Analyzing the Vehicle-to-Grid (V2G) Potential for Electric and Plug-In Hybrid Fleets

Vehicle-to-grid (V2G) describes a system where electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) can connect to the electric grid to provide ancillary services, such as frequency regulation, to grid operators. This thesis evaluates the opportunities for V2G-enabled EVs and PHEVs to participate in the regulation services market and lower their net costs, making them more cost competitive with conventional vehicles. We build a ten-year net cash flow model for a fleet of delivery trucks to assess the costs and benefits of adopting this technology. To project potential V2G revenue, we utilize a simulation model developed by a grid system operator. Based on exploration of numerous scenarios we determine which combination of factors produce the greatest overall benefit. Our results indicate that EV and PHEV fleets offer lower operating expenses for urban pickup and delivery services. In addition, fleet managers can expect to offset 5-11% of the total cost of ownership with V2G revenue.

Preserving Shelf Life and Reducing Reefer Fuel Consumption in Fresh Produce Distribution

Information collected in real-time during the transportation process can be used to produce predictive models for fuel efficiency and product rejections. Although future study is needed to refine the model for product rejections to the point of deployment, a clear framework exists for development of these tools.

Supply Chain Strategy in Post-Earthquake Haiti

This project focused on developing segmentation factors for an international, non-profit, healthcare organization. Utilizing the data for over 500 products currently in use at medical sites throughout Haiti, a series of segmentation factors were developed. These factors were then combined in multiple methods to show the effects of implementing segmentation across the supply chain.

Collaborative Direct to Store Distribution: The Consumer Packaged Goods Network of the Future

This project developed an analytical decision tool to quantify the impacts of employing multi-manufacturer collaborative distribution for promotion fulfillment in comparison to two traditional distribution approaches. In a case study, the model solution indicated that collaborative distribution is a viable strategy, and that optimizing distribution between both manufacturers’ networks creates value across the supply chain.

Incorporating Cycle Time Uncertainty to Improve Railcar Fleet Sizing

In this research, we address the issue of developing a method for a private fleet manager to determine the appropriate number of railcars in a fleet. We focus on incorporating the variability of railcar cycle time into the fleet-sizing decision. In addition, we recommend a process that enables fleet managers to use distribution fitting and simulation to understand the expected requirements of their fleet capacity. Finally, we suggest an economic approach to making the fleet sizing decision.

Risk Sharing in Contracts: The Use of Fuel Surcharge Programs

This project evaluates the financial implications to shippers and motor carriers in the United States truckload (TL) transportation industry of modifying the compensation structure of fuel surcharges. Fuel surcharges (FSCs) are contracts added as addendums to payment of service (called the line-haul rate in the transportation industry) that enable the sharing of fuel price volatility between shippers and carriers.

Improving a Sustainable Packaging Delivery System

This project analyzed a pilot reusable tote program implemented by a consumer products company that was suffering from an unsustainable attrition rate. We identified key factors behind tote attrition and designed a new program for implementation at MIT that will better address these factors, adding proof of concept to this innovative sustainable supply chain initiative.
Introduction

Welcome to the 2011 MIT Supply Chain Management Program Research Journal

The projects included in this journal were selected from the fourteen projects submitted by the SCM Class of 2011 at the Massachusetts Institute of Technology. The articles are written as executive summaries of the master’s thesis and are intended for a business rather than an academic audience. The purpose of the executive summaries is to give the reader a sense of the business problems being addressed, the methods used to analyze the problem, the relevant results and the insights gained.

The articles included in this publication cover a wide selection of interests, approaches, and industries. These projects were developed in partnership with companies ranging in size from startups to the largest companies in the world. They cover industries as diverse as office supplies, fresh produce, consumer goods, railroads and trucking. They also include humanitarian logistics (Haiti) and green supply chain issues (electric cars).

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

The 9-month SCM program is designed for early to mid-career professionals who want a more in-depth and focused education in supply chain management, transportation, and logistics. The class size each year is limited to 30-40 students from around the globe and across all industries. The Master’s Thesis project gives the students a hands-on opportunity to put into practice the learnings that they are receiving in their coursework.

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

Happy Reading!

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Analyzing the Vehicle-to-Grid (V2G) Potential for Electric and Plug-In Hybrid Fleets

By Kristen Nordstrom and Andres De Los Rios Vergara
Thesis Advisor: Dr. Jarrod Goentzel
Industry Advisor: Clay Siegert, XL Hybrids

Summary: Vehicle-to-grid (V2G) describes a system where electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) can connect to the electric grid to provide ancillary services, such as frequency regulation, to grid operators. This thesis evaluates the opportunities for V2G-enabled EVs and PHEVs to participate in the regulation services market and lower their net costs, making them more cost competitive with conventional vehicles. We build a ten-year net cash flow model for a fleet of delivery trucks to assess the costs and benefits of adopting this technology. To project potential V2G revenue, we utilize a simulation model developed by a grid system operator. Based on exploration of numerous scenarios we determine which combination of factors produce the greatest overall benefit. Our results indicate that EV and PHEV fleets offer lower operating expenses for urban pickup and delivery services. In addition, fleet managers can expect to offset 5-11% of the total cost of ownership with V2G revenue.

KEY INSIGHTS
1. Adopting an EV or PHEV and participating in V2G technology can provide savings in overall costs with respect to internal combustion engine vehicles (ICE). Higher capital and infrastructure investments are offset by significant savings in operational expenses.
2. The V2G revenue opportunities with ramp down only regulation service, absorbing excess energy, offset 5-7% of the total fleet cost and with ramp down & up service, both absorbing and providing energy, range from 9-11%.
3. The design mix of charger capacity, battery size, battery state of charge has an important impact on V2G revenue potential. Flexible operations having the ability to adjust fleet operating schedules can realize notable increases in marginal V2G revenue.

Introduction
The common characteristic that enables electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) to participate in vehicle-to-grid technology (V2G) is their rechargeable battery: the source of all or part of the energy required for propulsion. In theory, V2G could be a viable way to improve the cost-effectiveness (and promote the adoption of) EVs and PHEVs since revenue can be generated through participating in the energy and ancillary services markets. Our study examines the benefits of V2G at a fleet-level perspective, focusing specifically on corporate fleets of grid-enabled electric and plug-in hybrid electric trucks that are used on a daily basis to deliver products and services. We treat their batteries in aggregate and model the revenue potential for participating in the frequency regulation component of the ancillary services market in New England. Through simulation, we determine the revenue potential of V2G in this market. Finally, we assess how this revenue offsets the capital and operating costs to improve the business case for adopting EVs and PHEVs in corporate fleets in the future.

Fossil fuels are currently the main source of energy for on-road transportation in the United States (US). As fuel costs rise, businesses struggle to keep operating expenses low for internal combustion engine (ICE) vehicles. A
A conversation with the fleet manager for a large home and office delivery company confirmed that its new electric vehicle fleet was attractive due to low energy and maintenance costs and favorable acceptance by drivers. While EVs and PHEVs provide lower overall operating costs, they continue to remain a more expensive capital investment than conventional fossil fuel vehicles due to the high battery costs and lack of scale in the marketplace. An EV or PHEV fleet, when aggregated in a sizeable number, also constitutes a new load that the electricity system must supply.

However, such a fleet also represents a resource for the grid operator. The bi-directional power capability of the EV and PHEV make them well suited to provide ancillary services to the grid. Figure 1 contains a pictorial description of V2G. Fleets of vehicles can connect to the grid to provide services to the utility. The utility is connected to the vehicles as well as to the customers they service.

![Vehicle-to-Grid Technology](image)

**Figure 1: Vehicle-to-Grid Technology Photo Description**

**Methodology and Model Overview**

Due to the nascency of V2G and the high degree of uncertainty in the future of the technology, we used a simulation model to determine the V2G revenue potential for corporate fleets. We combined these revenue projections with the investment, infrastructure, and operating costs for each vehicle type (EV, PHEV, and ICE) using a 10-year net cash flow analysis. Interviews with fleet managers who have deployed EVs and PHEVs yielded realistic investment and cost estimates for the cash flow projections. Table 1 is a breakdown of the different cost components associated with each vehicle type.

Working with the ISO New England to understand the market for ancillary services, we decided to focus V2G revenue from frequency regulation (or regulation services). Regulation tracks the moment-to-moment fluctuations in customer load (demand) and corrects for the unintended fluctuations in generation (supply). If the load exceeds the generation, the grid will request an energy resource. If the generation exceeds the load, the grid will request a storage resource. Figure 2 is a depiction of the daily load pattern for a summer day in New England. The difference between actual demand and forecast demand is translated into area control error.

![ISO New England Electric Load Fluctuation](image)

**Figure 2: ISO New England Electric Load Fluctuation**

**Source:** (U.S. Energy Information Administration, 2011)

<table>
<thead>
<tr>
<th>Cost</th>
<th>EV</th>
<th>PHEV</th>
<th>ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital costs</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Infrastructure costs</strong></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operating costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Diesel</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Battery</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Controller</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charger and wiring</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brakes</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ICE Engine</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Electric Motor/Generator</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**Table 1: Cash Flow & Cost Revenue Components Table**
Figure 3 shows the area control error (ACE) signal for an hour-long period from 7 AM – 8 AM. The grid is at equilibrium at zero MW and the signals fluctuate around this point. When the signal is greater than zero MW the grid is requesting energy from its regulation service providers. When the signal is less than zero MW the grid is providing energy to its regulation service providers.

The market for regulation services comprises three different payments: a capacity payment, a service payment, and an opportunity cost payment. The capacity payment is based on the maximum capacity contracted from the vehicles, regardless of whether it is used or not. The service payment is based on the absolute sum of ramp up (discharging of the battery) and ramp down (charging of the battery). The opportunity cost payment compensates for revenue the provider forgoes by not generating energy while participating in the service.

We modified a simulation tool from the ISO New England that models the regulation services market. We altered the tool to meet the needs of an urban delivery fleet, i.e. to specify which hours the V2G resource is available and to ensure the vehicle's batteries are completely charged for departure the next morning.

Preliminary Results and Sensitivity Analysis
Our analysis projected cash flows for a 250-vehicle fleet that provides pickup/delivery services over routes 70 miles in length. We considered two different approaches for providing regulation services to the grid: (1) “ramp down” V2G, where the vehicle only responds to signals when supply exceeds demand, and thus only absorbs energy from the grid; and (2) “ramp up and down” V2G, where the vehicle responds to positive and negative signals and the battery both charges and discharges energy as requested. We then compared the total overall costs, including the capital investment, infrastructure, and operating costs for each vehicle. Following this analysis, we compared the total cost of ownership – investment and operating cost less V2G revenue – over the ten-year period.

Table 2 shows the results our base case scenario for “ramp up and down” vehicle-to-grid.

<table>
<thead>
<tr>
<th>METRICS</th>
<th>EV</th>
<th>PHEV</th>
<th>ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital &amp; Infrastructure Investment ($)</td>
<td>$27,770,000</td>
<td>$14,850,000</td>
<td>$12,500,000</td>
</tr>
<tr>
<td>Operating Cost ($)</td>
<td>$6,302,790</td>
<td>$18,059,959</td>
<td>$20,698,377</td>
</tr>
<tr>
<td>V2G Revenue ($)</td>
<td>$3,257,213</td>
<td>$3,042,820</td>
<td>$0</td>
</tr>
<tr>
<td>Total Cost of Ownership ($)</td>
<td>$30,815,496</td>
<td>$32,605,139</td>
<td>$33,198,377</td>
</tr>
</tbody>
</table>

Table 2: Ramp Up & Down V2G Base Case Results

While the EVs had higher upfront investment, their operating costs were significantly lower than PHEVs and ICE vehicles, resulting in the lowest cost of ownership over the 10-year period. It was surprising that the EVs also had much higher V2G revenue than PHEVs under the base case assumptions.

Anticipating that these base case assumptions may not be producing the best results, we conducted sensitivity analysis to determine how different configurations affected revenue and cost. We considered three discrete options for each of several key parameters in configuring EVs and PHEVs, as shown in Table 3 and Table 4. The values highlighted in red were the base case assumptions.

Table 3: Electric Sensitivity Analyses Variables

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery size (kWh)</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Charger size (kW)</td>
<td>6.24 / 19.2 / 30</td>
</tr>
<tr>
<td>SOC (%)</td>
<td>20 / 30 / 40</td>
</tr>
<tr>
<td>Regulation duration (h)</td>
<td>12/14/16</td>
</tr>
<tr>
<td>Regulation period (h)</td>
<td>20-8 / 18-6 / 16-4</td>
</tr>
</tbody>
</table>

Table 4: Plug-in-Hybrid Electric Sensitivity Analyses Variables

Among all combinations of the parameters considered in the sensitivity analysis, we determined the configuration of battery size, charger capacity, battery state of charge, and 12-hour regulation period that produced the lowest total cost of ownership, labeled as “Net Cost” in
Table 5. The best configuration for EVs and PHEVs under both “ramp down” V2G and “ramp up and down” V2G are provided in Table 5 along with the associated costs. The 10-year costs are further broken down into units that may be more familiar with fleet managers – cost per mile and cost per vehicle per day. As anticipated, the base case configuration underestimated the V2G revenue opportunity for PHEVs. With a larger battery and charger, the V2G revenue for PHEVs is closer to EVs.

The highest state of charge (SOC) was not attractive for EVs since a larger, more expensive battery would be required for fleet operations. For PHEVs, a higher SOC at the end of the day means the vehicle is driving more miles in hybrid mode, increasing its fuel consumption. Also, our analysis of ACE signals 66% are positive (ramping down or providing energy) and 34% are negative (ramping up or requesting energy). This means that a battery with a low SOC would generate the higher revenues as it can respond to the higher number of positive signals. These factors offset the tradeoff that a high depth of discharge diminishes the life of the battery.

Charger capacity is as or more important than battery size as a driver of V2G revenue. While high capacity chargers require larger investment, they also provide the largest revenue stream from regulation services. It is important to appropriately match charger capacity with battery size and SOC.

The timing for connection to the grid also has a large impact on revenue. Our analysis showed that the average regulation clearing price was 42% higher between 6AM and 8AM than between 6PM and 8PM, which means benefits for managers with flexibility in start time for fleet service operations. Also, revenues can increase by up to 30% for each additional hour parked; and the increment in costs due to an additional hour less than 0.2%.

Conclusions

Our results show that EVs and PHEVs offer lower operating costs compared with ICEs even without V2G revenue. Adding in the V2G revenue, the EV and PHEV fleets lower the total cost of ownership by 7-12% compared with the ICE fleet.

Given our assumptions, the V2G revenue potential for fleets is significant enough to pursue. According to our calculations, an EV/PHEV can earn $700-900 per year performing “ramp down” regulation services, resulting in a 5-7% reduction in cost. Further, an EV/PHEV can earn $1200-1400 per year with “ramp up and down” regulation services, resulting in a 9-11% reduction in cost.

Though the economics of V2G are still being explored and the future of the market rests heavily on technological innovation, fleet managers can hasten the transition to EVs and PHEVs and expect to significantly reduce the total cost of ownership with V2G revenue.

<table>
<thead>
<tr>
<th>BEST CASE</th>
<th>Ramp Down – V2G</th>
<th>Ramp Up &amp; Down - V2G</th>
<th>ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EV</td>
<td>PHEV</td>
<td>EV</td>
</tr>
<tr>
<td>Battery size (kWh)</td>
<td>99</td>
<td>10</td>
<td>99</td>
</tr>
<tr>
<td>Charger size (kW)</td>
<td>19.2</td>
<td>19.2</td>
<td>19.2</td>
</tr>
<tr>
<td>SOC (%)</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Regulation period</td>
<td>20:00 - 8:00</td>
<td>20:00 - 8:00</td>
<td>20:00 - 8:00</td>
</tr>
<tr>
<td>10 year total</td>
<td>$ 32,529,037</td>
<td>$ 32,723,614</td>
<td>$ 32,747,383</td>
</tr>
<tr>
<td>V2G Revenue</td>
<td>$ 2,268,780</td>
<td>$ 1,758,834</td>
<td>$ 3,499,284</td>
</tr>
<tr>
<td>Net Cost</td>
<td>$ 30,260,257</td>
<td>$ 30,964,780</td>
<td>$ 29,248,099</td>
</tr>
<tr>
<td>per mile</td>
<td>$ 0.735</td>
<td>$ 0.739</td>
<td>$ 0.740</td>
</tr>
<tr>
<td>V2G Revenue</td>
<td>$ 0.051</td>
<td>$ 0.040</td>
<td>$ 0.079</td>
</tr>
<tr>
<td>Net Cost</td>
<td>$ 0.683</td>
<td>$ 0.699</td>
<td>$ 0.661</td>
</tr>
<tr>
<td>per vehicle per day</td>
<td>$ 51.43</td>
<td>$ 51.74</td>
<td>$ 51.77</td>
</tr>
<tr>
<td>V2G Revenue</td>
<td>$ 3.59</td>
<td>$ 2.78</td>
<td>$ 5.53</td>
</tr>
<tr>
<td>Net Cost</td>
<td>$ 47.84</td>
<td>$ 48.96</td>
<td>$ 46.24</td>
</tr>
<tr>
<td>V2G Revenue per vehicle/year</td>
<td>$ 907.51</td>
<td>$ 703.53</td>
<td>$ 1,399.71</td>
</tr>
<tr>
<td>Reduction in TCO from V2G</td>
<td>7.0%</td>
<td>5.4%</td>
<td>10.7%</td>
</tr>
<tr>
<td>Savings vs. ICE</td>
<td>8.9%</td>
<td>6.7%</td>
<td>11.9%</td>
</tr>
</tbody>
</table>

Table 5: Best Case Scenario Results
Preserving Shelf Life and Reducing Reefer Fuel Consumption in Fresh Produce Distribution

By Carlos Seminario & Emmanuel Marks
Thesis Advisor: Dr. Edgar Blanco

Summary: Information collected in real-time during the transportation process can be used to produce predictive models for fuel efficiency and product rejections. Although future study is needed to refine the model for product rejections to the point of deployment, a clear framework exists for development of these tools.

KEY INSIGHTS

1. Real-Time transportation information can add significant operational value to firms who can collect and analyze such data in an efficient and accurate manner.
2. Rejections and Fuel Efficiency show behaviors that can be explained and predicted as a function of variables that occur during transportation.
3. More research should be performed in an effort to improve the model that predicts customer rejections.

Introduction

Companies today have access to huge amounts of information from all echelons of the supply chain. Interpreting and using this information for competitive advantage is challenging, however. This thesis utilizes information generated by systems that monitor temperature and GPS information during refrigerated transportation of packaged salads and seeks to expand the way it can be used and analyzed to generate value for the supply chain. Specifically, the project seeks to investigate how cold chain information generated during the transportation process can be interpreted and analyzed to 1) reduce customer load rejections and 2) improve transportation fuel efficiency.

The study covers the transportation segment spanning company XYZ’s packaged-salad distribution centers to its customers’ (retailers) distribution centers. The real-time data analyzed in this project is sent from moving trailers via cellular technology every fifteen minutes to a central server.

Effects of Temperature On Shelf Life

To create a predictive model for rejections, the relationship between temperature and packaged-salad shelf life was investigated.

In theory the effects of out-of-range temperature on the shelf life of salad products can be modeled. Products with evidence of short shelf life are more likely to be rejected at the time of delivery. Therefore, it may be possible to model the effects of out-of-range temperature on customer rejections. To achieve this, the results of two experiments undertaken by company XYZ were used. In each experiment, produce was exposed to temperatures above recommended ranges.

With the insights obtained from these experiments, a hypothesis of the relationship between out-of-range temperature exposure and rejections likelihood was built and is illustrated by Figure 1. The y-axis measures produce’s shelf life starting at 100% and being rejected by customers at 40%. The slopes of the plotted curves represent the temperature to which the product is being exposed during transportation (the more negative the slope, the higher the exposure temperature). The vertical dashed lines represent a customer stop.
Note that there is a decrease in shelf life towards delivery three. The lower curve represents a load with sub optimal temperature exposure, the upper curve an expectable load. Note the change in slope of the line segment labeled Tx compared with optimal T4 located above it. This change in slope is meant to signify an out-of-range temperature occurrence that lasts only as long as line segment Tx. Accordingly, the lower curve displays that this load’s product arrives to delivery three with less shelf life than required by specification.

**Temperature Monitoring During Transport**

To provide some insight on how temperature behaves in a typical load that experiment an out of range event, Figure 2 displays the temperature on the y-axis and time on the x-axis. In addition, the graphical representations of loads also display trailer’s transport process by stage with Trailer at company XYZ, denoted in blue, Trailer traveling, denoted in purple and Trailer at customer location, denoted in orange.

The load displayed shows a two-stop trip. Point 1 denotes the beginning of the precooling cycle (when the trailer is cooled before being loaded). Point 2 indicates an inflection point in temperature during unloading at the first customer location and subsequently temperatures rise. Point 3 shows an out-of-range temperature that could potentially result in product damage. This out of range temperature event begins at the first customer visited and is addressed after the second customer is visited.

**Regression Modeling**

An analytical methodology was employed to review the large amount of data collected. Regression techniques were used to build models that predict product rejections and reefer unit fuel consumption as a function of the variables that exist as part of the real-time transportation data and the data that can be linked to it.

Rejections were viewed as binary in nature, a rejection either occurred within a load or it did not. Accordingly, a logistics regression approach was undertaken in order to produce a predictive model for this variable. The logistics regression model uses a function to estimate the probability $p$ that any observation will be in group 1, in this case group 1 represent loads with a rejection event. If the value of $p$ is greater than 0.5, the record is classified as belonging to group 1. The general equation for the probability $p$ of a record being in group 1 is given by:

$$p = \frac{1}{1 + e^{(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k)}}$$
Differently, reefer fuel consumption is calculated in gallons from the moment the trailer leaves the company’s pick location until it comes back after delivering the produce to its customers and is continuous in nature. Accordingly, the Multiple Regression method was selected to model Fuel Consumption. The following general equation for the models follows:

\[ \hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \]

After defining the appropriate regression methods to be applied, a regression table was built to run both regressions. The regression table contained 1,439 records after the cleaning outliers. The Logistics and Multiple Regressions were performed in accordance to standard accepted techniques.

**Fuel Consumption Model**
The model obtained for Fuel Consumption shows that with ten variables it is possible to explain approximately 70% of the Fuel Consumption per Load. Four of these explanatory variables are dummy variables (Asset Group, Stop Group, Rejection Event, and Season), and two are Interaction Variables (the combination of Mileage and Pick Location); the rest are numerical variables.

Each variable on its own plays a significant role in determining the level of fuel consumption of each load. This is evidenced by the low p-values obtained for all variables included in the final model. The obtained Multiple Regression model follows:

\[ \text{Predicted Fuel Consumption} = -4.36 + 1.58\text{Asset Group} + 2.02\text{Stop Group} + 5.50\text{Reject} - 7.98\text{Time Out of Range} + 0.016\text{Mileage} + 15.40\text{Load Duration} \\
+ 2.03\text{Autumn} + 2.74\text{Summer} - 0.011\text{Miles} \times \text{Location 2} \\
- 0.016\text{Miles} \times \text{Location 3} - 0.016\text{Miles} \times \text{Location 2} \]

**Rejections Model**
Conversely, with respect to Rejections, no significant results were obtained from the model by running the Logistics Regression. There are many possible reasons for this outcome. Rejections may not always be the result of the variation of conditions measured during the transportation process. Causes that are subjective or difficult to record could occur. For example, a customer could be full of inventory and not want to receive a load that was ordered. Furthermore, the proportion of loads with rejections compared to loads with no rejections is too small to be significantly meaningful. Lastly, the temperature control standards used by company XYZ are managed to such a fine degree that it becomes difficult to perceive the effect this variable has on rejections.

Although the model was not useful to predict rejections, the level of accuracy to predict loads that will not experience a rejection event improved compared to the base case (from 91.1% to 98.6%). The model suggests that the more the mileage and the number of stops, the higher the probability that a rejection will happen. The insight obtained from the model could be used to offer top customers loads with characteristics that minimize the odds of having a rejection.

Of the two explanatory variables in the model, ‘Mileage’ cannot be changed. Thus, the variable company XYZ can work with to offer top customers routes with a reduced rejections probability is ‘Number of Stops’. Top customers could be offered loads with a reduced number of stops, or with the priority to be the first stop on the route. Of course cost benefit analysis would be required. The obtained logistics regression model follows:

\[ p = \frac{1}{1 + e^{(-5.94 + 1.05\text{NumbStops} + 0.014\text{Mileage})}} \]

**Conclusions**
From the data collected, an effective model of fuel consumption has been created. Although the rejections model is accurate in effectively predicting when rejections will not occur, it did not yield significant results in effectively predicting when rejections will occur. Three areas of exploration flow from these results:

1. It is possible that variables not identified in this study play a significant role in defining the probability that a load will be rejected.
2. Salad products may be tolerant to a wider range of temperature than currently prescribed and, accordingly, reefer temperature requirements could be relaxed.
3. More damage may be occurring to bagged salad products during transportation than is evident at the time of delivery and, accordingly, rejections are understated since damage does not become apparent until product is on the store’s shelf, or in the consumer’s possession.

In light of these possibilities, the model should be improved by including new variables currently not available in the database and by expanding the number of supply chain stages analyzed. Doing so could allow company XYZ, and potentially the industry, to benefit from a potent operational monitor.
Supply Chain Strategy in Post-Earthquake Haiti

By Scott Alexander
Thesis Advisor: Jarrod Goentzel

Summary: This project focused on developing segmentation factors for an international, non-profit, healthcare organization. Utilizing the data for over 500 products currently in use at medical sites throughout Haiti, a series of segmentation factors were developed. These factors were then combined in multiple methods to show the effects of implementing segmentation across the supply chain.

KEY INSIGHTS
1. It is useful to develop segmentation factors relying on objective data as well as subjective classification. For non-profit organizations, there are a variety of options besides profitability.
2. Combining multiple segmentation factors is an effective method to developing groups to which policies can be assigned.
3. In implementation, an approach focusing on policy will differ greatly from one focused on the procurement process. Identifying one best answer is extremely difficult.

Introduction
Currently the partner organization, Partners In Health (PIH), runs a dozen medical sites throughout the nation of Haiti. PIH has been established in the country for nearly twenty years, and has seen its operations and services grow exponentially over that time period. Recently, the earthquake of January 2010 and the cholera outbreak months later have combined to further stress the underlying supply chain that supports this growth in services and capabilities.

The staff at PIH has been constantly seeking improvement in its supply chain operations in the country, and for this project, I focused on utilizing the concept of segmentation. Currently, the supply chain serving Haiti does not distinguish between different products as effectively as it could—this project will test the validity of applying segmentation in a non-profit, non-commercial setting.

Methodology
To approach this process, I started by working with data provided by PIH as well as staff in Boston to develop segmentation factors that had reliable data records and/or were identified as important characteristics by PIH. After several iterations, these factors were fully defined and the process continued by evaluating which method for combining them would produce the most useful groups. There are multiple approaches one can take to solve this problem, and for this project I have described two: a Policy focus and a Process focus.

Lastly, I developed supply chain policies pertaining to lead-times, review periods, K values, safety stock, and re-order points. These policies varied by segmentation factor or group, thus allowing the classifications established to be used to establish policy.

Segmentation Factors
Table (1) shows the multiple factors that were developed for this project. While not all were utilized in the final methods, each was identified as being potentially useful and/or important enough to warrant being placed in a separate category. Table (1) provides a list for each factor as well as a description of what the factors accounts for.

Segmentation Application
After identifying the useful segmentation factors, the issue was how to best combine them to develop groups or buckets that could be used to create supply chain policies. For this project, I described two different approaches.
Policy Approach
For this method, I examined the factors for information that was easily transferable to items such as lead-time, K values, and safety stock. Of the two approaches, this one focused more on objective, quantifiable factors that easily led to equations and policies being created.

Fig (1) Policy Approach: Segmentation Groups

I started with the factor that describes the demand for products- Usage. This immediately created four different buckets. Of those, I left the “Infrequently” group alone- this became one of the final segmentation groups after only one iteration. I deemed this necessary because these products do not have enough demand to warrant further evaluation- applying other segmentation factors would only complicate the picture.

For the remaining products, I created three main groups:
- **Short**: This is products that have a greater than “Infrequently” Usage and are Sourced from either “Haitian Vendor” or “Pepfar/Global Fund.” Being sourced from these areas allows for shorter lead-times, which in turn affects the policies implemented.
- **Weekly Long**: Those products with a Usage of “Weekly” and are Sourced from either “IDA” or “Other” are assigned to this category. They are identified separately because their lead-time is longer (due to their sourcing characteristics) but their demand is not quite high enough for the last category.
- **Daily + Long**: This is the group of fastest movers (Usage of “Daily” or “Hourly”) but with the longest lead-times (Sourced from either “IDA” or “Other”). Due to these characteristics, this group requires the greatest amount of supervision, and its policies will reflect that.

Process Approach
Figure (2) shows how this approach could be implemented. For this segmentation, quantifiable results were not the main goal; instead, the focus was on answering procurement-related questions. With this different focus, the resulting segmentation application looks quite different.

**Cold Chain**: Products require cold chain storage as they move through the supply chain.

**Crisis**: Products that should be stockpiled, or held at greater inventories than other-wise indicated, because they are needed to prevent/respond to crises. Examples of these drugs include those used to treat cholera- the seriousness of an outbreak will be larger affected by the treatment available earlier on.

**Daily Report**: Products that have previously been identified by PIH staff as being important enough to track on a daily basis, often to do demand patterns or importance
Distribution: Products that are identified as having a “Specialized” or “Surgical” use. In other words, only products that are NOT used at all sites.

Sourcing: The remaining products, if they have not been identified as having special circumstances in any of the previous groups, are broken into two groups. The two groups focus on whether the products are procured in Haiti (“Haitian Vendor” or “Pepfar/Global Fund”) or elsewhere (“IDA” or “Other”).

Segmentation Implementation
Regardless of the approach used, the effect of segmentation is felt at this stage as actual supply chain policies are developed based on the groupings completed. For the purposes of this project, I only applied policy development to the Policy Approach as an example case. In reality, once a method was chosen and agreed upon, the policy assignment(s) would work in a similar fashion. The method for assigning values differed by variable. Some of them (such as L for lead-time) hold true across segmentation groups- they are not assigned based on their group, but rather on a certain factor (in this case Sourcing). The rest are assigned purely based on segmentation group, and can be adjusted accordingly. A picture of this application is shown in Figure (3), with the policies as assigned by group.

With these policies in place, the corresponding Microsoft Access database will automatically compute actual policies, such as safety stock and re-order point by product. In this way, using multiple factors to create several groups will actually dictate policies for all the products in the supply chain.

Conclusion
This project was intended to show the general approach to applying segmentation in a non-profit, healthcare setting. The segmentation process creates so many options that there are a variety of possible solutions. As shown in the two competing approaches (Policy vs. Process) it is difficult to create a single best answer through this implementation. Different approaches, with varying priorities and objectives, can create supply chains with vastly different looks and operations.

Regardless, this project highlighted the usefulness of developing segmentation factors, combining them to form groups, and applying policies to those groups for Partners in Health. There would only need to be minor modifications to this step-by-step analysis to create a methodology that would be useful to other organizations. The underlying process is the same:

1. Develop segmentation factors that rely on either objective, quantitative data or subjective classifications that prioritize product characteristics.
2. Combine these factors to create several larger segmentation groups that are comprised of products with similar demand patterns, storage and procurement processes, and/or intended uses. Other possibilities exist for grouping as well.
3. Assign supply chain policies to these established segmentation groups. Policies should be based on group characteristics or even individual segmentation factors. Follow-on policies will result from this initial assignment- policies can and should be updated over time.

Figure (2) Process Approach: Segmentation Groups

Figure (3) Policy Assignment
Collaborative Direct to Store Distribution: The Consumer Packaged Goods Network of the Future

By Nanette Le and Melanie Sheerr
Thesis Advisor: Prof. Stephen C. Graves

Summary: This project developed an analytical decision tool to quantify the impacts of employing multi-manufacturer collaborative distribution for promotion fulfillment in comparison to two traditional distribution approaches. In a case study, the model solution indicated that collaborative distribution is a viable strategy, and that optimizing distribution between both manufacturers’ networks creates value across the supply chain.

KEY INSIGHTS
1. Multi-manufacturer collaborative direct to store distribution is the most cost effective flow under some conditions and should be considered as a viable distribution option.
2. A sales lift creates significant benefit under multi-manufacturer collaborative direct to store distribution for both manufacturers. However, further research is needed to investigate the degree of the sales lift directly attributable to this distribution strategy.
3. The partnership between the manufacturers and the retailer will need to include a savings sharing agreement since the distribution of costs and savings associated with comingling do not accrue equally to all three parties.
4. The optimal flow for a given retailer DC depends highly on the situation, and general guidelines for cost conditions under which each flow is optimal are unable to be gleaned.

Introduction
Large retail chains procure products from consumer packaged goods (CPG) manufacturers. Promotional events are common in this industry and drive a large volume of sales in a short period of time. For a promotional event, CPG manufacturers provide products from multiple product families beyond the volume they routinely provide to the retailer. This one-time, high-volume shipment presents a joint decision for the manufacturers and the retailer as to which distribution strategy to employ. In this project, two manufacturers, Manufacturer A (MANA) and General Mills, were interested in exploring the benefits of an innovative distribution strategy: collaboratively shipping their promotional products direct to the retailer stores.

This project explored the conditions under which co-shipping in support of promotional events can create value for the retailer and for the CPG manufacturers. To this end, an analytical decision tool was developed to quantify the impacts of co-shipping directly to the retailer stores in comparison to two more traditional distribution approaches in which each company delivers product independently. The first traditional strategy entails independently delivering product to the retailer distribution center, from where the retailer would transport the product to the stores. The second traditional strategy involves each manufacturer independently delivering directly to the retailer stores. For descriptive convenience, independent distribution through the retailer distribution center will henceforth be referred to as Flow 1, independent direct store delivery as Flow 2, and comingled direct store delivery as Flow 3.

Current Manufacturer Sourcing Networks
Within the scope of this project, MANA has a network
of plants from which it ships directly to retailer distribution centers when employing Flow 1, as shown in Figure 1. When MANA independently employs a Direct Store Delivery (DSD) distribution strategy, it ships all of the relevant products to one location before loading the store-bound trucks, as shown in Figure 2. High volume category plant sites serve as the designated mixing locations when MANA employs this strategy as in Flow 2. In Flow 3, the comingled DSD strategy, MANA would ship relevant products from their respective plant locations to the mixing site, which could be any facility in the MANA or General Mills networks as shown in Figure 3.

In contrast, General Mills has a network of eight distribution centers across the country, all of which carry the full complement of products. Therefore, the distribution centers are assumed to be the General Mills product sources, and the costs associated with the transfer of goods from the manufacturing plants to the distribution centers are excluded. All General Mills products will therefore originate from a single site, regardless of which distribution flow is employed as depicted in Figures 1, 2, and 3.

Model Methodology
The optimization model created in this project is a modified minimum cost network flow linear program. The model selects the source locations that will satisfy demand at the lowest total cost, subject to constraints that specify the business practices of the two manufacturers as outlined in the previous section. Each flow is optimized independently to determine the least expensive routes under that flow, and then the three solutions are compared to determine the optimal flow. The model solves for the optimal flow for the area served by one retailer distribution center. In order to make decisions for an entire retail chain, the model is run iteratively for each retailer distribution center.

Results
The model was used to analyze a representative portion of one retailer’s network as a case study. Results show that collaborative distribution is the most cost effective strategy in two thirds of the regions that were studied.

Sensitivity Analysis
Since the initial values of the model parameters were estimates or averages, it is critical to analyze the robustness of the solution with respect to variation in the inputs. Sensitivity analysis was conducted on each of the input variables, all else being held constant, to assess the impact on the total cost of distribution and selection of the optimal flow. While varying input costs obviously impacts the total cost of distribution, variation of half of the key input variables between 50% and 150% of their initial value, all else held equal, had little or no impact on the result of which distribution flow is the least expen-
sive. The variables that do impact the flow decision are the following: the per stop fee, the peddling fee, retailer pick/load cost, retailer transportation costs, MANA high volume category demand, and General Mills demand. The impact of each depends on how significantly it contributes to the cost of each flow, though the trigger point at which the optimal Flow selection changes varies on a case-by-case basis for each DC.

Calculation and Distribution of Costs
As shown in Table 1, implementing the traditional distribution method (Flow 1) across all DCs is the most expensive option, followed by Flows 2 and 3. By optimizing across the network and delivering to each DC via its respective most cost effective method, a total supply chain savings of 6% can be realized as shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>% Savings vs. Flow 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow 1</td>
<td>N/A</td>
</tr>
<tr>
<td>Flow 2</td>
<td>1%</td>
</tr>
<tr>
<td>Flow 3</td>
<td>4%</td>
</tr>
<tr>
<td>Optimized Network</td>
<td>6%</td>
</tr>
</tbody>
</table>

Table 1: Total Savings Relative to Flow 1 from Employing Each Distribution Strategy across the Representative Portion of the Retailer's Network. The costs are based on the optimized source and mixing site selection for each Flow.

While delivering DSD via Flow 2 or Flow 3 saves money across the supply chain as a whole, the distribution of the burden of these costs shifts among the three parties. In all cases, there is significant savings to the retailer from implementing DSD either through Flow 2 or Flow 3, as seen in the second column of Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Savings to Retailer</th>
<th>Savings to MANA</th>
<th>Savings to General Mills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow 1</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Flow 2</td>
<td>46%</td>
<td>-66%</td>
<td>-67%</td>
</tr>
<tr>
<td>Flow 3</td>
<td>68%</td>
<td>-86%</td>
<td>-106%</td>
</tr>
<tr>
<td>Optimized Network</td>
<td>60%</td>
<td>-61%</td>
<td>-65%</td>
</tr>
</tbody>
</table>

Table 2: Savings to Each Party from Employing Various Distribution Strategies

However, in almost all of these cases, the retailer savings come at an additional expense to the manufacturers. Across the network as a whole, each manufacturer shows additional expenses of over 60% to implement DSD in Flows 2 and 3, or to optimize the network as shown in the third and fourth columns of Table 2. Therefore, other incentives must exist for the manufacturers to be interested in pursuing these DSD strategies.

Manufacturer Incentives to Participate in DSD
One incentive to entice the manufacturers to participate in DSD systems would be for the retailer to share some of its cost savings. Since incremental value is created for the supply chain by optimizing the distribution strategy across the representative portion of the retailer’s network, it is possible to develop a savings sharing mechanism in which all three parties capture some of this value.

Alternatively, the manufacturers would be willing to employ Flows 2 or 3 if they believed that there would be a resulting increase in revenue that would more than compensate for the increased costs. The model created for this project allows the expected sales lift to be input as a parameter. The estimated sales lift provided by the manufacturers was significantly greater than the cost of distribution under Flow 3. Given this assumption, the Base Case model showed that Flow 3 yields the greatest supply chain net benefit for every retailer DC region studied. Further research would be required to determine if the estimated levels of sales lift are truly able to be realized.

Finally, to incentivize adoption of Flow 3, a redistribution of costs between MANA and General Mills may also be necessary since the costs of comingling do not accrue equally to both companies. The optimal mixing site is selected to minimize costs across the entire supply chain in order to create the most value. However, in the model built for this project, the manufacturer that does not house the mixing site bears a significantly larger portion of the incremental costs from the collaboration since there is an additional move for either the MANA high volume products or the General Mills products which incurs transportation and handling. In addition, the model allocates the comingle fee to the manufacturer that is moving product to the mixing site. There are many ways that MANA and General Mills may consider reallocating the incremental transportation, handling, and overhead costs incurred in comingling. However, it is clear that MANA and General Mills should agree on some redistribution of these costs.

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1 Since General Mills’ cost to distribute its products from its plants to its distribution centers is outside the scope of this project, the General Mills absolute relevant costs are much lower than MANA’s costs. This lower baseline cost results in larger percentages of negative savings for General Mills than for MANA in Table 2, even though MANA is bearing a larger proportion of the absolute negative savings.
Conclusion
It was observed from these results that multi-manufacturer collaborative distribution is a feasible distribution strategy for promotion fulfillment that can create value under certain circumstances. However, the optimal strategy must be determined on a case-by-case basis. General guidelines for the conditions under which comingled direct to store delivery should be employed are unable to be established.

The manufacturers’ incentive to employ collaborative distribution depends upon establishing a method of sharing savings with the retailer, or upon the expectation of increased revenue due to higher sales from employing this distribution strategy.
Incorporating Cycle Time Uncertainty to Improve Railcar Fleet Sizing

By Jay Jagatheesan and Ryan Kilcullen
Thesis Advisor: Dr. Jarrod Goentzel

Summary: In this research, we address the issue of developing a method for a private fleet manager to determine the appropriate number of railcars in a fleet. We focus on incorporating the variability of railcar cycle time into the fleet-sizing decision. In addition, we recommend a process that enables fleet managers to use distribution fitting and simulation to understand the expected requirements of their fleet capacity. Finally, we suggest an economic approach to making the fleet sizing decision.

**KEY INSIGHTS**
1. By measuring cycle time variability and using it to drive fleet sizing decisions, managers can identify lanes that are forcing excessive fleet requirements.
2. The use of distribution fitting and Monte Carlo simulation can help a fleet manager gain a more accurate projection of fleet size requirements.
3. By comparing the cost of excess capacity with the cost of under-capacity, a fleet manager can determine how much risk he or she should take in selecting a fleet size.

**Introduction**
Determining the appropriate fleet size for a shipper that operates a private fleet is a challenging task. In selecting the size of the fleet, fleet managers must balance the high customer service expectations of their channel partners, the variability of product demand and transit operating times, and the desire to achieve high asset utilization performance from the capital invested in their fleet.

In this research, we address the issue of developing a method for a private fleet manager to determine the appropriate number of railcars in a fleet. Specifically, we focus on the incorporating the variability of railcar cycle time (the time it takes a railcar to make a complete trip from origin to destination and back to the origin) into the fleet-sizing decision. In addition, we recommend a process that enables fleet managers to use distribution fitting and simulation to understand the expected requirements of their fleet capacity. Finally, we suggest an economic approach to interpreting the results of the simulation in order to make the fleet sizing decision.

The intent of this research is to improve the process by which managers perform the fleet-sizing analysis and to develop a method that provides greater insight into the effect of cycle time variability on fleet size requirements. By considering the effect of cycle time variability on the requirements of the fleet, managers can ensure that their fleet size selection is in line with the risk tolerance appropriate to balance the needs of customer service with the asset utilization of the fleet.

**Research Scope**
We worked with a large chemical manufacturer that ships a variety of liquid products in bulk form. The identity of this chemical company has been masked in this report and will be referred to as Kendall Square Chemical Company (KSCC) in the remainder of this document. The primary customers of KSCC are industrial manufacturers who use these products as raw material inputs into their own process. The primary transportation mode used by KSCC is rail. Because of the specialized handling requirements of its products, KSCC, like many companies in the chemical industry, is forced to maintain a
private fleet. KSCC’s fleet includes several sub-fleets which are each divided along product families. All cars in the fleet are either owned by KSCC or leased under a long-term agreement (10 to 20 years). We used actual transit time data from KSCC’s fleets in order to conduct the analysis in this research. However, all data and fleet sizes displayed in this document have been masked in order to disguise proprietary data.

Research Approach
In our research, we evaluated three different methods of fleet sizing strategies in order to compare and contrast their benefits. In the first two methods, we performed deterministic analysis using basic descriptive statistics to arrive at a recommended fleet size. In the third method, we used a stochastic model that involves distribution fitting of the underlying cycle time data and a Monte Carlo simulation to develop distributions of required fleet sizes. From this third model, we have also demonstrated the potential value of using an economic model to select an appropriate fleet size by comparing the cost of extra railcar capacity with the cost of insufficient capacity. These methods are described in the following sections.

Method #1: Current Practice – Mean Buffering
The current method employed by KSCC is to determine a fleet size by calculating the mean cycle time for each origin-destination pair within a fleet. Once the mean cycle time is calculated, it is combined with information about the annual demand of the customer and the capacity of a railcar to determine the number of railcars required for servicing this customer. Once the requirements are determined for each pairing, KSCC buffers the total fleet size by increasing these mean requirements by fifteen percent. This buffering is intended to protect against uncertainty and variability in the system.

The most significant limitation of this model is that it does not use the variability of railcar cycle time as input to help determine an appropriate fleet size. By failing to use this property of the cycle-time data, the current model is forced to use a percentage buffer against the mean.

Method #2: Incorporating Transit Time Variability
In this method we introduced the standard deviation of transit time data into the fleet sizing process. This method arrives at a fleet sizing decision by using the mean and standard deviation of transit time data under the assumption that the data can be characterized by a normal distribution. While we will later show that the assumption of a normal distribution is, in some cases, flawed, this method can be used to demonstrate the insight that can be provided by incorporating transit time variability.

<table>
<thead>
<tr>
<th>Destination City</th>
<th>Deterministic Coefficient of Variation</th>
<th>Method 1: Cars Required to Buffer Mean 15%</th>
<th>Method 2: Cars Required @ 65% of Normal Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>City A</td>
<td>0.28</td>
<td>9.0</td>
<td>8.7</td>
</tr>
<tr>
<td>City B</td>
<td>0.69</td>
<td>35.1</td>
<td>38.7</td>
</tr>
<tr>
<td>City C</td>
<td>0.32</td>
<td>10.3</td>
<td>10.0</td>
</tr>
<tr>
<td>City D</td>
<td>0.11</td>
<td>2.3</td>
<td>2.1</td>
</tr>
<tr>
<td>City E</td>
<td>0.46</td>
<td>13.0</td>
<td>13.3</td>
</tr>
<tr>
<td>City F</td>
<td>0.13</td>
<td>27.7</td>
<td>25.2</td>
</tr>
<tr>
<td>City G</td>
<td>0.35</td>
<td>11.7</td>
<td>11.5</td>
</tr>
<tr>
<td>City H</td>
<td>0.28</td>
<td>15.6</td>
<td>15.1</td>
</tr>
<tr>
<td>Cars Staged</td>
<td></td>
<td>11.5</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total Fleet Size</strong></td>
<td></td>
<td><strong>136.2</strong></td>
<td><strong>134.6</strong></td>
</tr>
</tbody>
</table>

For this method, we set the fleet requirement for an origin-destination to cover the total cycle time of the 65th percentile value on the cumulative distribution function, in order to offer an alternative to the current method of buffering the mean by 15%. The resulting values for each O-D pairing are then summed to find a total recommended fleet size. As can be seen in Figure 1, the aggregate total fleet size recommendations of Method #1 and Method #2 are similar at 136.2 and 134.6 respectively. However, by looking at the requirements for individual O-D pairings, significant differences between the two models can be seen.

To demonstrate this difference, consider the cases of City B and City F. In City B, the coefficient of variation of transit times is high, and as a result of this high degree of variability, Method #2 recommends 3.6 railcars more than Method #1. In City F, which has a coefficient of variation of only 0.11, Method #2 recommends 2.5 fewer cars than Method #1 because of the low variability of the destination. This highlights an important advantage of a method that incorporates transit time variability. Incorporating variability enables fleet managers to set high buffers for highly variable destinations, while maintaining smaller buffers for less variable destinations. In addition, Method #2 would help a fleet manager to easily identify the components of cycle time for destinations that account for the most variability. He or she can then focus on managing the variability in these components in an effort to reduce overall fleet size requirements.

While Method #2 allows for the recognition of transit time variability in the fleet sizing process, it is flawed in its assumption that all transit time distributions follow a normal distribution. This flaw is explained in more detail.
in the following section during the discussion of Method #3.

**Method 3: Distribution Fitting and Monte Carlo Simulation**

In Method #3, we used a Monte Carlo technique to simulate railcar cycle times in order to create a distribution of required fleet sizes. The first step in this approach was to use historical cycle time data to fit probabilistic distributions for each leg of the railcar cycle for each origin-destination pairing. In the Monte Carlo simulation, railcar cycle times were replicated using a random number generator and the probabilistic distributions of cycle times. These simulated cycle times were then converted to railcar requirements to form a histogram of required fleet sizes. This histogram maps the range of possible outcomes for fleet sizes based on the distributions of the transit data used in the simulation process.

This method has several important implications for fleet managers. One such implication is the importance of distribution fitting to characterize the skewness of the underlying cycle time data. By not assuming a single distribution type to characterize transit data, this method enables the fleet size requirements to accurately reflect the nature of the underlying data. To illustrate this we offer the following two examples.

Figure 2 shows an example of a destination in which the distributions for each of the three phases of the cycle time have a small amount of skewness. As such, the resulting distribution of fleet size requirements is symmetric around the mean.

However, our research demonstrated the distributions of cycle time data for KSCC are frequently not symmetric. As a result, the fleet size requirements in these cases will also be skewed, as you can see in Figure 3. If these distributions were assumed to be Normal, as in the case of Method #2, the result would be an over-estimation of fleet size requirements.

An additional benefit of Method #3 is that by creating a distribution of fleet size requirements rather than a deterministic value, it enables a fleet manager to employ a variety of risk management techniques to arrive at an appropriate fleet size. We describe one such technique in the following section.

An Economic Model: The COST PERCENTILE Method

In order to determine the point on the distribution of possible fleet sizes that best balances all of the competing goals in fleet management, we recommend that an economic model be used which balances the cost of having excess capacity of railcars with the cost not having enough to meet demand. In order to develop this idea, we adopted a concept from inventory management known as the Newsvendor Model.

In an inventory context, the Newsvendor analysis is applied when a set of conditions are met that require someone to purchase material before true demand is known. In this context, there is a cost penalty associated with not satisfying demand as well as a cost associated with ending the selling period with excess inventory. In order to find an order quantity that balances the risks of these two costs, the Newsvendor model uses a calculation known as the critical ratio. We have adopted for use in railcar fleet sizing and refer to it as the COST PERCENTILE. After discussions with a KSCC stakeholder regarding the cost impact of various mitigation strategies for a railcar shortage, we calculated the COST PERCENTILE to be 0.70.

After determining the COST PERCENTILE value, we select the point on the cumulative distribution of fleet sizes that corresponds to the COST PERCENTILE value (in this instance, 0.70). This point is at the intersection of the two arrows in Figure 4, and occurs at a value of 125 railcars.
Therefore, the recommendation for this fleet using the COST PERCENTILE method with the stated overage and underage assumptions is to select a fleet size of 125 railcars. It must be noted that although there are similarities between Newsvendor analysis and railcar fleet sizing decisions, further research should be conducted before directly applying this economic model.

**Conclusion**

The implications of our research for a fleet manager are as follows:

1. Incorporating cycle time variability into a fleet sizing model is necessary in order to gain an accurate understanding of the underlying sources of volatility in the fleet. By measuring variability and using it to drive fleet sizing decisions, managers can begin to identify lanes that are forcing excessive fleet requirements and focus efforts to reduce variability.

2. In the case of Kendall Square Chemical Company, assuming that the distributions of transit times are normally distributed leads to an over-estimation of fleet sizes. This over-estimation of railcar requirements can be prevented by recognizing the distributions of cycle time data. In many cases, transit and customer holding time data exhibit positive skewing. This skewing results in the mean providing an inaccurate depiction of the central tendency of the data. The use of distribution fitting and Monte Carlo simulation can help a fleet manager gain a more accurate understanding of fleet size requirements.

3. There is potential to factor in economic considerations when selecting a fleet size from a distribution of size requirements. By comparing the cost of excess capacity against the cost of under-capacity, a fleet manager can determine how much risk he or she should take in selecting a fleet size.
Risk Sharing in Contracts: The Use of Fuel Surcharge Programs

By Madhavi Kanteti and Jordan Levine
Thesis Advisor: Dr. Chris Caplice

Summary: This project evaluates the financial implications to shippers and motor carriers in the United States truckload (TL) transportation industry of modifying the compensation structure of fuel surcharges. Fuel surcharges (FSCs) are contracts added as addendums to payment of service (called the line-haul rate in the transportation industry) that enable the sharing of fuel price volatility between shippers and carriers.

KEY INSIGHTS
1. The aggregate cost of transportation on a trucking lane, comprised of the line-haul rate and the fuel surcharge, is the critical economic metric between shipper and carrier. Any modification made by a shipper to its fuel surcharge will be countered by a carrier with a compensating bid. Thus, a shipper’s attempt to decrease transportation costs by modifying its fuel surcharge program will not lead to significant cost savings.
2. Standardization of fuel surcharge programs across the industry will maintain the risk sharing properties of fuel surcharges while enabling shippers and carriers to better understand costs by isolating fuel costs from transportation operating costs.
3. To achieve the benefits of industry-wide standardization, a critical mass of shipping companies should simultaneously transition to a zero based trigger point fuel surcharge schedule while communicating the transition to other shippers via trade journals and industry forums.

Introduction
Various industries employ risk sharing contracts to manage the risks and volatility associated with commodity prices, inaccurate customer demand forecasts, or unpredictable events. The volatility in the price of fuel in the latter part of the twentieth century to the present has required the various parties involved in the trucking industry to employ risk-sharing contracts as an addendum to payment for services in the form of fuel surcharges.

On the basis of the research conducted, the authors conclude that the fuel surcharge system can be improved for industry-wide benefit. Standardization by transitioning to a zero trigger point, establishing an appropriate escalator, and using the U.S. average retail fuel price published weekly by the Department of Energy (DOE) will prevent underbidding on lanes, increase transparency, reduce administration, and further increase the resilience of the United States truckload (TL) industry.

The Null Hypothesis: Revenue Neutrality
Central to our research is the concept of revenue neutrality. This concept says for any modification made to the FSC by a shipper, the carrier will counter with an adjustment to the line-haul bid. This means that ultimately line haul rates and FSC schedules are compensating. This concept of revenue neutrality was re-enforced throughout our research and after thorough analysis was accepted by the authors as the common practice in the industry.

Methodology
To validate the null hypothesis of revenue neutrality we conducted field research and quantitative analysis. The field research included interviews of two large shipping companies that recently transitioned to a zero trigger
point based FSC schedule, a web-based survey sent to 800+ carriers and completed by 100+ carriers, and follow-on interviews with carrier survey participants.

**The Fuel Surcharge Equation**

In standard contract negotiations, the shipper will publish their fuel surcharge schedule in addition to their request for lanes to be serviced. The carrier will then offer a bid given the lane and fuel surcharge economics. In some situations, a carrier will counter with their own fuel surcharge schedule.

The most commonly employed formula to compute per mile fuel surcharges is given by Equation 1.

The fuel price is the agreed-upon price of fuel between trading partners. The trigger point is a negotiated price between trading partners. If the fuel price goes above this point, the FSC is paid by the shipper. The basis is normally defined as $.01/mile. The escalator represents the efficiency of the motor carrier’s equipment.

**Research Findings: Null Hypothesis Validated**

The following evidence demonstrates support for revenue neutrality:

1. Two multi-national shipping organizations that transitioned their trigger point to $0.00 observed a revenue neutral transition.
2. Carrier survey responses shown in Figure 1 show that carriers will almost always factor the FSC into their line-haul bid.
3. Figure 2 shows that approximately 80% of the carrier survey respondents acknowledged modifying their line-haul rate when a shipper used one of the eight regional average retail prices of fuel instead of the national average.

Research Conclusions: Industry Standardization

Given that any changes made to an FSC contract are subject to the hypothesis of revenue neutrality, it does not seem possible for a shipper or carrier to establish a new FSC or modify their existing FSC in order to significantly reduce costs (shipper) or increase revenue (carrier). That said, there appears to be significant advantages in standardizing the fuel surcharge structure across the industry.

**Standardization - Trigger Point**

The current industry standard trigger point is in the range of $1.01-$1.51. When fuel surcharges were first introduced, the price of diesel fuel was in this range. Standardization of the trigger point, by establishing a $0.00 standard, will enable a shipper to “unbundle” fuel costs from transportation costs. This “unbundling” will lead to the following industry-wide advantages:

1. Shippers will be able to improve their financial and operational planning by being able to better forecast fuel costs.
2. Carriers will be able to better compare lane economics which will prevent under-bidding on lanes. Under-bidding due to mathematical error could lead to service failure.
3. Both shippers and carriers will be better positioned to differentiate rate increases and decreases that are caused by fuel pricing versus changes in the market conditions in the transportation industry.

As stated earlier, two shippers identified a positive outcome to a transition to a $0.00 trigger point-based FSC schedule. The $0.00 trigger point standard was also favored by the participants of the carrier survey. As Figure 3 demonstrates, 52% of carriers support the transition to a $0.00 trigger point.
Would you favor a zero trigger point based fuel surcharge schedule?

Figure 3. Carrier response to Trigger Point Modification
Of the 48% that oppose the transition, 30% perceive it to be an administrative burden, but in follow-on interviews acknowledged that the transition would be fairly simple.

**Standardization – The Escalator**

The most contentious issue of the FSC discussion is the escalator. The escalator is supposed to represent the fuel efficiency of a carrier’s fleet. What seems an easy calculation is quickly influenced and complicated by concepts including but not limited to, dead-head miles and cash flow. The key aspect of the escalator is that it defines whether or not an FSC determined by a shipper is “at-market”, “below-market,” or “generous”. Despite most dry-van equipment achieving miles per gallon efficiency greater than 6.0, escalators tend to be much lower as a result of the above mentioned influencing factors.

The two common themes that emerged from the carrier survey and multiple interviews with carriers is that carriers completely oppose a “below-market” FSC, and are almost ambivalent to a “generous” FSC as shown in Figure 4.

Some carriers even oppose a “generous” fuel surcharge because it forces them to drop their line-haul rates, in effect, placing the cost of transportation into the FSC. In a period of low fuel pricing, this can negatively influence carriers’ profit margins. For this reason, we advocate an industry standard escalator. If one single point cannot be identified, a range of values (for example between 5.2 and 5.8) could also be appropriate.

This research did not make significant headway into what this escalator standard or standard range should be. However, the author’s can suggest the following places to start:

1. Some carriers indicated that shippers with private fleets offer a proper FSC because of internal knowledge of fleet efficiency (escalator).
2. The carrier survey conducted asked carriers to identify below average, average, and above average FSC programs. Table 1 displays how carriers perceive different escalators.

<table>
<thead>
<tr>
<th></th>
<th>Below Average</th>
<th>Average</th>
<th>Above Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Van</td>
<td>5.73</td>
<td>5.16</td>
<td>4.63</td>
</tr>
<tr>
<td>StdDev</td>
<td>0.58</td>
<td>0.47</td>
<td>0.53</td>
</tr>
<tr>
<td>Reefer</td>
<td>5.32</td>
<td>4.75</td>
<td>4.17</td>
</tr>
<tr>
<td>StdDev</td>
<td>0.50</td>
<td>0.42</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Table 1. Escalator Summary Statistics; Source - carrier survey

**Standardization – Fuel**

To make the FSC contract most effective in sharing risk between the carrier and shipper, it is important to select the fuel price that reflects the fuel paid at the pump. It can be seen from Table 2 that some regional fuel prices are ~13 cents higher than the U.S. average retail fuel price whereas other regional fuel prices are ~ 4 cents lower than the U.S. average retail fuel price.

<table>
<thead>
<tr>
<th></th>
<th>New England</th>
<th>Mid West</th>
<th>West Coast</th>
<th>California</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>+21.8</td>
<td>-4.5</td>
<td>+6.5</td>
<td>+12.2</td>
</tr>
<tr>
<td>2009</td>
<td>+16.2</td>
<td>-3.4</td>
<td>+9.9</td>
<td>+14.0</td>
</tr>
</tbody>
</table>

Table 2. Average Difference between regional fuel price and the U.S. Average retail price over 20
Based on a comparative analysis of TL lanes of a large food and beverage shipping company the authors conclude that:

1. If a shippers’ business were largely in either the high fuel prices regions or low fuel price regions, then choosing regional fuel price would be appropriate.
2. For a shipper that has lanes all over the country, the U.S. average fuel price is preferred.

Of note is there are data analysis companies with the ability to provide very precise estimates of fuel costs of a given lane considering such factors as the wholesale price of fuel and actual miles travelled by a motor carrier. This method enables a shipper to get near real time data on fuel costs and empowers them to better forecast fuel spend. Nevertheless, the carrier survey responses suggest that, despite the benefits of this data analysis, if a shipper employs this method and ends up reducing the carrier’s margin, the carrier will respond with a higher line-haul bid.

**Conclusions**

The authors of this thesis advocate an industry standard for fuel surcharges for the following reasons:

1. Revenue neutrality demonstrates that neither side (shipper or carrier) can increase their profit margin by manipulating the FSC because the line-haul will compensate.
2. If a modification to the FSC contract can be made that simplifies the complexity, but does not modify the risk sharing properties, it should be made. Standardization simplifies administration. Simplicity prevents under-bidding and service failures.
3. The modification to a $0.00 trigger will “unbundle” fuel costs from transportation costs.

The major advantage to standardizing the FSC is to enable shippers and carriers to focus their efforts and time on the negotiation of transportation economics and not on fuel price volatility and forecasting.

**How to Achieve Standardization**

Individual companies transitioning to a zero trigger point-based system will not lead to the benefits of an industry transition covered in this thesis. Rather, individual companies modifying their FSC programs will simply further complicate the industry. As such, it is the industry standard that will lead to benefits to all parties. For this reason, a critical mass of shippers must transition to a zero trigger point based FSC while simultaneously communicating to and encouraging other shippers to transition. Methods to expedite a transition to an industry-wide-zero-based FSC include presentations at industry conferences and publication of articles in industry trade journals. As the number of shippers using a zero based FSC increases, the number of carriers aware of the benefits will also increase.

**Further Research**

FSCs in the less-than-truckload (LTL) industry and airline industry are also often the object of contention. Airlines and LTL freight providers have been challenged by customers for using FSCs as a revenue stream. If collaboration amongst TL shipper competitors can lead to an industry standard, then perhaps competitors in the LTL arena can collaborate to establish industry norms. This effort will enable risk sharing while reducing friction amongst airline providers and air travelers as well as consumers of LTL services and LTL providers.
Improving a Sustainable Packaging Delivery System

By Erin Connolly & Emily Keane
Thesis Advisor: Dr. Edgar Blanco

Summary: This project analyzed a pilot reusable tote program implemented by a consumer products company that was suffering from an unsustainable attrition rate. We identified key factors behind tote attrition and designed a new program for implementation at MIT that will better address these factors, adding proof of concept to this innovative sustainable supply chain initiative.

KEY INSIGHTS
1. The most influential factors contributing to tote attrition rate are time between orders, tracking totes through the supply chain, and the relative convenience of return.
2. Adding reverse logistics to a supply chain requires more intensive tracking, especially when end users are a key link.
3. The factors affecting tote attrition that the Sponsor can most influence are timing of communication, tote return convenience, and incentive structures.

Introduction
Environmental sustainability initiatives among corporations are becoming increasingly prevalent. When implemented successfully, these initiatives can decrease operating costs and secure relationships with customers who are willing to pay a premium for sustainable practices. This, in turn, can boost a company’s brand and increase shareholder value. One such initiative in the retail industry involves using plastic, reusable cartons (known as totes) to deliver products to customers. The customers must then return the totes to the company, becoming an integral link of the supply chain. This thesis analyzed a pilot program conducted by a consumer products company (referred to as the Sponsor) where totes were used to deliver orders to one of their corporate customers (known as University A). It explores the factors contributing to the high attrition rates observed in the pilot and designs a subsequent program and logistics system at MIT for ease of tote return, focusing on operational efficiency as well as how to communicate with and engage customers using incentives and creativity to return totes.

Research Objective
The Sponsor needs to implement a financially and environmentally sustainable pilot of the reusable tote program in order to roll out the program to corporate customers nationwide. The objective of the thesis was to understand why the pilot at University A was not sustainable and to design an improved pilot at MIT. A successful and sustainable implementation at MIT will add weight to the proof of concept of reusable tote programs and serve as a catalyst for nationwide program roll out for the Sponsor.

Methodology
To analyze the pilot program at University A, we observed and mapped the logistics processes, interviewed various stakeholders, and conducted data analysis of the actual level of tote loss as well as segmented customer ordering patterns to find linkages between customer characteristics and tote loss. We also built a model of tote attrition using system dynamics methodology. To design the program at MIT, we interviewed various stakeholders, observed deliveries made by the drivers,
and analyzed density of orders and ordering patterns of MIT customers.

University A Analysis
Our literature review revealed that reusable packaging programs worked best with customers in concentrated areas who require frequent deliveries. University A meets these characteristics, but high service levels and contractual restraints between the Sponsor and University A hindered the logistics system’s ability to optimize for tote return. A detailed overview of the lifecycle of a tote through the entire system – from being fulfilled in the fulfillment center (FC), to delivery at the customer’s location, to its empty trip back to the FC - is seen in Figure 1.

As seen in Figure 1, totes were only tracked until they reached the customer location. During the reverse logistics loop the totes were only scanned when they returned to the fulfillment center. This system structure missed opportunities to track the totes at other locations in the reverse logistics loop.

Analysis of the ordering patterns revealed that customers could be segmented by their compliance with the program (percentage tote loss) and their order volume and frequency. Figure 2 captures the percentage tote loss by customer, showing that:
- 8% lost 11%-20% of their totes
- 13% lost more than 20% of their totes

Customers are defined as the person who placed the order on the Sponsor website. Percentage tote loss is defined as number of totes lost by the customer divided by the number of totes that were delivered to that customer. A summary of customer segmentation is shown in Figure 3.

Customers can be segmented as follows:
- The significant majority of customers are in compliance with the program and represent 42% of orders
- Those who lost between 1%-20% of their totes are relatively high-volume customers

Figure 1: Operational Flow of a Tote Order Through the System

Figure 2: Customers by % Tote Loss

<table>
<thead>
<tr>
<th>Percentage Tote Loss</th>
<th>Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>600</td>
</tr>
<tr>
<td>1-10%</td>
<td>50</td>
</tr>
<tr>
<td>11-20%</td>
<td>40</td>
</tr>
<tr>
<td>21-30%</td>
<td>30</td>
</tr>
<tr>
<td>31-40%</td>
<td>20</td>
</tr>
<tr>
<td>41-50%</td>
<td>10</td>
</tr>
<tr>
<td>50%</td>
<td>0</td>
</tr>
</tbody>
</table>

- 26 -
Those who lost more than 20% of their totes are lower volume consumers.

It can be concluded from this segmentation, then, that there are two types of customers to which the Sponsor should focus its outreach. First, a small group of repeat offenders who are losing their totes due to the infrequency of their orders, and second, the customers who order frequently enough to be aware of the program, but need regular communication and incentives to sustain continued tote returns.

We concluded that if the days between orders are greater than the time that a customer will wait before throwing the tote away or repurposing it, which we call average time to discard, then there is a greater chance of the tote being lost, which increases the cost of a reusable tote program. This conclusion can be seen in Figure 4, which shows the customer’s average tote loss percentage by the average days between orders.

For the very high frequency customers, who are ordering less than 5 days apart, we also believe that average time to discard is the factor overpowering their frequent interaction with the delivery driver, causing their high attrition rates. We believe that due to the greater number of totes that they receive due to their high order volume, they have a lower time to discard than the other customers.

We used system dynamics theory to summarize the factors behind tote loss, as seen in Figure 5.

**MIT Customer & Campus Analysis for Design**

While there are differences between University A and MIT, operational implementation of a reusable tote program will be similar because there are few levers to pull in terms of tweaking operational processes and custom-

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Figure 3: Customer Segmentation by Percentage Tote Loss

Figure 4: Percentage Tote Loss by Days Between Orders

Figure 5: Factors Influencing Tote Return and Tote Loss

WOM is defined as Word of Mouth.
ers-service levels. Without major structural changes to the operational network, the design of the reverse logistics portion of the supply chain will be relatively similar. Given the average number of orders at MIT during the eight month study period, it can be concluded that MIT will have similar ordering patterns to University A's customers.

**Factors for Design of a Reusable Tote Program**

There are many ways the Sponsor can design the new reusable tote program at MIT to improve its effectiveness. Using six key factors integral to program success, two new design tracks are proposed for the delivery of the Sponsor's products at MIT. One design relies on the current operating systems and structures to minimize investment on the Sponsor, while the other design is aimed at maximizing effort to optimize the system. The proposed programs consider both operational practicalities in the logistical design and communication and incentive efforts that are needed to drive consumer behavior to maximize carton return and lower attrition rates. The key factors include:

1. **Collaboration** – When designing for current systems and structures (CSS) as well as the recommended design (RD), collaboration is of the utmost importance. A customer’s willingness to be flexible will be a good indicator of their buy-in into the program. The more willing the customer is to put in their own resources, such as facilities and staff, the more likely the program is to succeed.

2. **Operational Consistency** – Consistency in return options could be one of the most influential factors in getting customers to return totes. University A’s program lacked clear messaging to customers surrounding return options. All available options must be available at the outset and consistently communicated to the customer.

3. **IT Systems** – While the CSS design will use existing IT systems, in the recommended design we recommend that the Sponsor invest in better tracking systems to monitor the reverse logistics process and understand where the totes are being lost in the system. However, given the substantial investment needed to upgrade the existing customer management system, this investment will most likely not be initiated during the pilot at MIT.

4. **Communication** – Communication about the program should occur before the program starts and continue at regular intervals. Messaging must be targeted to customers during specific phases of their ordering and tote return process. We recommend in both CSS and RD that customers receive an integrated communication rollout in the initial phase of the program, and those who have not returned totes receive periodic communications to remind them to return their totes.

5. **Incentives** – The Sponsor has a number of options for positive and negative incentives, but in the recommended design, we urged the Sponsor to only use positive, non-monetary incentives, using an emerging theory for problem-solving known as gamification, which uses elements of games to engage users and solve problems creatively.

6. **Experiment Design** - We favor a campus wide experiment size, rather than segmenting the campus in order to conduct a number of micro-experiments. Although some granularity will be lost, the larger experiment size will provide consistency for the Sponsor’s operations and customer messaging.

**Conclusion**

In the case of a reusable tote program that involves the end user, the program must be designed to maximize ease of use for this end user. These users are often not the direct beneficiaries of the financial and environmental benefits of a successful program, but their compliance will determine the success of the program. Therefore, the Sponsor and the customer must work in concert to ensure that each end user is properly educated and incentivized to align his/her interests with that of the program.

We believe that a university campus will be one of the most difficult environments for the Sponsor to implement a reusable tote program, due to its extensive delivery locations, which inhibits tracking and timely pickup. We are confident that if the Sponsor can achieve satisfactory attrition rates on MIT’s campus, then they will have a platform for scale up nationwide. Given the diverse nature of customers’ internal geographic configuration and varying ability to control their end users, it is essential the Sponsor identify specific corporate customers that are poised for success for a reusable tote program.

Ultimately, implementing a reusable tote program is about innovation in operations and how to shape consumer behavior to benefit the reverse logistics portion of the supply chain. Through collaboration, targeted communication and positive incentives, the Sponsor can increase the potential for success in reusable tote programs, which will ultimately increase the value proposition for both shareholders and customers.
Complete List of 2011 SCM Thesis Projects

Supply Chain Responsiveness for a Large Retailer
This thesis developed a three-model approach for analyzing the impact of lead-time and review time in a large retailer’s supply chain network. The foundation of all three models is based on the periodic-review (R,S) policy. These models mimicked the “Direct-to-Store” and “Regional Distribution Center” supply chain network.

Modeling Order Guidelines to Improve Truckload Utilization
Freight vehicle capacity, whether it be road, ocean or air transport, is highly under-utilized. This thesis describes the impact of ordering guidelines on the trucking efficiency of a large firm and how those guidelines and associated practices can be changed in order to gain better efficiency.

Multi-Echelon Inventory Optimization For an Oil Services Company
This project developed and analyzed the demand patterns and inventory levels for an Oil Services company. After segmenting ABC’s SKU base into fast and slow movers, this project then utilized two separate models, to provide statistical guidance for inventory levels. Our models and analysis present options that can reduce ABC’s inventory holding by up to 35%.

e-Commerce Fulfillment Models for Luxury Brands in Asia
This thesis provides a fundamental understanding of Polo Ralph Lauren’s current business operations and of current e-Commerce fulfillment models for luxury apparel brands in China. An assessment of gaps was also conducted between current fulfillment operations of PRL and those of other luxury brands and 3PLs operating in China, specifically on delivery lead-time, last mile delivery options, end-to-end customer service, and return logistics. Based on our findings, business and supply chain strategy recommendations were generated for PRL to offer best in class luxury fulfillment service, further strengthening its growth and brand image.

A Qualitative Mapping and Evaluation of an Aerospace Supply Chain Strategy
This project tested the applicability of the Perez-Franco, Singh, & Sheffi methodology to the aerospace industry. We conducted a qualitative mapping of the supply chain strategy for a specific satellite program in Lockheed Martin Space Systems. Outcomes from this case show the usefulness of the methodology to a wide number of industries, including aerospace.

Marine Dock Optimization for a Bulk Chemicals Manufacturing Facility
The petrochemical manufacturing industry is considering capital asset utilization with increased scrutiny. The authors consider the problem of marine dock utilization in the context of this particular industry as well as parallel problems in other industries. They recommend a framework for simulating and benchmarking dock operations to allow for quantifiable and comparative assessment of this asset.

The Effects of Vendor and Quality Control Variability in the Procurement of Raw Materials in a Bio-Pharmaceutical Company
The majority of the players in the pharmaceutical industry have not traditionally been motivated to optimize supply chain and operational efficiencies. Several factors in the industry, however, are helping to turn management attention towards supply chain and operational efficiency. This paper looks at a bio-pharmaceutical company and attempts to map and model the raw-material procurement process. Raw-material inventory and supply chain responsiveness are used as dependent variables to compare scenarios of concentrated improvement in vendor and internal lead times.
Merging Qualitative and Quantitative Criteria for Freight Investment Using Scenario Planning
Continual investment is needed to preserve and expand a U.S. transportation system that faces growing freight volume. This thesis demonstrates how scenario planning enhances the investment decision-making process by building consensus and helping planners to shift from prediction to preparation for the future.

Optimized Transfer Pricing Model for Asia Pacific
Multinational corporations can impact overall profit by setting internal transfer prices to take advantage of differences in tax rates and tariffs. This thesis reviews methods used in Asia Pacific and constructs a mathematical model to determine the optimal transfer price using data from a hypothetical company.