain organization at a granular level.

The survey results showed us clearly that strategic functions are centralized and operational functions are decen-
talized, while tactical functions are either centralized or decentralized depending upon the business context for our respondent companies.

<table>
<thead>
<tr>
<th>Plan/Execute</th>
<th>Strategic</th>
<th>Tactical</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Long - Yearly</td>
<td>Medium - Quarterly, Monthly</td>
<td>Short - Daily, Weekly</td>
</tr>
<tr>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Examples</td>
<td>- Long-term Capacity Planning</td>
<td>- Transportation Planning</td>
<td>- Order Fulfillment</td>
</tr>
<tr>
<td></td>
<td>- Sourcing</td>
<td>- Inventory Planning</td>
<td>- Order Management</td>
</tr>
<tr>
<td></td>
<td>- Short-term Demand Planning</td>
<td>- Manufacturing Planning</td>
<td>- Shipment Handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Shipment Handling</td>
<td>- Internal Improvement</td>
</tr>
</tbody>
</table>

We obtained this result by conducting k-means cluster analysis. (k=3) of respondent companies on the basis of the centralization of their supply chain functions. We created three distinct groups based on whether they were highly centralized in their supply chain functions, named as “centralized cluster”; highly decentralized, named as “decentralized cluster”; or had a combination of centralization in strategic functions and decentralization of operational functions, named as “hybrid cluster”. Our analysis revealed that the hybrid cluster companies had the lowest cost.

**Factors Influencing Centralization**

We also evaluated the factors (among supply conditions, customer requirements, government regulations, competitive situation, cost considerations, and capacity constraints) that influence companies to centralize or decentralize their supply chain functions. The factor analysis showed us that:

(a) **Cost was the key driver for centralizing strategic functions, and customer service was the key driver for decentralizing operational functions for our respondent companies.**

This result is intuitive though not obvious because strategic functions are applicable to the entire organization but not tailored to a business unit and hence, it made good economic sense to centralize strategic functions and operational functions by their nature are customized to a particular need. Once again, it made good economic sense to decentralize operational functions.

(b) **Industrial product manufacturers and consumer product manufacturers were influenced by similar factors. However, industrial product manufacturers had cost as a dominant factor, while customer requirements dominated the structure design for consumer product manufacturers.**

Industrial goods are typically made to specifications and hence tend to focus on costs, whereas consumer goods manufacturers have to compete among other players to gain mindshare and a cost focus might not give them adequate competitive advantage.

(c) **“Customer requirements” was a critical driving factor for logistics service providers.**

**Cluster Analysis on Centralization and Cost Structure**

Our research also showed that companies that centralize their strategic functions and decentralize their operational functions, (which we call the hybrid structure), achieved the lowest cost.

**Dynamics of Centralization**

After evaluating the current practices in industry, we iden-
Identified three key factors influencing centralization or decentralization of the supply chain organization in companies:

- **Cost** - Companies striving to achieve a target cost based on competitor prices tend to centralize their supply chain functions to exploit the resulting economies of scale.
- **Customer Service** - Companies that want to provide a high level of customer service to their customers tend to decentralize their supply chain functions.
- **Control (risk and incentive)** - "Control" is a soft factor, which can be explained through two key dimensions within the control factor: risk and incentive.

Any of these three factors - cost, customer service, or control - can dominate in an organization and the dominant factor would structure the supply chain organization to be either centralized or decentralized. These factors also influence the transitions and oscillations in the organization as priorities change or when products mature.

**Case Study 1 – Sourcing at the Leading Consumer Products Company**

To test out our model, we examine the case of a company, a maker of mobile computing cases and accessories. This company is based in Southern California and sources a majority of its products from manufacturers in China. The different business units buy goods directly from suppliers in China and Taiwan. The company recognized the potential of integrating the sourcing function and resorted to centralizing it to a central location. However it faced a number of challenges:

- longer sourcing decisions and difficulties in maintaining the high level of customer service;
- misalignment of incentives at the region created resistance from local business units; and
- high transportation cost.

This resulted in a situation where the company had to discontinue the centralized procurement process and revert to the previous approach. The incentive misalignment can be thought of as a dysfunctional "control" factor in the organization, which was not aligned to the change in the corporate strategy. The "cost" factor was motivating the company to centralize; the "customer" factor was motivating the company to decentralize.

Without adequate processes in place the company was unable to convert a corporate strategy into reality – a classic illustration of transitions and misaligned processes in that organization.

**Case Study 2 – Shipment Handling at the Pharmaceutical Company**

As another evaluation of our model, we present the case of a leading pharmaceutical and animal health company that provides medical products and vaccines for livestock, pets and wildlife. The company has a very high market share with more than 60 to 70% in its top selling products. With fierce competition in the industry, high customer service level is a critical success factor.

To accommodate the business needs, the company decentralized its shipment handling so that decisions can be made closer to the customers. This decentralization of shipment handling caused additional inventory holding and some redundancy, but the reduction of lost sales was attractive.

With this structure, the company was able to achieve high levels of customer service. At the same time to reduce costs, the company outsourced most of its operational functions and even some part of its tactical functions. This enabled the company to make optimal decisions under multiple constraints and still achieve low supply chain costs.

This case is an excellent illustration of a company that has aligned processes to not violate any of the factors. The company is able to achieve high levels of customer service by decentralizing its operational functions, manage the "cost" factor by outsourcing, and retain control at the centre. The company’s close partnership with its partner has enabled it to lower costs, build trust, and yet achieve the level of control that is vital for a successful realization of corporate strategy.

**Conclusion**

Our research showed us that strategic functions are centralized for cost considerations, and operational functions are decentralized to improve customer service in our respondent companies. We also found that companies that centralize their strategic functions and decentralize their operational functions are able to achieve the lowest supply chain costs as a percentage of sales. The results, however, cannot be generalized and any recommendation will have to take into consideration the unique business context of the company and environmental situation.
Complete List of MLOG 2008 Theses

**An Assessment of the Value of Retail-Ready Packaging** - By Ling Burke & Kathy Jackson
This research project assessed the use of retail-ready packaging (RRP) across varying retailer types and products to determine conditions where RRP provides a net benefit for retailers. Taking into account the supply chain benefits and costs for the retailer, six U.S. retail channels were selected for this study.

**Product & Customer Profiling for Direct Store Delivery (DSD)** - By Liang Chen
This research collected industrial and researchers' opinions about the value and suitability of the DSD model and analyzed the benefits of the DSD model by building two models: the generic distribution model and the costs of stock-out model. Besides company strategy, economy of scale and geographic locations, the research proves that the DSD model is most suitable for products with high volume, high velocity and high demand variations.

**Green Automotive Supply Chain for an Emerging Economy** - By Gene Fisch, Jr. and Tien Song Paul Neo
This project developed requirements for a sustainable green automotive supply chain within a start-up enterprise entering the Indian emerging market. A supply chain-wide environmental management system, based on the ISO14001 standard, is used to integrate the identified green solutions for implementation and improvement within an auditable framework.

**Evolutionary Challenges of Home-Based Healthcare** - By Katie Fowler
This project studied the viability, projected growth, and sustainability of home-based healthcare on the basis of affordability, acceptability, and availability. Three firms, two manufacturers and one pharmaceutical were researched and interviewed to determine their strategies to succeed in the home healthcare market. Conclusions comprise observations about how the dynamics of stakeholders are interrelated, and strategies are suggested for the sustainable growth of home-based healthcare.

**Network Flow Design & Safety Stock Placement for a Multi-Echelon Supply Chain** - By Hitesh Gupta
This study developed a three stage procedure for the design of network flow and placement of safety stock in a multi-echelon supply chain shared by a large consumer goods manufacturer and a prominent retailer. The procedure provides a way to optimize the supply chain reducing the logistics cost, while achieving desired customer service levels.

**A Multi-Echelon Supply Chain Model for Strategic Inventory Assessment Using a Kanban Replenishment System** - By Philip Hodge and Josh Lemaitre
This project developed a simulation model to determine the optimal inventory position when using a Kanban replenishment system for a heavy machinery manufacturing company. The model uses a stepwise optimization approach, targeting the total relevant cost as the objective function. We created for the company a generalized consumption-based treatment, which predicts optimal inventory settings for parts within 3 bins’ accuracy.

**Supply Chain Planning Decisions under Demand Uncertainty** - By Yanfeng Anna Huang
This project developed a three-step approach to analyze and optimize supply chain designs under demand uncertainty. This approach adopts a Monte Carlo simulation and real option analysis method in conjunction with supply chain models. Its spreadsheet implementation was used to analyze ocean shipping plans and inland trucking plans.

**Customer Focused Collaborative Demand Planning in Hi-tech Industry** - By Ratan Jha
This project proposes a solution to leverage collaborative forecast information for planning using quantitative techniques. A statistical forecast is generated using top-down and bottom-up approach. A joint forecast, which is a forecast weighted by statistical and collaborative forecast is then generated. On an average, the joint forecast was much more accurate than either the collaborative or the statistical forecast.

**Vendor-Managed Inventory Forecast Optimization and Integration** - By Xihang (Eastman) Kou
This project developed a novel way of measuring and comparing account level Vendor-Managed Inventory forecasts with traditional high-level demand planning forecast. Insights were developed on how to integrate this valuable forecast and inventory information upstream into the demand planning process to effectively improve supply chain forecast accuracy.
The Impact of “Never Run Out” Policy: Assured Supply Chain with Dual Reorder Point Expediting - By Gil Su Lee
This project developed the (s1, s2, Q) policy, a policy with dual reorder points to expedited orders through a faster mode of transportation. An expedited order is triggered by a sudden change in demand or lead time to prevent a stock out by taking preemptive action, when there is a risk of a stock out. Using heuristic algorithms and simulation, it finds a normal reorder point and an expedited reorder point where the total supply chain cost is minimized and savings can be made, while keeping a service goal of 100% cycle service level.

Evolutionary Supply Chain Risk Management: Transforming Culture for Sustainable Competitive Advantage - By Romain Lévy
Summary: This project proposes a comprehensive framework to supply chain risk management based on the state-of-the-art in academia and business, and applies it to a CPG company to develop a case study. The research also draws from fields outside the normal realm of supply chain risk management, proposing notably a market approach to supply chain risk management.

Framework for Selection of Distribution Strategies
By Chunlin Li
This study reviewed distribution strategies and established a framework for the selection of distribution strategies. In addition, this project analyzed advantages and disadvantages of utilizing different distribution strategies. Through case analysis, the study evaluated the benefits and costs of applying the distribution center model for the seed industry and addressed the issue of demand lags by shaping the demand.

Analysis of Cost versus Reliability in a Multi-Echelon Supply Chain for a Chemical Plant - By Nan Li & Guanghao Zhang
The object of the thesis is to develop a simple approach or heuristic for managing various types of uncertainty within a chemical production/inventory system. Then the company can use it for production planning to minimize the total cost at any required Cycle Service Level (CSL) under variable demand’s production reliability.

Carbon Reduction in Supply Chains: the Strategic Case - By Nicholas H. Macan
This project examines the strategies used by firms to reduce greenhouse gas emissions from their supply chains. It analyzes the performance in emissions reduction of forty firms, the twenty largest in the UK and US, and expands upon this analysis through a detailed discussion of specific behavior by firms such as Wal-Mart, Tesco, Nestle and Railex. Two types of emission reduction strategy, cost strategies and revenue strategies, are identified and developed.

Home-based Healthcare: Issues and Challenges - By Prashant Nagpure
This report elaborates on the concept of home-based healthcare using the synthesis of various published healthcare research, recent developments in technology, and scenario-based analysis of healthcare delivery in the future. Using the underlying assumption that care delivered at home could reduce healthcare costs due to prevention, the report presents a model of home-based healthcare and a few propositions that are key for delivering such healthcare.

Strategies for High Volume Supply Chains in India - By Don J. Palathinkal
This research evaluated supply chains for high volume products in India. Case studies of PepsiCo India and Tata Motors, two multinational companies operating in India were used to identify supply chain challenges such as obsolete manufacturing practices and inadequate transportation infrastructure of the Indian emerging market. The case study analyses compared with multinationals operating in the U.S., then provided information on various successful strategies for supply, product design and manufacturing, and distribution in India.

The Impact of Assured Supply Inventory Policies - By Daniel Stanton
This research presents a case study of a distribution center in a fast food restaurant supply chain, where the replenishment policy is “Never Run Out.” Supply chain costs and configurations at the distribution center are analyzed, and alternative supply chain strategies are suggested. These results are incorporated into a total relevant cost analysis, and applied to the decision between alternative transportation modes.

Customer Service Driven Supply Chain Segmentation - By Prakit Worawattananon
This thesis develops a model for a company to set up its supply chain segmentation based on customer services. The paper introduces the “Push-Pull Segmentation Model” which is the model that balances company’s and customer’s perspectives in the segmentation process; demonstrates how to implement the model by applying it to a case study; and shows results from this case.
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