RESEARCH JOURNAL

CLASS OF 2010

Summaries of select research projects by graduates of the MIT-Zaragoza Master of Engineering in Logistics and Supply Chain Management (ZLOG)

Impact of Point of Sale Data on Demand Planning for a Two level Supply Chain
By Luis Diego Artiñano and Kavita Keerthi
Thesis Advisor: Dr. Rogelio Oliva

How Do Recession and Oil Prices Influence the Network Design?
By Jorge Capitanachi and Ioannis Theodorou
Thesis Advisor: Dr. David Gonsalvez and Dr. Asvin Goel

Supply Chain Integration and Inter-organizational Learning
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Thesis Advisor: Dr. María Jesús Sáenz

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By Wiko Kabiling
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The Power of Aggregation: Postponement Strategies in Pharmaceutical Supply Chains
By Sumeet Ladsaongikar and Roberto Martínez
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Sourcing Strategies for a Photovoltaic Power Plant
By Mani Ponnuswamy
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Ecological Footprint of the Pharmaceutical Supply Chain
By Noelle Thomas and Katharina Weber
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Optimal Sourcing Strategies for Managing Supply Chain Risk for Platinum Group Metals (PGM) in Automotive Catalytic Converters
By Federico Vargas
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Introduction

Welcome to the 2010 Master of Engineering in Logistics and Supply Chain Management (ZLOG) Research Journal!

The eight papers included in this journal were chosen from the sixteen theses submitted by the ZLOG Class of 2010 at the Zaragoza Logistics Center. The articles are written as executive summaries and are intended for a business, rather than an academic, audience.

The purpose of the executive summaries is to give the reader a sense for the business problem being addressed, the methods used to analyze the problem, and the relevant results, conclusions, and insights gained. The complete theses are, of course, much more detailed.

We have also included a complete list of this year’s ZLOG theses with short descriptions at the end of this journal.

The articles included in this publication cover a wide range of interests, approaches, and industries. The topics include: Forecasting, Inventory and Risk Management, Renewable Energy, Green and Reverse Logistics, Network Design, Traceability and Supply Chain Integration, and Global Health and Humanitarian Supply Chains. This variety of topics illustrates one of the hallmarks of the ZLOG program: the students’ ability to focus their course work and research on the topics that most interest them.

The ZLOG program is designed for early to mid-career supply chain professionals who want a more in-depth and focused education in supply chain management, transportation, and logistics.

The class size is limited each year to 30-35 students coming from around the globe and across all industries.

The projects highlighted in this journal reflect the variety of ZLOG student interests. Most of the projects are conducted in conjunction with the Zaragoza Academic Partner (ZAP) Program, an initiative to enhance applied research and closer industry-academia relationships in the field of supply chain management.

The ZAP Program gives ZLOG students the opportunity to work closely with industry professionals on actual supply chain problems, and gives companies an opportunity to interact with a student or student team along with a professor as expert thesis advisor who together bring new insights and approaches to a current supply chain project.

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

Happy reading!

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Introduction

Most firms base their planning decisions on demand signals coming from immediate downstream players. These signals are not representative of the end customer demand and are usually distorted and amplified as they move upstream. To overcome this situation the analysis of point of sale data (POS) can add value to upstream players, as they bypass the abovementioned distortion and get better insights on the demand’s behavior.

Although the benefits of POS seem to be unquestionable, many have argued how this data should be utilized to materialize them. Some suggest using POS data to directly forecast sell-in demand; others argue using it to calculate future sell-in demand based on a sell-through demand forecast.

Our approach identifies ways of how POS data can complement the order based forecast. This contrasts with older approaches which analyze the benefits of POS and orders history separately.

The thesis studied the use of POS data collected at the Distribution Centers (DCs) to enhance the planning process at the Master Distribution Center (MDC) by providing a valuable trend analysis of demand and a model for reducing variability of incoming orders. The figure below shows the flow of POS data from DC to MDC and the impact on demand signal variability.

With the use of a seasonal exponential smoothing model to predict 13 weeks of POS data, the trend analysis...
proved to give accurate insights about next periods’ orders arriving to the MDC.

A complementary order revision model was developed to bring orders closer to POS demand. And based on the confidence intervals of the POS data forecast, this order revision model suggests changes to the orders’ quantity to keep it within the predicted range of demand.

The procedure for selecting the forecasting model, the trend analysis tool and the order revision model is discussed in brief below. The criteria defined for classifying demand as non-recurring is also presented.

**Forecasting Model Selection**

The objective of the model selection process was to define a base model capable of functioning with all SKUs and providing accurate predictions. Simplicity over performance was preferred; nevertheless, with the flexibility to adjust to different demand patterns by tailoring the model’s parameters to each case. To have an accurate trend analysis a representation of the pattern is enough rather than having point to point accuracy.

A total of 30 models were run for a sample of SKUs and it was observed that the Seasonal Exponential Smoothing Model with a 53 seasonality period was the best fit based on the Schwarz Bayesian Criterion (SBC) criteria. SBC avoids selecting over fitted models by penalizing the number of parameters used. Thus, this model uses only two parameters: the level smoothing weight and the seasonal smoothing weight to forecast. And to have an even simpler approach, category-average parameters were used (the categories of lifecycle stages and demand variability were used to classify the SKU sample). The chart below shows the forecast of one SKU. Notice how the prediction follows the demand pattern.

**Trend Analysis**

The traditional trend analysis consists of using only history data without considering predicted values. Since this prediction has information about the product seasonality, the traditional trend line is not able to adjust for changes and therefore it can mislead the decisions taken upon this result. In the following chart, this trend analysis is shown for one SKU compared to the future actual data. Notice the high difference in trend line direction.

The trend analysis suggested consists of a linear regression line composed of 26 order history data points and the 13 POS forecast data points. This mix of history and prediction gives a responsive trend line capable of making adjustments based on the most recent events. In the following chart, a proposed trend analysis is shown for one SKU compared with the actual data along the same period. The gap in between the trend lines at the end of the chart is measured as the trend line error, and the sample average result for this error is 24.1%.

**Order Revision Model**

The accuracy of the proposed trend analysis depends on a constant relationship between POS and orders. It is for this that the order variability must be controlled to make this a more reliable tool.

The order revision model was developed to control this variability by keeping the orders within the predicted range of demand. Through the use of the POS forecast confidence intervals, arriving orders at the MDC that go beyond this range are returned for revision to the DCs. This revision indicates an increase or reduction in the order quantity. The DCs would not know upfront what the limits are to avoid influencing the original DC decision which might contain valuable local market information.
A simulation for this model was run on the SKU sample. The four key performance metrics monitored during this exercise were variability and inventory reduction, service level and revised orders. The only assumption was that no quantity updates were made for those orders falling within the range and that followed a revised order in the previous week.

The following chart shows the order revision model applied to one SKU for the 13 week forecast period. Notice that the first and second orders were trimmed and the fourth order was increased.

[Chart showing order revision model for one SKU over 13 weeks]

The average sample results showed an order variability reduction of 5.24%, an inventory reduction of 8.26%, a service level reduction of 1.66%, and a percentage of revised orders of 11.78%. In addition to these key metrics, the trend line error to analyze the revised orders reduces by 2.13% as a result of the improved order variability.

Regarding the negative impact on service level, this would have been less in a real situation considering the assumption made about no order updates.

As order patterns become more stable and managers gain confidence in this model, it is possible to systematically increase the performance of the system by gradually narrowing the confidence intervals. Experimentation with different intervals and their corresponding required safety stock proved positive results without impacting service level. It also suggested a method to determine the optimal confidence level policy to manage orders more proactively.

Non-recurring Demand

The upper bound of the 95% confidence interval of the POS prediction was defined as the criterion to identify demand as non-recurring. This will facilitate the communication between MDC and DC about overruled order revisions. If the MDC is aware an order is responding to a legitimate high demand, it will allow the original quantity to go through. In addition to this, this criterion will allow the MDC’s forecasting system to label those outlier orders that should not be considered in the history data analysis. However, this will require the detection of those high orders following the observed peak in demand and labeling them as such in the forecasting system.

Conclusions

The recommended forecasting model to use with POS data is seasonal exponential smoothing with a seasonality of 53 weeks. This model is flexible enough to work with all SKUs and allows for easy implementation and operation as it only requires two parameters. This model can use category-average parameters but these should be revised periodically at least every six months.

The trend analysis based on POS data is a useful tool to complement the MDC order forecast. It allows the demand planner to identify discrepancies between demand and forecasted orders, and then resolve them through the current forecast validation process.

The order revision model showed a positive impact in variability and inventory reduction with a minimum invasion to original orders. As a result, this made orders more predictable by POS and consequently improved the trend line error. However, the service level requires close monitoring to avoid stock out situations. As for implementing this model, one crucial point is to have the agreement and collaboration of the DCs, since due to their active participation their views should be considered a before launching this initiative.

Finally, the criterion for non-recurring demand will serve the order revision model so as to facilitate the communication between MDC and DC, and it will provide useful information for the order forecasting process.

References


Introduction

Recession, volatility in fuel prices and globalization exert tremendous pressure on most logistics companies’ supply chains. These macroeconomic factors affect not only the performance of such companies but also the way their network is designed and operated. There is on-going interest of logistics companies to identify inefficiencies and areas of improvement that, if addressed, will give them a competitive advantage.

Current Situation

The company sponsoring this thesis is one of the world’s leading providers of express delivery and logistics services, including freight forwarding, transportation management, and warehousing and distribution.

In the company’s annual report of 2009, it is mentioned that a threat to its business model is its vulnerability to trading volume declines given its high level of operational gearing to support its global network. The global economic crisis that decreased
trading volumes in 2008 and 2009 has not left the company unscathed. In 2009, the company posted revenues in excess of €20 billion, more than 10% drop compared to revenues in 2008. The cost of fuel, excluding aircraft fuel, exceeded €600 million in 2009, more than the profit in 2009.

The division leading the company’s operations in the Iberian Peninsula is seeking to identify the changes needed in its Spanish network in response to changes in fuel prices and demand levels.

**Problem Definition and Approach**

The multi-customer network that the company has developed in Spain consists of 6 central distribution centers and 8 cross-docking platforms that serve all delivery orders received on a daily basis with a specified lead time as seen in the following graphic.

The multi-customer network has thousands of final delivery destinations. The demand pattern was analyzed for all destinations and the 45 clusters that better represent the demand distribution were selected (depicted below).

The final mathematical formulation that models the company’s network involves 1 product, 6 CDCs, 8 cross dock platforms, 45 demand nodes (as depicted below) and 2 types of trucks.

The costs associated are:

**Cross Dock Costs**
- Fixed costs of operating a cross dock. It includes the building’s fixed costs, equipment fixed costs and administrative overheads.
- Throughput cost per unit (aka handling cost) at the cross dock. It includes operations-related labor costs and other costs.

**Transportation Costs**
- Fixed cost per truck (depending on the type of truck). It includes drivers’ wages, insurance costs, amortization costs and financial costs.
- Variable cost per truck (depending on the type of truck). It includes fuel consumption, driver’s eating allowance, truck’s maintenance and repair costs.

The network was modeled as a minimum cost network flow problem and a mixed integer programming (MIP) formulation was solved for 342 different scenarios of fuel price and total demand. The optimal network configuration for all these scenarios was determined. The fuel price varied from €0.20/lt to €3.60/lt and total demand in mainland Spain varied from 400 tons/day to 4,000 tons/day.

This research project is not limited to identifying the effects of varying macroeconomic factors but also includes creating a methodical simulation of the company’s network that can be repeated and used in the future for examining the network performance under various conditions by its management. Results of the simulations can be visualized using an in-house developed graphic dashboard as shown in the following figure:
Results & Recommendations

- **Mix of direct and indirect shipments leaving each central distribution center (CDC)**

  Regardless of the fuel price level, increasing demand results in a smaller proportion of goods being cross docked. When demand is higher than 100%, then the proportion of direct shipments varies from 84% to 100%. When demand is lower than 100%, the proportion of goods leaving the CDCs directly for the final destinations varies from 55% to 86% depending on the scenario. The utilization rate of trucks in the XD-final destination route is much smaller than in the other routes. The company can increase the utilization rate by providing service with a longer delivery lead time, using a medium-sized truck and introducing milk-runs.

- **Mix of types of trucks that should be used in each route**

  Small trucks are mainly used predominantly when regional demand values are low and for the remaining goods after the subtraction of multiple full large truck loads. This is because the large truck is much larger without being that more expensive than the small truck. For demand values less than 2,000 tons/day 15-20% of trucks used are small (otherwise the proportion is around 5%).

- **Assessment of the performance of the company’s Cross Docks**

  Currently, the company has all 8 cross docks operating in its network. Simulations indicate that having all 8 cross docks operating is the optimal configuration only for demand values within the range of 2,400-3,000 tons/day (more than 120% of today’s demand). The cross docks sorted by throughput volumes in decreasing order are: 1) Valladolid, 2) Zaragoza, 3) Alicante, 4) Valencia, 5) Malaga, 6) Amorebieta, 7) Vigo and 8) Oviedo.

  Our findings also suggest that the same region can be served by more than 1 cross dock.

- **Costlier destinations for the company to serve**

  Our findings suggest that the three most expensive provinces to serve are: La Rioja, Valencia and Navarra. The three cheapest provinces to serve are: Madrid, Cantabria and Murcia. The aforementioned provinces exhibit a consistency with respect to how expensive or cheap they are relative to the rest of the provinces. The company’s network is geared to satisfy demand its biggest market, Madrid, but not its second biggest market, Cataluña, or third, Andalucía. One way to reduce the costs of serving the most “expensive” provinces is the collaboration with competing logistics companies so as to reduce what logistics companies hate most: transporting air. Although that is easier said than done, both (or more) competing companies will benefit. Another option is to increase the delivery lead time to these provinces so that accumulation of demand allows the shipment of full truck loads.

Cited Sources


The Company’s Annual Report 2009, Group Management Report
Introduction

Companies have long been searching for the key components of performance. In recent years management has increasingly focused on supply chain interaction as a potential area for improvement and differentiation. A central driver of the efforts to improve and innovate is the ability to gain new knowledge and apply this to new situations, in other words, learning.

The role of learning in a supply chain relationship has been understood intuitively as important, though this has not been confirmed through actual measurement due to its intangible nature. Some efforts have therefore also been directed towards increasing learning capacity, but as the actual drivers of performance have been largely unknown, companies traditionally tend to spread these efforts across various areas without a clear understanding of the impact.

However, as large companies develop sizable networks of thousands of suppliers, it is becoming increasingly more important to focus on those factors that truly have an impact on performance.

The goal of this thesis was to explore how inter-organizational learning affects the supply chain and which performance drivers should receive increased focus in order to improve the integration of supply chain partners.

Approach

The corporation with which the study was conducted has worldwide operations with more than 50,000 employees. Their supplier base for the parts and service part of the business consist of more than 2000 tier one suppliers.

In order to select potential elements impacting performance, a review of research in the field of inter-organizational learning...
organizational learning was conducted. From this two primary models were derived:

![Diagram](image1)

**Figure 1 – Representing the hypothesized model used to test the relationship between learning (Absorptive Capacity), safety (Psychological Safety) and perceived performance from the suppliers**

![Diagram](image2)

**Figure 2 - Representing the hypothesized model used to test the relationship between trust, alignment (Cultural Alignment) and perceived performance from the suppliers**

The first step of the research was to collect the necessary input data to test the models, mainly from two sources: (i) a survey, in order to gather the information needed from the suppliers to connect their behavior with their performance. The survey consisted of 1672 suppliers, the top 80% suppliers in terms of 2009 4th quarter spending, from which 415 valid responses were obtained. (ii) KPIs, an input source that came directly from the company and was the actual delivery performance from the suppliers who had answered the survey.

The second step, once we had the inputs, was to conduct a regression analysis to discover if statistical significance could be found to prove the hypotheses from the two models. We discovered that, on one hand, a strong statistical relation exists between trust and alignment, and between psychological safety and absorptive capacity, and on the other hand, a very weak relation exists from the interaction effects.

The third step was the quasi-experimental research, in which the results of the survey were combined with the impact of an inter-organizational event and the effect of this event upon the KPIs used by the company to measure its suppliers. The analysis of these KPIs (delivery performance) was examined through a classification of the four concepts involved in the models to determine how a specific disruption in time (treatment) affected the dynamics of the supply chain. The analysis was split into two distinct time periods based on the treatment; stability and volatility in the demand environment.

Finally, the findings from the regression and the quasi-experiment were combined to obtain stronger and more general conclusions and to draw several managerial implications that could be useful for the company.

**Results**

Four concepts of behavior between supplier and buyer in a supply chain relationship were explored and found to be positively related to perceived and actual performance with statistical significance.

**Learning (Absorptive Capacity)**

The ability of an organization to cooperate with supply chain partners in order to explore new information, knowledge, ideas or innovation, to discuss it openly internally, draw new conclusions, and implement ideas into new solutions, was found to be strongly linked to the perceived performance in a supply chain relationship. Given the right risk-safe cooperative environment, this ability can also be linked to actual performance in a volatile market situation.

**Alignment (Cultural Alignment)**

Supply chain partners that are integrated through alignment in their set of values, corporate culture, goals and objectives will tend to have a stronger relationship than those who are not. Furthermore, their ability to predict each other’s behavior will also improve the capacity in the relationship to deal with change. The level of alignment in the supplier-buyer
relationship was found to have a direct impact on both perceived performance by the supplier and actual performance as measured by the buyer.

Trust
Organizations that take into consideration the impact of their actions on both sides of a supply chain relationship will tend to develop a higher level of trust. Trust is also influenced by working towards areas with mutual benefits. A clear link was found between the perceived level of trust in the supplier-buyer relationship and the perceived performance. However, in an environment of change, trust alone may not be sufficient to drive actual performance. Without common goals and objectives, trust may lead to negative results for one of the partners in the relationship. A high level of trust was found to have a positive impact on actual performance, under the condition that the supplier and buyer were also closely aligned.

Safety (Psychological Safety)
A working climate where opinions and experiences are shared freely without risk of persecution is often believed to be a cornerstone of a functional business. The impact of such a working climate was found to have a direct positive impact both on perceived relationship performance from the supplier side and on the actual performance measured on the buyer’s side. In addition to this, as previously stated, a drive towards an improved inter-organizational learning environment will have a direct impact on both perceived and actual performance. However, in order to take full advantage of this, it will be important that the correct working environment is already in place in the relationship. Sharing ideas and past experiences can only be effective if by doing so there is little risk of jeopardizing the relationship. Perceptions are of particular importance in this area, as the willingness to share information will be controlled by the perceived expected consequence of such sharing, regardless of the actual consequence. The direct relationship between safety and learning was also found through the survey results.

The results are summarized in figure 4, which also includes a number of suggestions for improvement of each concept. The suggestions were based upon the survey results as well as the theoretical concepts behind.

Conclusions
We found how relatively intangible concepts such as trust and cultural alignment, along with a positive environment for voicing opinion and capacity for learning, have a direct impact on supply chain relationship performance. This finding can be used to justify investments into these relationship areas.
Introduction

A new environment for vaccines is emerging. Vaccines are one of the most cost-effective public health interventions and are critical to meeting the United Nations Millennium Development Goal of reducing deaths among children less than five years old. In the past decade, the rate at which new vaccines have been introduced into the world market has been unprecedented (see Figure 1). The pipeline of vaccine development addresses some of the biggest causes of child mortality, including malaria (WHO, UNICEF, World Bank, 2009).

Furthermore, funding for the adoption of such vaccines by low-income countries is made available by the GAVI Alliance, a public-private partnership that co-finances the purchase of a set of prequalified vaccines by countries deemed eligible based on socio-economic status.

However, given the finite capacity of vaccine delivery systems, finite sources of funding and varying disease burden, countries will be faced with the need to choose which vaccines to adopt into their national immunization programs in the coming years. Therefore, just as proliferation of stockkeeping units or product variety is increasing implied demand uncertainty in commercial supply chains (Chopra and Meindl, 2010), the rapid introduction of new vaccines creates a more uncertain adoption landscape, making it more difficult for supply to meet demand.

Forecasting these adoption dates is an important pre-requisite to forecasting global demand for vaccine doses, which in turn is essential for different stakeholders in the global vaccine supply chain – for planning production capacity, for projecting funding requirements, and for designing or expanding the appropriate supply chain infrastructure (Sekhri, 2008).

GAVI has teamed up with the Program for Appropriate Technologies in Health (PATH) to develop a platform for the strategic forecasting of vaccine demand. This independent study was conducted with a view to recommending how longterm adoption dates might be fed into the overall demand forecasting process, so as to inform and facilitate strategic planning by GAVI and other stakeholders in the global supply chain for vaccines.

Summary:
This thesis investigates the factors that affect the adoption of vaccines by low-income countries into their national immunization programs, particularly in an emerging environment where countries have to choose among many available vaccines. The thesis proposes a rule-based model that uses public data to forecast adoption over a 20-year horizon and uses a sample forecast to quantify future adoption delays.

KEY INSIGHTS
1. Forecasts can no longer look at vaccines individually but must consider the portfolio of vaccines that countries adopt.
2. A rule-based approach that uses adoption preferences, spacing and “look-ahead” captures the dynamics of such concomitancy.
3. Pending adoptions will continue to accumulate and should be measured in the long-run to inform objectives and policies.

Strategic Forecasting of Vaccine Adoption by GAVI-Eligible Countries

By Wiko Kabiling
Thesis Advisor: Dr. Laura Rock Kopczak

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A Rule-Based Forecasting Model

This thesis uses findings from literature, data analysis and expert opinion to propose a rule-based model to forecast vaccine adoption dates for GAVI-eligible countries over 20 years.

The resulting model incorporates three elements that shape a country’s adoption schedule: preferences (a country’s prioritization of some vaccines over others), spacing (the number of years between vaccine adoptions), and look-ahead (countries’ delay of current adoption in anticipation of important vaccines in the development pipeline).

Preference tables are developed for the WHO subregions based on regional disease burden. These tables are then modified to account for GAVI cofinancing. The change that GAVI co-financing brings to a country’s preference is a function of vaccine coverage rates and national income.

The spacing of adoption is forecast to be two, three or five years, based on recent estimates of national coverage rates for the third dose of the diphtheria-tetanus-pertussis vaccine (DTP3), which has served as a representation of the strength of a country’s vaccine delivery system.

The model also includes pipeline anticipation, where countries are able to “look-ahead” to the introduction of important vaccines into the market, thereby allowing the model to predict how some countries can wait for these vaccines rather than adopt those that, while already available, are also less-preferred.

Results: Measuring the Effect of Concomitancy

Sample forecasts using these rules show that adoption delays will continue to accumulate as a result of concomitancy. These translate into missed opportunities at improving global health, which can be quantified using two proposed indicators:

Weighted Country-Vaccine-Year Delays (CVYs)
The number of years between a vaccine introduction and its adoption by a country, multiplied by the regional disease burden score for that vaccine in the country.

Weighted People-Vaccine-Year Delays (PVYs)
CVY delays multiplied by the country’s population under 5 years old.

On a global scale, the missed opportunity is 20,963 total CVYs or 125 trillion total PVYs by the year 2030. Figure 3 and Figure 4 show how these delays progress over time. In these area stack charts, delays accumulate when years go by without vaccines being adopted. On the other hand, the slope is reduced when countries begin to adopt the vaccines. The areas are color-coded by coverage and income group.

The accumulation of delays can be explained by two factors. The first is the spacing of adoption in relation to the introduction of new vaccines. The least poor groups generally accumulate fewer delays. The low coverage groups, on the other hand, drive the overall slope upward, since low coverage in the model translates to wider adoption spacing.

The second factor is the look-ahead effect for the introduction of the malaria vaccine, especially for the African sub-regions. As countries anticipate the malaria introduction, the adoption of other vaccines such as measles, pneumococcal, rotavirus, HPV, typhoid and shigellosis get put off.
Additionally, CVY delays begin to drop towards the end of the forecast period, as there are no more additional pipeline vaccines being considered and countries have a chance to catch up on any relevant vaccines it had not adopted. The drop in delays occurs sooner for the least poor countries than for low coverage countries and the rest.

Conclusions

This study sheds light on several key insights. First, in a concomitant environment, forecasts can no longer look at vaccines individually but must consider vaccines concurrently, evaluating the portfolio of vaccines that countries adopt.

Second, delayed adoptions will continue to accumulate as a result of concomitancy, translating into missed opportunities at improving global health. Measuring such delays is important in setting objectives and in evaluating alternative policies. This thesis proposes metrics within the adoption forecasting framework to do just that.

Third, countries looking ahead in favor of preferred pipeline vaccines will increase the delays in adoptions even more. Because of this effect, the issue of pipeline anticipation should be investigated further.

Fourth, some of the older vaccines like measles may be left out as countries prioritize adoption based on disease burden and availability of GAVI cofinancing.

Finally, countries most at risk in the concomitant environment are the poorest of GAVI-eligible countries that are starting the decade with low coverage of basic vaccines like DTP3.

Further research should take into consideration vaccine affordability, state fragility, adoption difficulties like countries’ cold chain capacity, which are likely to affect preferences and spacing. The thesis complements field work being done by PATH in Kenya, Tanzania and Zambia to characterize the current adoption logic used within the ministries of health, findings of which are due at the end of 2010. These may provide additional ideas to explore in further developing the model presented here.

This study contributes to research by taking a valuable first step towards a complete framework for strategic adoption forecasting, one that is relevant to the new concomitant environment for GAVI-eligible countries. It is the authors’ hope that this lays the groundwork for generating insights that will ultimately guide conversation and action.

Cited Sources


Introduction

For the past several years there has been a significant proliferation in the number of Stock Keeping Units (SKUs) across most companies. This has been largely driven by severe competitive pressures in industry whereby in the quest for higher market share, companies have tried to capture niche customer segments. This trend is especially evident in industries such as consumer products, electronic goods, pharmaceuticals, and so on.

As a result of this SKU proliferation, there has been a significant increase in supply chain complexity.

Not only does manufacturing have to produce a larger variety of products but also overall inventory levels in supply chains have increased significantly with an increase in the number of SKUs. In the quest for market share, a large number of companies have thus significantly increased overall supply chain costs.

One of the ways to deal with increasing complexity of number of SKUs is the concept of postponement, a concept wherein companies can delay the differentiation of their product at a later stage in their supply chain. This would help companies respond to demand much faster as the overall lead-time for order fulfillment would reduce, the further one went downstream in the supply chain. Also, delaying differentiation could have the advantage of reducing overall inventory levels in the supply chain as generic “Sub-Assembly” or “Work in Process” inventory would be stored as opposed to Finished Goods inventory. This generic work in process inventory could be used for multiple finished products, thus reducing the level of Finished Goods Inventory required to maintain a specified service

KEY INSIGHTS

1. The postponement decision can be affected by the number of SKUs in the particular product being postponed.
2. Unit costs of inventory in the Finished Goods and Work in Process form can significantly alter savings from postponement.
3. Variations in lead-time for differential process steps in current and postponed scenarios can affect the possible benefits.

Summary:

This thesis attempts to create and implement a structured approach for the decision to postpone the packaging decision at a later point in time in a global pharmaceutical company. The approach includes selection criteria for products that could show significant benefit thorough postponement. It also includes a simulation model that attempts to recreate the present and postponed inventory management scenarios.

Postponement Strategies for Pharmaceutical Supply Chain

By Sumeet Ladsaongikar and Roberto Martinez

Thesis Advisors: Prof. Beste Kucukyazici and Prof. Mustafa Cagri Gurbuz

Sumeet Ladsaongikar graduated from the MIT-Zaragoza Masters in Logistics & Supply Chain Management program in 2010. He received his MBA from the Indian Institute of Technology, Kharagpur, India, in 2006 and his Bachelor’s degree in Electrical Engineering from the University of Mumbai, India, in 2003.

Roberto Martinez graduated from the MIT-Zaragoza Masters in Logistics & Supply Chain Management program in 2010. He received his MBA from INCAE Business School, Costa Rica, in 2010 and his Bachelor’s degree in Economics from the Monterrey Institute of Technology, Mexico, in 2000.

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Not only does manufacturing have to produce a larger variety of products but also overall inventory levels in supply chains have increased significantly with an increase in the number of SKUs. In the quest for market share, a large number of companies have thus significantly increased overall supply chain costs.

One of the ways to deal with increasing complexity of number of SKUs is the concept of postponement, a concept wherein companies can delay the differentiation of their product at a later stage in their supply chain. This would help companies respond to demand much faster as the overall lead-time for order fulfillment would reduce, the further one went downstream in the supply chain. Also, delaying differentiation could have the advantage of reducing overall inventory levels in the supply chain as generic “Sub-Assembly” or “Work in Process” inventory would be stored as opposed to Finished Goods inventory. This generic work in process inventory could be used for multiple finished products, thus reducing the level of Finished Goods Inventory required to maintain a specified service
level. In this study, we have tried to study the application of postponement to the supply chain of a large global pharmaceutical company. In the pharmaceutical industry supply chain, country-specific government regulations and language specifications make it mandatory for pharmaceutical companies to have packaging that is customized for almost every country. In a global scale pharmaceutical company, this results in a huge increase in the number of SKUs. Also, given the nature of the pharmaceutical industry wherein the final product needs to be delivered with a very high service level, this phenomenon results in high inventory levels across the supply chain. In order to deal with this complexity, this thesis examines the applicability of the concept of postponement to this problem. The methodology used is as described in the following exhibit:

In the first phase of the study, the supply chain of the sponsor company was studied. Inventory at the sponsor company could be categorized into three basic types:

i. Drug Substance (DS) Inventory – This is the preliminary stage of drug formation. This is the key active ingredient in the final drug.

ii. Drug Product (DP) Inventory - This is the primary dosage form in which the drug is manufactured. An example of a DP would be a 50 mg tablet of aspirin in a ready to consume form.

iii. FP (Finished Product) - This is the final stage of drug formation. Drug product packed in the appropriate package with the correct country specifications and instructions would constitute the Finished Product.

The material flows and inventory positions in the sponsor company in the present (AS-IS) and the postponed (TO-BE) scenario can be depicted as shown in the following exhibit.

In the present (AS-IS) scenario, Drug Product and Finished Product is manufactured based on a pull from the market and the finished product is stocked in the CPOs. In the postponed scenario, Drug Product would be stored in inventory at the factory and only packaging and delivery would be performed on market pull.

Product Selection Process

After getting an initial understanding of the sponsor company’s supply chain, criteria for selection of product was identified. The 5 criteria used for selection of products for postponement were as follows:

i. Number of SKUs in the product

ii. Dollar value of sales

iii. Safety Stock levels in the CPOs

iv. Contribution of the product to the total cost of goods sold

v. Increase in inventory value from the DP to the FP stage

An analysis of 200+ products with 500+ dosage forms was conducted with each of these 5 criteria to identify the products which would give the greatest possible benefit from postponement. Products which were in the top-quartile for each of the above criteria were selected for further analysis. Out of these selected products, one product was chosen for creation of a simulation model. The model was created for two purposes – to quantify the benefits from postponement and to perform sensitivity analysis for variation in key input parameters.

Simulation model & Sensitivity Analysis

Two simulation models were created for evaluating the postponement decision. The first one was the AS-IS model which attempted to replicate the present inventory management and material flow system and the second one was the TO-BE model which recreated the system with the implementation of postponement. Demand distributions for the SKUs were considered based on past demand data from the sponsor company. For inventory ordering and replenishment a standard (r, Q) model was assumed. In the AS-IS and TO-BE scenarios, inventory holding costs were calculated and the difference between the holding costs across the two models were the expected savings from postponement. The simulation model was created using the Arena simulation software.
The results of the simulation were as shown in the following exhibit:

As seen in the above exhibit, with up to 3 SKUs, there is a net loss if postponement were to be implemented. However, beyond 4 SKUs the savings from postponement start increasing. At 10 SKUs for the product, close to a 4% reduction in inventory holding cost could be expected for the selected product. For a higher number of SKUs, the reduction in the inventory holding cost is expected to be even greater as there is greater pooling of demand uncertainty from SKUs sold in different countries.

We then perform a sensitivity analysis to examine the impact of changes in key factors such as FP and DP unit costs, variation in lead times for the DP manufacturing, packaging and delivery stages as well as packaging capacity on the level of savings from postponement.

For changes in the unit cost of the DP and FP inventories, we assume a 10% or a 20% increase or decrease in the unit cost of the DP and FP inventories. An increase in FP unit costs could be due to higher packaging, transportation or warehousing costs, whereas changes in DP costs could be due to changes in the DP manufacturing process as well as variation in DP manufacturing process from one plant to another. The impact of these changes in unit costs is as shown in the following exhibit.

As a general trend, in the case of the selected product, a change in the FP unit cost seems to affect the possible savings more than changes in the DP unit costs. The results of the impact of variation in the lead times at the manufacturing, packaging and delivery stages is shown below:

An increase in the coefficient of variation of the manufacturing lead times increases the savings from postponement significantly as compared to similar increase in the variation in packaging and delivery variation. This could be because of the fact that in the TO-BE process, the DP inventory buffer in the manufacturing plant would obviate the need to have higher FP safety stocks in the CPOs to account for the variation in the manufacturing lead-time. In comparison, the variation in packaging and delivery lead times affect the AS-IS and the TO-BE scenarios equally, and therefore, there is no significant improvement in savings from postponement due to greater variation in these lead times.

Conclusions

From the simulation results, we can conclude the following:

- Postponement may be a good decision only if implemented in a product with a large number of SKUs and therefore a greater level of pooling of demand variation.

- Changes in the unit costs of the inventories can significantly impact the level of savings from postponement.

- Variation in the lead time for differential process steps (such as DP manufacturing) between the present and the postponed scenarios can result in significant changes in the benefits from postponement.
Sourcing Strategies for a Photovoltaic Power Plant

By Mani Ponnuswamy
Thesis Advisor: Dr. David Gonsalvez

Summary:
This thesis studies the dependence of a photovoltaic (PV) power plant's lifetime cost and lifetime revenue on the choice of its solar PV panels. An actual power plant located in Germany is modeled in Matlab using the electrical parameters of its PV panels. The plant's panels in the model are then sequentially replaced with 98 different types of panels and individual simulations are run for each type. Based on the results, a generalized framework for choosing solar panels and its suppliers is developed.

KEY INSIGHTS
1. The selection of the optimum PV panel for a chosen site is independent of its nameplate power rating and its country of manufacture.
2. A simulation-based approach for PV panel selection is necessary to achieve optimal tradeoff between lifetime revenue and lifetime cost.
3. A payback period-based approach is not capable of distinguishing significantly between PV panels.

Introduction
Procurement questions such as ‘What is the right technology for my product?’ and ‘What criterion should I use to buy material?’ are very crucial for solar photovoltaic (PV) power plant projects where material costs are a substantial portion of total lifetime cost. This research builds a framework to help answer some of these questions in the solar PV supply chain context.

In this research, the PV chain (shown above) is viewed from the perspective of a solar power plant installer - the solar PV supply chain participant who is responsible for deploying PV systems outdoors. The analysis has been done with the intention of maximizing the supply chain profitability of the segment of the chain between the solar panel manufacturers and the end customers. The analyses and conclusions in this research rely upon cost and energy yield data obtained from a 1.512MWp ground-mounted, solar PV power plant constructed in Germany by The Company in 2008. The PV plant is modeled in Matlab using the electrical parameters of its PV panels. The plant’s panels are then sequentially replaced with 98 other panel types and the lifetime cost and lifetime revenue are computed for each type. Finally, the findings and conclusions based on the results are generalized so that they are applicable to any PV power plant project.

The Company and its PV Plant
The Company performs engineering, procurement and installation activities for rooftop and ground-mounted solar photovoltaic systems. In the case of the solar PV plant built by The Company in 2008, the customer already had a “feed-in tariff pre-approved” site. The Company had a fixed budget but was free to choose the installed capacity and the solar PV panel type as well as its suppliers. A 1.512MWp system composed of 8460 mono-crystalline panels was decided upon. The Company chose Chinese modules because (1) German panels were more expensive, (2) Chinese panels had no known quality or reliability issues and (3) there were no incentives that made German panels more attractive. In addition, German panels were usually difficult to procure for domestic use since about 60% of them were sold in the export market. The PV panels were ordered from the supplier 2 months ahead of project commencement. Once the components arrived at the site, it took 15 men and 4 weeks to prepare the land, build the mechanical support structures, unload, sort and install the panels, and wire them to all the other electrical
components. The result was a 1.512 MWp plant with 3 separate power generation stations that were equipped with systems of 2880 170Wp panels, 2880 175Wp panels and 2880 180Wp panels respectively. In addition to the power generation system, the plant was also equipped with a weather station (to record solar irradiance and ambient temperature levels at the panel surface every minute) and a power monitoring system that collects data on the operating conditions and the output power of each of the systems. The figure below shows the breakdown of the total installed cost of this plant. Note that solar panels contribute the most to the cost.

The Model

Matlab was used to build the model used in this research. A functional representation of the model is shown in the figure below.

Once the model is configured with the panel’s electrical parameters (obtained from the panel manufacturer’s datasheet), it can provide the maximum power achievable (MPP) from that panel for any given combination of solar irradiance (G) and ambient temperature (T_{amb}). The equations underlying this model are non-linear and complex due to the electrical characteristics of the photovoltaic material and the Newton-Raphson numerical method is used to solve them. The model is validated using 4 different panel types (2 mono-crystalline, 1 poly-crystalline and 1 thin-film) and it is found that the model’s characteristics are in very good agreement with the characteristics reported in the datasheet. The algorithm, underlying equations and the validation results are omitted here due to space constraints but are available in the thesis document. To account for losses such as direct current (DC) to alternating current (AC) conversion loss, mismatch, and environmental losses such as shading and soiling, a multiplicative loss factor is incorporated into the model.

Also, to achieve a good trade-off between minimizing estimation error and minimizing computational effort, data averaged over 15-minute intervals was chosen for this work. Energy over the 15-min interval (E_{15min}) and the annual energy yield (E_{annual}) are computed from the 15-min power (P_{mpp}) using the following formulae.

\[ E_{15min}(i) = \frac{P_{mpp}(i)}{4} \]
\[ E_{annual} = \sum_{i=1}^{35040} E_{15min}(i) \]

where 35040 corresponds to the approximate number of 15-min intervals in a year.

The model is configured with the panel’s parameters and simulated with G, T_{amb} conditions at the plant’s physical location in the year 2009. A comparison between simulation and actual measurement for two days in May 2009 is shown below (Energy is in units of kWh and time is in hours).

The annual energy yield from 2009 obtained from simulation is within 1% of actual measured yield. This further proves the model’s validity.

A Counter-Intuitive Behavior in PV Panel Yields

Between two panels from the same supplier, belonging to the same technology with identical manufacturing processes, one would expect the panel with a higher nameplate power rating to be more “powerful”. However, actual data from the plant as well as simulation data show otherwise. This can be seen in the following figure where, for certain G and T_{amb} conditions, a 175Wp panel performs better than an 180Wp panel. In fact, for the conditions at the plant in 2009, the 175Wp panels generated 3.5% more energy than the 180Wp panels!

This counter-intuitive behavior may be explained as follows. Nameplate power ratings on PV panels are based on laboratory measurements at standard test conditions (G=1000W/m^2 and T=25C). However,
these conditions are almost never realized in real-life. Besides, due to the inherent non-linear dependence of power on $G$ and $T_{\text{amb}}$, it is impossible to correctly estimate a PV panel’s performance without the use of simulation models. Given that panel prices are directly proportional to their nameplate power ratings, this finding has cost implications as well. This behavior further exemplifies the need for a mathematical simulation model such as the one developed in this thesis to project energy yields of panels before making sourcing decisions.

**Lifetime Energy Yield and Lifetime Cost**

Once the first year’s energy yield ($E_1$) and cost of panels ($C_{\text{panels}}$) are known, the lifetime energy ($E_L$) and lifetime cost ($C_L$) are computed as follows.

$$E_L = E_1 \left(1 - (1 - dr)^L\right)$$
$$C_L = C_{\text{panels}} + 12000 + 8000(L - 1)$$

where $L=20$ is the plant’s lifetime in years, $dr$ is the panel’s performance degradation rate (1% for crystalline and 3% for thin-film), €12,000 and €8,000 correspond to the O&M cost in year 1 and years 2...L respectively.

Next, the model is sequentially configured with electrical parameters from the datasheets of 98 other panels and $E_L$ and $C_L$ are computed for each panel.

**Results**

The results of lifetime energy versus lifetime cost of 61 panels are shown in the following figure. The panels have been differentiated according to the country of manufacture.

It is interesting to note the presence of a crystalline module from a foreign supplier that provides better performance both in lifetime energy yield and lifetime cost. Simulations show that choosing this panel instead of the currently installed panel would result in a 15% increase in lifetime energy while simultaneously cutting down lifetime costs by 19.5%!

A comparison of the cumulative revenues for three panel options is shown in the figure below. The calculations have been done with a €0.4675/kWh feed-in tariff corresponding to the German EEG policy for solar plants installed in 2008. It is interesting to note that, while the largest revenue option yields almost twice the lifetime revenue of the lowest cost option, the payback period is almost the same for the three panels. In fact, 75% of the panels simulated had payback periods of 6 to 7 years, regardless of the technology or the supplier location.

![Cumulative Revenue Chart](chart.png)

The following table summarizes the sample statistics of the results from the 99 panels simulated.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Lifetime Revenue</th>
<th>Lifetime Cost</th>
<th>Payback Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (in %)</td>
<td>13%</td>
<td>105%</td>
<td>85%</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>0.20</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td>Deviation of current panel from ideal</td>
<td>15%</td>
<td>12.5%</td>
<td>2%</td>
</tr>
</tbody>
</table>

There were some marked differences between some panels. For example, a panel with a lifetime cost of €3.6 million resulted in a 122% increase in lifetime revenue over another that cost only 8% less! It was also seen that the two best panels for this power plant (in terms of lifetime revenue minus lifetime cost) perform within 4% of each other. One is a 175Wp panel from a domestic supplier and the other is an 185Wp panel from an international supplier. It is reasonable to infer that neither the maximum power rating nor the country of manufacture seem to influence the profitability.

**Conclusions**

There are immense opportunities to increase the solar PV supply chain surplus in the form of optimal sourcing of PV panels. Incentives in the PV supply chain should be aligned so that every participant is working towards increasing this surplus. This thesis shows the importance of simulation models for choosing optimal panels for a chosen site. Moreover, the lifetime energy-lifetime cost chart that has been suggested could be an effective tool for supplier negotiations as well as to assess the financial viability of the project.
The Environmental Impact of Logistics
Evaluating and Reducing the Environmental Impact of Transportation and Warehousing by Using the Example of a Pharmaceutical Company

By Noelle A. Thomas and Katharina A. Weber
Thesis Advisor: Dr. Mustafa Çagri Gürbüz and Dr. Beste Kucukyazici

Summary:
This thesis addresses the question of how to measure and reduce environmental impacts from logistics activities. Therefore, a measurement framework for the most relevant environmental factors - CO2 emissions, waste production, and energy consumption - is developed and then applied in a case study to a pharmaceutical company.

KEY INSIGHTS
1. Air transportation is the driving factor in the CO2 emissions from transportation. This can be addressed through mode shift. Other reduction activities include increased capacity utilization and fuel efficiency for truck transportation.
2. Collaboration regarding warehousing and temperature regulation methods minimizes material use and disposal in a company’s logistics chain.

Introduction
Nowadays, companies are facing increased pressure from a broad group of stakeholders to minimize their environmental impact:

Governments are increasing environmental regulations related to waste as well as emissions, forcing companies to rethink their processes in order to prevent fees and penalties. Moreover, increasing pressure from customers and the public, which poses greater awareness concerning environmental issues, also has to be taken into account. Additionally, because of increasing raw material and oil prices, a reduction of environmental impact is usually related to significant cost reducing goals.

At the same time, globalization of sourcing, manufacturing, as well as marketing of products, has extended the reach of supply chains and increased the need for global transportation and warehousing. These increased logistics activities cause multiple impacts on the environment, namely CO2 emissions from transportation actions as well as waste production and energy consumption from warehousing activities.

Because of the constant growth of such global logistics activities, a need emerges to manage the environmental impacts from logistics activities. However, to begin to manage the environmental impact of a company’s global logistics activities, it is first necessary to measure it. It is therefore crucial for a company to clearly understand the source and quantity of its environmental impact and track it over time.
Therefore, a framework for the measurement of each of the named factors will be defined in this work and then applied in a case study to a pharmaceutical company’s distribution activities. Distribution in this context is understood as the storage and movement of finished goods from the destination warehouse to local warehouses. Consequently, production and packaging activities are not included in the case study, nor are distribution to and waste at the final customer.

After determining the current CO2 emissions, waste production volume, and energy consumption, recommendations for reductions of these factors are given and quantified.

**Case Study Background**

The company profiled in this study is a major pharmaceutical company based in Europe. The central warehouse and packaging facilities are located in Europe and they serve about 40 markets across the world. The company is committed to developing and introducing new products to the market, and invests heavily in research and development. Their primary focus is on producing branded, nongeneric medicines that are sold under patent protection. In addition, most of their goods are cold-chain products that require temperature regulation transportation and warehousing conditions. Due to strict quality standards and tight regulatory guidelines, the supply chain of this company is faced with short lead times, high levels of inventory, and stochastic demand for certain products. The high value density of the products also places additional pressure on the supply chain to protect the pharmaceuticals from pilferage and tampering. These are factors that must be considered when evaluating current and potential logistics scenarios.

In order to determine the environmental impacts of the company analyzed, it was decided to employ the methodologies presented by the Greenhouse Gas Protocol (WRI and WBCSD, 2004) and by the Chartered Institute of Management Accountants (2002) for all calculations performed.

**Environmental Impacts from Logistics Activities**

The analysis of the data yields the result as seen in the following table:

<table>
<thead>
<tr>
<th>Annual Environmental Impact</th>
<th>CO2 Emissions</th>
<th>Solid Waste Disposal</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50,000 t</td>
<td>68,000 t</td>
<td>38.6 mil kWh</td>
</tr>
</tbody>
</table>

Regarding the CO2 emissions, the analysis showed that around 95% of the emissions are caused by air transportation, while only around 5% of the emissions are caused by road transportation. Other modes of transportation play no significant role. It also showed that the vehicle capacity utilization, especially in trucks, is usually low.

Because of the high share of emissions resulting from air transportation, a shift from air to other modes of transport offers the biggest potential for reduction options. However, it might also be one of the most complex ones to implement. The longer lead times require more inventory in transit as well as an increased safety inventory at the destination warehouse. Additionally, it has to be taken into account that other issues like lead time reliability, product value, shrinkage, or product safety in general have a significant impact on cost and risk of a mode shift from air to sea transportation.

Another possibility that could also significantly influence emissions is the improvement of the utilization of vehicle space. Better capacity utilization, by keeping the freight volume constant, means that less trips are needed, which leads to less CO2 emissions. This could be achieved by either sending larger shipments less frequently, pooling shipments, or by redesigning product packaging in order to make it more dense. However, because of the high value density of pharmaceutical products, security issues like insurance limits for the total value in a shipment, have to be kept in mind.

A different option could be to increase the fuel efficiency of trucks, leading to lower fuel consumption for the same transportation performance. Research showed that basic measures such as properly inflating tires or training drivers in fuel efficient behavior might have a significant impact. However, because of the relatively small share of this mode of transportation in total emissions, the results on total emissions of all this measures remain rather limited.

For the solid waste analysis, each waste product is analyzed by the volume generated (see table below) and the environmental implications. Even though wood is the smallest component of the entire waste
stream, it represents a material that could be completely avoided by introducing a plastic pallet system into this segment of the supply chain, resulting in an annual savings of over 1 million Euros.

<table>
<thead>
<tr>
<th>Waste Material</th>
<th>Annual Tons Generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrugated Fiberboard</td>
<td>34000</td>
</tr>
<tr>
<td>Plastic</td>
<td>17860</td>
</tr>
<tr>
<td>Paper</td>
<td>7000</td>
</tr>
<tr>
<td>Styrofoam</td>
<td>4760</td>
</tr>
<tr>
<td>Wood</td>
<td>4350</td>
</tr>
<tr>
<td>Total</td>
<td>67970</td>
</tr>
</tbody>
</table>

In contrast, corrugated fiberboard comprised almost half of the entire tonnage of the waste stream, resulting from passive cooling containers used to regulate the temperature of the product. The disposal of these goods could be addressed simply by communication and collaboration of the different stages of the supply chain. Instead of disposing of these containers at the first destination, they can easily be reused further down the supply chain by local distributors and primary customers. Other waste streams, specifically plastic wrap and styrofoam, could also be significantly reduced by greater communication and collaboration about the use and utility of certain materials, and how these can be extended beyond its first destination. Also, the inherent value of the waste generated can create logistics operations that are amenable to reselling these materials to avoid disposal costs and possibly gain additional revenue streams.

In relation to energy consumption, the data collected indicated the total amount of energy being consumed to operate the central warehouse in Europe and the 40 regional warehouses in the logistics network. Until the company can identify specific functions of the warehousing operations and allocate certain energy flows to these operations, determining specific reduction strategies remains difficult. However, based on site visits and discussions with logistics providers, the main source of energy consumption was the direct cooling of goods through refrigeration, even though this method was often combined with other temperature regulation mechanisms. Due to the sensitive nature of pharmaceutical products, it is not recommended that these policies be modified unless more detailed data that specifies the cooling methods used at each facility individually become available.

The table below summarizes the complexity and impact of the discussed measures aimed at reducing emissions and waste.

<table>
<thead>
<tr>
<th>Area of Reduction</th>
<th>Measure</th>
<th>Complexity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ Emissions</td>
<td>Mode Shift</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td>Increased load factor</td>
<td>mid</td>
<td>mid</td>
</tr>
<tr>
<td></td>
<td>Increased fuel efficiency</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Solid Waste Disposal</td>
<td>Extend life of cooling containers</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Plastic Pallets</td>
<td></td>
<td>mid</td>
<td>mid</td>
</tr>
</tbody>
</table>

Implications

Pharmaceutical companies can use the information from this case to measure, manage, and possibly minimize the environmental impacts of their logistics and distribution functions. For further actions, it might be helpful to collect further-reaching data and also standardize the data collected as well as the data collection process. Another possible action could be to extend the scope of the study. Although this study extends only to the regional warehouses, it could be expanded to include environmental impacts of the supply chain downstream of this point. For example, this analysis would be more robust if it included the transportation from the regional warehouses to consumers and the waste generated from the actual consumption of the goods. However, the scope of this study does allow pharmaceutical companies to understand the magnitude and nature of the environmental impacts over which they have greater control and influence. Testing the reduction strategies within this scope makes it easier for them to understand how to minimize environmental impact. This information can then be passed down to other entities in the supply chain, and the pharmaceutical company can assume a more active role in helping to manage those impacts for activities further removed from direct company operations.

Cited Sources


Introduction

The ultimate goal of procurement is to have raw materials available, when required, at the lowest possible cost and at a desired quality. Unfortunately, in today's globalized markets, uncertainties in customer demand, supply availability and supply cost make this goal highly challenging. Furthermore, in situations where the raw materials procured, e.g., platinum group metals, have a highly volatile price, the challenge is even greater.

Traditionally, automakers have relied on long term supply contracts to avoid or reduce the risks related to demand uncertainty and supply availability of Platinum Group Metals. However, in the case of these metals, price changes are very likely, and although these agreements address supply availability they do not address supply cost variability. Thus, automakers end up with the risk of price changes. For example in 2001, there was immense speculation around supply shortages of palladium in Russia. In response, Ford Motor Co. proactively entered into a binding contract for large quantities of palladium at a price of $1094 per ounce. However, demand began to fall throughout 2001. Meanwhile, contrary to initial speculation, supply of the metal went up. Russia started to stabilize its production while South Africa, another big supplier, increased production. The combination of increased supply and decreased demand drove the price of palladium down by almost 65%, to around $400 per ounce at the beginning of 2002. To add to the pain, Ford’s Research and Development department announced that they had found new ways to decrease the quantity of palladium required per car. At the end of the fiscal year, Ford revalued their inventory at $440 per ounce and wrote-off $1 billion in losses.

One reason why supply cost variability was kept outside of procurement planning in the past was the limited availability of information. However, with recent technological advances, this is no longer a constraint. In fact, advances in information technologies have made it possible to effectively trade more commodities (such as Platinum Group Metals) in exchange markets.

In the past few years, trading commodities in exchange markets has become a common practice. This gives procurement managers the opportunity to add more flexibility to their supply chains since they can now use spot procurement as an alternative to relying upon procurement through fixed supply contracts. Also, futures markets allow locking the

Summary:

This thesis focuses on two major questions. First, what is the value of implementing a hedging strategy to minimize the risk implied in the procurement of price volatile raw materials? Second, under what circumstances can a hedging strategy, such as entering a long position in the financial markets, be exploited such that in the long run the expected benefits outweigh the losses? To evaluate the above two points, a Monte Carlo Simulation is developed and applied to compute total procurement cost for scenario with and without hedging.

KEY INSIGHTS

1. Futures contracts present opportunities for reduction in the total procurement cost of price volatile raw materials.

2. The hedging strategy should be coupled with a sourcing strategy where a portion of the forecasted PGM is sourced using long term contracts and the rest is purchased on the spot physical market.
price of raw material for a determined time period through financial mechanisms (usually referred to as hedging). This also serves as a source of price discovery since these exchange markets inherently operate under the forces of supply and demand.

In this thesis, a model that includes the above mentioned variables is proposed and evaluated. Besides accounting for demand uncertainty and price variability, the simulation model proposed measures the benefits and risks involved with adopting a procurement strategy that includes financial mechanisms such as future contracts. The results obtained by this strategy are measured and compared against a procurement strategy that does not use such financial mechanisms. The two strategies, hedging vs. no hedging, were evaluated based on the corresponding total cost incurred during the duration of a supplier contract. The model also evaluates the robustness of the expected total cost of both strategies while adopting different sourcing scenarios, e.g., 80% of the forecasted PGM’s procured through a supplier contract and 20% bought in the spot physical market.

**Simulation Framework**

The baseline situation approached in the thesis is an automaker that uses long term quantity contracts with their suppliers to guarantee secure delivery of PGM. In return the automaker obtains certain discounts over the spot price at time of delivery and some flexibility on the quantities ordered. The contract duration is \([0, T]\), and quantities are ordered once per period \(t\) and are delivered once per period \(t\). In addition, the decision maker will like to evaluate the benefits of entering a long position by buying and selling futures in the exchange of futures markets as a way to hedge against the price volatility.

Two basic procurement strategies, hedging vs. no hedging, will be compared and analyzed by varying uncertain variables. The purpose of the simulation model and of this study is not to search for optimality on the quantities ordered or the optimal financial hedging strategies. The objective is to evaluate the robustness of the results of these two different basic strategies under different circumstances.

The uncertain variables considered are: i) the spot price of the PGM, ii) the futures prices of PGM, iii) Forecast Accuracy, iv) Actual sales (demand of vehicles). Historical data was used to model the uncertain variables.

The decision variable in the model is how much to buy from the supplier (using the long term contracts) and how much to buy on the spot physical market to satisfy the forecasted PGM requirements. The decision variable is “Amount purchased on long term contracts”. If this variable is 60% then by default the amount purchased on the spot physical market is 40%.

**Model Development**

The model was developed using Microsoft Excel, and the software used to generate the random variables and then simulate is @Risk. Since the purpose of the model is to compare two basic strategies, no hedging vs. hedging, the simulation model calculates the Total Cost for both strategies. This cost is calculated for the duration of the contract \([0, T]\). For the hedging strategy, the probability of profit or loss is plotted as a histogram or a cumulative function.

Depending on the values of the spot price and futures price generated, there will be an expected profit if the futures price at which the contract was entered in time \(t\) is lower than the future price at which the contract is sold in time \(t+3\) or \(t+6\) for 6 month contracts. On the other hand, if the futures price at which the contract was entered in time \(t\) is higher than the future price at which the contract is sold in time \(t+3\) or \(t+6\) for 6 month contracts here will be an expected loss.

**Numerical Experiments**

Numerical experiments were run for a supplier contract with a timeframe of 60 months, i.e., the contract duration is \([0, 60]\). The simulation was
customized and designed for platinum. Each time the simulation was run, the uncertain variables were generated 500 times and the total cost for both, the hedging and no hedging, was calculated and recorded.

Eight different scenarios were evaluated with the simulation model. For the two conditions of the variable actual sales, 4 different situations of forecast accuracy were generated: a positively biased forecast, a forecast with a mean around 100% of accuracy, a negatively biased forecast and a perfect information scenario. These four different situations were chosen with the objective of analyzing and understanding the behavior of the hedging strategies as the financial instrument (future contracts) uses the forecasts as inputs.

### Results

In the eight scenarios evaluated, the total cost achieved in the strategy of Hedging using 3 month futures contracts is less than the total cost obtained in the strategy of No hedging. This happen because in each of these scenarios the total cost in the hedging strategy is reduced by adding the expected profit obtained by trading futures contracts. However, if there is an increasing trend in the Actual sales, the expected profit and the probability of having profit are greater than if there is a decreasing trend in Actual Sales.

Regardless of the trend in Actual Sales, the hedging strategy has better results when the forecast is positively biased. In scenarios 1 and 5 have the highest expected profit, respectively in increasing and decreasing trend of Actual Sales. This happens because the hedged quantities are calculated based on the forecasted future requirements of PGMs, thus, if the forecasts are positively biased then the amount traded in the financial hedging is upscaled too.

Regarding the sourcing strategies (represented by the decision variable), if the forecast is positively biased (for example, scenarios 1 and 5) then the minimal cost is achieved by procuring 60% using the long term contracts. On the other hand, if the forecasts are negatively biased (scenarios 3 and 7) then the sourcing strategy that achieves the minimal total cost is by procuring 100% using the long term contracts.

In the eight scenarios evaluated, the minimal cost was never achieved by procuring 100% of the forecasted amount on the spot physical market, this happened in both the hedging and without hedging strategy. This result shows that the discount over spot price (benefit in the long term contracts) moves the optimal solution toward a sourcing combination where a percentage of the required PGMs is procured using long term contracts.

### Conclusions

Regardless of the trend in actual sales, the hedging strategy analyzed presents opportunities for cost reduction. To achieve this, the hedging strategy should be coupled with a sourcing strategy where a portion (60%-80%) of the forecasted PGM is sourced using long term contracts and the rest (40%-20%) is purchased on the spot physical market. With such a hybrid strategy, the total cost associated with the procurement of PGM can reach results that are comparable to the ones obtained under the “perfect information” scenario, where the forecast is 100% accurate.

Even a company whose core business is not in trading financial instruments can safely hedge itself against the price volatility of platinum by adopting 3-month long futures contracts. This strategy is beneficial as there is less room for speculation on the futures prices of the underlying commodity; thus, the risk of losing money is lower than the case of “going long” in the futures markets.

The spot physical market provides the manufacturer an alternative source of supply. It offers the advantage of immediate delivery of material in case the demand is greater than anticipated. It also allows the manufacturer to sell its excess inventory in case of an economic recession. Overall, the spot market gives the manufacturer greater flexibility compared to the traditional, lengthy supply contracts.

By observing the behavior of an unknown sample of buyers and sellers auctioning for the commodity, a participant can gain valuable information about the commodity’s future prices in the futures trading markets. At least, the information that can be obtained is likely to be better than internal company’s forecast.

One of the inputs to the hedging strategy developed in this research is the forecast of the amount of PGM needed in the future. It is seen that higher profits can be expected in scenarios where the forecast is, on an average, biased towards overestimation that the scenarios where the forecast is biased towards underestimation.
Complete List of ZLOG 2010 Theses

Impact of Point of Sale Data on Demand Planning for a Two level Supply Chain,  
By Luis Diego Artiñano and Kavita Keerthi

This thesis explores ways to improve the planning process at a Master Distribution Center through the development of a trend analysis technique based on point of sale data that provides supportive insights about the demand's behavior to the current forecasting activities. In addition, an order revision model was built to ensure a stable incoming order stream and consequently improve the accuracy of the trend analysis.

How Do Recession and Oil Prices Influence the Network Design?,  
By Jorge Capitanachi and Ioannis Theodorou

This thesis investigates how demand volumes and fuel prices can affect the performance and configuration of a logistics company’s network in Spain. The network is modeled as a minimum cost network flow problem and the optimal network configuration is found by solving a mixed integer programming (MIP) formulation. An in-house developed graphic dashboard allows the user to interact with the simulations’ results.

Sustainable Supply Chain Strategy In Latin America,  
By Andrés Castaño

This project identifies the most important insights of Latin American (LatAm) companies’ actions in relation to Sustainability in supply chain. A comparison to a sample of the biggest companies (Leaders) in the world from different industries help to understand that Latin American companies are modifying some aspects of their supply chain toward sustainability; however, a supply chain integral view is still needed for innovative actions.

Strategy to Improve Supply Chain Efficiency,  
By Jesús Díaz and Nelson Díaz

This Thesis is a research on the impact of AutoID technologies, and in particular Barcodes, on warehousing processes at one upstream oil and gas service company. It looks to identify how improving chemical’s inventory accuracy and visibility could benefit its operations.

Supply Chain Integration and Inter-organizational Learning,  
By Samuel Gradín and Vegard Jansson

This project looked at organizational learning in supplier-buyer relationships, producing a general framework for understanding and predicting the dynamics of learning. By being more effective in interchanging knowledge and in the learning process, a successful supplier relationship can achieve improved performance and increase the capability to cope with change in a globalized and rapid changing market.

Strategic Forecasting of Vaccine Adoption by GAVI-Eligible Countries,  
By Wiko Kabiling

This thesis investigates the factors that affect the adoption of vaccines by low-income countries into their national immunization programs, particularly in an emerging environment where countries have to choose among many available vaccines. The thesis proposes a rule-based model that uses public data to forecast adoption over a 20-year horizon and uses a sample forecast to quantify future adoption delays.

Classification of SKU as a Way to Improve Company Performance: A Case Study from the Telecommunication Industry Project,  
By Yuliya Kasirava and HanCheol Lee

This thesis offers classification as one of the methods to lower the cost associated with spare parts inventory for a company operating in the telecommunication industry. Several classification methods were examined and compared in terms of total relevant costs. Further simulations were carried out in order to examine the impact on total costs.
The Power of Aggregation: Postponement Strategies in Pharmaceutical Supply Chains
By Sumeet Ladsaongikar and Roberto Martinez

This thesis attempts to create and implement a structured approach for the decision to postpone the packaging decision at a later point in time in a global pharmaceutical company. The approach includes selection criteria for products that could show significant benefit thorough postponement. It also includes a simulation model that attempts to recreate the present and postponed inventory management scenarios.

A Comparative Analysis of Different In-Market Distribution Channel Strategies in Africa
By Gifty Esi Mankartah

The pharmaceutical market in Sub-Saharan Africa is perceived to be small and risky. In recent years, there has been growing interest in this market due to its future business potential. This thesis identifies in-market distribution channel options, assesses key risks, and explores possible strategies for mitigating these risks.

Security Concerns in Container Shipping: Review of Risk Based Approaches
By Gala Orquín

This thesis tackles the question of security measures implemented at ports and their effects in the supply chain. Through simulation of the CSI security scheme, different inspection levels of containers are analyzed and the consequent safety stock levels calculated. The feasibility of 100% scanning of US bound containers remains unproven.

Sourcing Strategies for a Photovoltaic Power Plant
By Mani Ponnuswamy

This thesis studies the dependence of a photovoltaic (PV) power plant’s lifetime cost and lifetime revenue on the choice of its solar PV panels. An actual power plant located in Germany is modeled in Matlab using the electrical parameters of its PV panels. The plant’s panels in the model are then sequentially replaced with 98 different types of panels and individual simulations are run for each type. Based on the results, a generalized framework for choosing solar panels and its suppliers is developed.

Sales Forecasting & Replenishment for a Medium-sized Toy Retailer
By Carolina Ruiz and Neil F. Smith

This thesis examines the impact of adopting a more sophisticated time-series forecasting method and replenishment model on the store-level replenishment performance of a medium-size toy retailer. A comparison of the proposed replenishment policy to the toy company’s current replenishment policy is made through a simulation exercise.

Push versus Pull Systems: A Case Study of a Humanitarian Supply Chain
By Karla Ruvalcaba

This thesis is an exploratory research that looks into how beneficial the implementation of a pull system would be for a humanitarian organization’s supply chain, based on actual data provided. It also determines if the results on the inventory management are consistent with the organization’s current inventory policy.

Ecological Footprint of the Pharmaceutical Supply Chain
By Noelle Thomas and Katharina Weber

This thesis addresses the question of how to measure and reduce environmental impacts from logistics activities. Therefore, a measurement framework for the most relevant environmental factors - CO2 emissions, waste production, and energy consumption - is developed and then applied in a case study to a pharmaceutical company.
Optimal Sourcing Strategies for Managing Supply Chain Risk for Platinum Group Metals (PGM) in Automotive Catalytic Converters
By Federico Vargas

This thesis focuses on two major questions. First, what is the value of implementing a hedging strategy to minimize the risk implied in the procurement of price volatile raw materials? Second, under what circumstances can a hedging strategy, such as entering a long position in the financial markets, be exploited such that in the long run the expected benefits outweigh the losses? To evaluate the above two points, a Monte Carlo Simulation is developed and applied to compute total procurement cost for scenario with and without hedging.

Design of Closed-Loop Supply Chains under Uncertain Demand
By Jinrong Wei

This thesis focuses on two major questions. First, what is the value of implementing a hedging strategy to minimize the risk implied in the procurement of price volatile raw materials? Second, under what circumstances can a hedging strategy, such as entering a long position in the financial markets, be exploited such that in the long run the expected benefits outweigh the losses? To evaluate the above two points, a Monte Carlo Simulation is developed and applied to compute total procurement cost for scenario with and without hedging.