

**AN APPROACH TO SOURCING OPTIMIZATION AT A HIGH VOLUME SOFT
DRINK MANUFACTURER**

By
Sandeep Khattar
B.S.E. Mechanical Engineering, University of Michigan (2000)

Submitted to the Sloan School of Management and the Department of Mechanical Engineering
in Partial Fulfillment of the Requirements for the Degrees of

Master of Business Administration
and
Master of Science in Mechanical Engineering

In Conjunction with the Leaders for Manufacturing Program at the
Massachusetts Institute of Technology
June 2006

© Massachusetts Institute of Technology, 2006.
All rights reserved.

Signature of Author _____

Sloan School of Management
Department of Mechanical Engineering
May 12, 2006

Certified by _____

David Simchi-Levi, Thesis Supervisor
Professor of Engineering Systems Division and Civil & Environmental Engineering

Certified by _____

David E. Hardt, Thesis Reader
Professor of Mechanical Engineering

Certified by _____

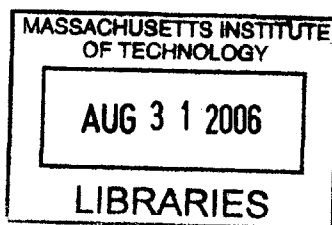
Stephen C. Graves, Thesis Supervisor
Abraham J. Siegel Professor of Management

Accepted by _____

Lallit Anand, Chairman, Committee on Graduate Students
Department of Mechanical Engineering

Accepted by _____

Debbie Berechman, Executive Director of Masters Program
Sloan School of Management



BARKER

[THIS PAGE IS INTENTIONALLY LEFT BLANK]

AN APPROACH TO SOURCING OPTIMIZATION AT A HIGH VOLUME SOFT DRINK MANUFACTURER

By
Sandeep Khattar

Submitted to the Sloan School of Management and Department of Mechanical Engineering on
May 12, 2006 in partial fulfillment of the Requirements
for the Degrees of Master of Business Administration and
Master of Science in Mechanical Engineering

ABSTRACT

The Pepsi Bottling Group (PBG) is the world's largest manufacturer, seller, and distributor of carbonated and non-carbonated Pepsi-Cola beverages. The supply chain network in the United States consists of 52 plants, over 360 warehouses, and an ever growing portfolio of SKU's. Currently, there is no robust method for determining the sourcing strategy – in which plant(s) to produce each product. The objective of this thesis is to develop an approach that allows PBG to determine where products should be produced to reduce overall supply chain costs while meeting all relevant business constraints.

An approach to sourcing utilizing an optimization algorithm is presented, along with a suggested implementation plan. This approach has demonstrated the potential to generate significant cost savings throughout the supply chain.

The research for this thesis was conducted during an internship with the Pepsi Bottling Group, in affiliation with the Leaders for Manufacturing program at the Massachusetts Institute of Technology.

Thesis Supervisor: Stephen C. Graves
Title: Abraham J. Siegel Professor of Management

Thesis Supervisor: David Simchi-Levi
Title: Professor of Engineering Systems and Civil & Environmental Engineering

Thesis Reader: David E. Hardt
Title: Professor of Mechanical Engineering

[THIS PAGE IS INTENTIONALLY LEFT BLANK]

ACKNOWLEDGEMENTS

I would like to thank the following people:

*The Leaders for Manufacturing program
for the chance to be a part of this incredible experience.*

*The Integrated Planning team at
the Pepsi Bottling Group for their support of this project.*

*My fellow LFM and Sloan classmates, who helped make
these past two years two of the most enjoyable of my life.*

*The brothers of Lambda Fi Mu,
who taught me the meaning of "brotherhood in squalor".*

*Finally, a special thanks to my family for the constant love, support and
guidance they have given me in every adventure I have pursued.*

[THIS PAGE IS INTENTIONALLY LEFT BLANK]

TABLE OF CONTENTS

Chapter 1: Introduction and Overview	9
1.1 Pepsi Bottling Group Overview.....	9
1.2 Supply Chain Overview.....	9
1.3 Manufacturing Operations Background.....	13
1.4 Products.....	13
1.5 Pepsi Bottling Group Service Model.....	14
1.6 Project Motivation	16
1.7 Thesis Structure	16
Chapter 2: Supply Chain Optimization Background.....	18
2.1 Layers of Supply Chain Excellence.....	18
2.2 Sourcing Optimization Background	22
2.3 Planning Problem at PBG	22
Chapter 3: Developing a Model for Sourcing Optimization.....	25
3.1 Model Overview	25
3.2 Model Inputs	25
3.3 Formulation of Model.....	33
3.4 Modeling Tool Background.....	34
3.5 Methodology	35
Chapter 4: Analysis of Model Output.....	38
4.1 Central Business Unit Model Analysis.....	38
4.2 East Coast Business Units Model Analysis	42
4.3 Supply Chain Master Planning	46
Chapter 5: Implementation of Optimization Tool.....	50
5.1 IT Infrastructure.....	50
5.2 Planning Horizons.....	51
5.3 Process Implications	51
Chapter 6: Organizational Change Analysis.....	53
6.1 Strategic Design.....	53
6.2 Political	54
6.3 Cultural	55
Chapter 7: Conclusion.....	57
References.....	60

LIST OF FIGURES

Figure 1: Pepsi Bottling Group Business Units	10
Figure 2: PBG Supply Chain	11
Figure 3: Pepsi Bottling Group Supply Chain Organization Chart	11
Figure 4: Pepsi-Cola U.S. Bottling Network	12
Figure 5: PepsiCo flavor portfolio	13
Figure 6: U.S./Canada brand mix	14
Figure 7: Wireless Handheld Computer	15
Figure 8: Capabilities required to achieve supply chain excellence	18
Figure 9: Portion of supply chain network modeled.....	25
Figure 10: Calculation of cost allocation percentage breakdowns	28
Figure 11: Calculation of variable cost per unit.....	29
Figure 12: Customer demand in the baseline scenario	33
Figure 13: Pepsi Bottling Group supply chain network.....	36
Figure 14: Stage 1 vs. Stage 2.....	37
Figure 15: Production comparison between Detroit and Howell in optimized scenario	40
Figure 16: Location of Howell vs. Detroit.....	41
Figure 17: East Coast baseline model evaluation	43
Figure 18: East Coast model transportation cost comparison.....	44
Figure 19: East Coast model optimization scenario	44
Figure 20: East Coast cross Business Unit sourcing.....	45
Figure 21: The case for cross Business Unit sourcing.....	46
Figure 22: Sample PBG weekly demand	47
Figure 23: Production data for a can package.....	48
Figure 24: Optimized production data	48
Figure 25: Optimization tool system architecture.....	50
Figure 26: Sourcing process changes.....	52
Figure 27: Stakeholder map of sourcing optimization project at PBG	55

LIST OF TABLES

Table 1: Production variable cost categories	27
Table 2: Variable cost allocation categories	27
Table 3: Variable cost allocation basis	28
Table 4: Baseline sourcing matrix	32
Table 5: Central Business Unit baseline results.....	39
Table 6: Central Business Unit optimization results.....	39
Table 7: Central Business Unit optimized scenario production breakdown.....	40
Table 8: Cost comparison of Howell and Detroit plants.....	41
Table 9: Results of Stage 1 validation analysis	42

Chapter 1: Introduction and Overview

1.1 Pepsi Bottling Group Overview

The Pepsi Bottling Group (NYSE: PBG) is the world's largest manufacturer, seller, and distributor of Pepsi-Cola beverages. The company was formed in March 1999 through one of the largest initial public offerings in the history of the New York Stock Exchange.

PBG generates over \$11.8 billion in annual revenue¹, with over 66,000 employees² worldwide. It operates in the United States, Canada, Greece, Mexico, Russia, Spain and Turkey. PBG sales of Pepsi-Cola beverages account for 55% of the Pepsi-Cola beverages sold in the United States and Canada and 40% worldwide. The PBG sales force features more than 30,000 customer service representatives who sell and deliver nearly 200 million eight-ounce servings of Pepsi-Cola beverages per day³. Within the U.S. and Canada, most of this volume is sold in supermarkets, followed by the convenience store and gas station channels. In North America, the sales force interacts directly with most customers to sell and promote Pepsi products (Direct Store Delivery).

The soft drink industry is highly competitive. Among the main competitors for the Pepsi Bottling Group are bottlers that distribute products from the Coca-Cola Company. PBG competes primarily on the basis of brand awareness, price and promotions, retail space management, customer service, and distribution methods.⁴

1.2 Supply Chain Overview

The supply chain network in the U.S. consists of 52 plants and over 360 warehouses. This network is divided into 7 business units, as shown in Figure 1.

¹ Pepsi Bottling Group 2005 Annual Report, p. 30

² Pepsi Bottling Group 2005 Annual Report, p. 2

³ Pepsi Bottling Group's website: <http://www.pbg.com/about/about_overview.html>

⁴ Pepsi Bottling Group 2005 Annual Report, p. 22

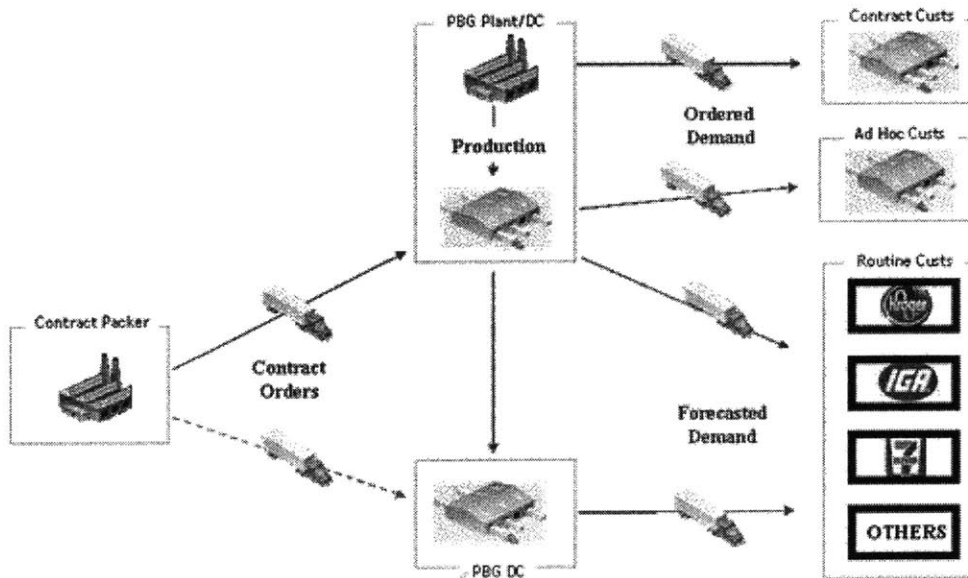


Figure 2: PBG Supply Chain⁵

The supply chain group within PBG is broken into three main groups as shown in the organization chart in Figure 3: Supply Chain Systems, Warehouse Operations, and Integrated Planning (IP). The integrated planning group is responsible for demand forecasting and production planning.

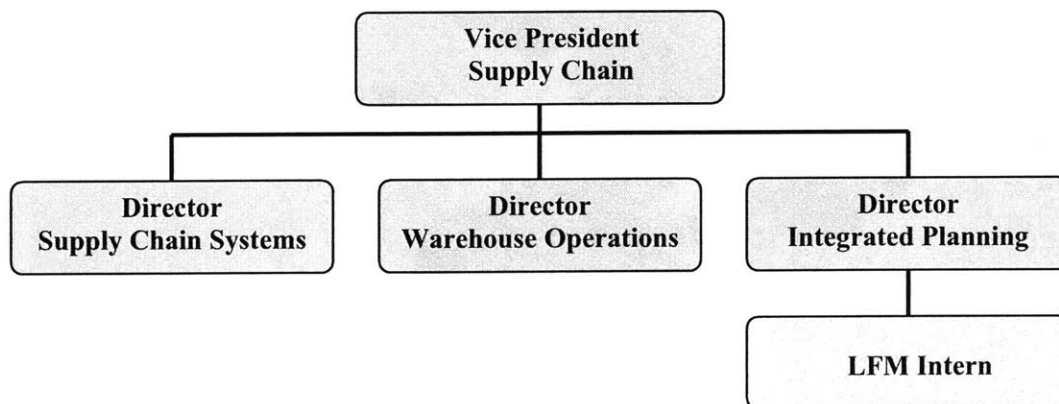


Figure 3: Pepsi Bottling Group Supply Chain Organization Chart

⁵ Figure adopted from Areté Inc.

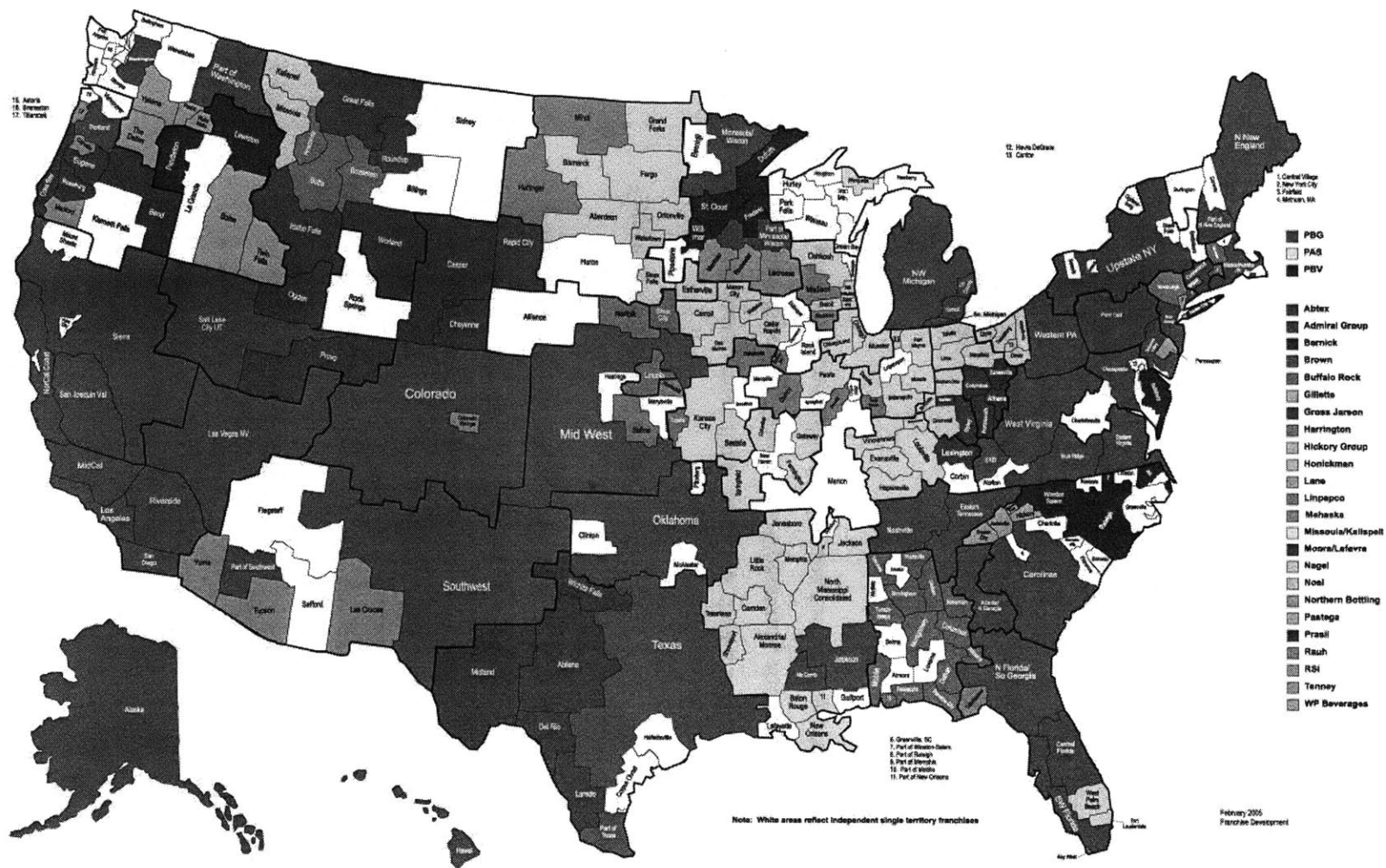


Figure 4: Pepsi-Cola U.S. Bottling Network

1.3 Manufacturing Operations Background

Each manufacturing plant is capable of producing a certain array of SKU's (stock keeping units). Some plants, for example, do not have the capability of producing non-carbonated soft drinks, such as bottled water. Decisions are made periodically to add product capabilities to some plants while removing them from others. These decisions are driven largely by capacity constraints and differences in variable production costs. Some plants run more efficiently than others for various reasons, allowing them to produce products at lower costs.

Within a plant, switching from production of one type of product to another incurs a certain amount of setup time. This time is influenced by the two types of changes: flavors and packages. Large tanks contain the flavored syrup base for the various soft drinks, and switching from one flavor to another requires the tanks to be cleaned. Package changeovers require adjustments to be made on the production lines, such as feed rates.

1.4 Products

SKU's in the soft drink business are defined by unique combinations of flavor and package. Figure 5 below shows the flavors offered by Pepsi, and Figure 6 shows the product mix (as a percentage of total volume) in the U.S. and Canada.



Figure 5: PepsiCo flavor portfolio⁶

⁶ Pepsi's website: <http://pepsi.com/pepsi_brands/all_brands/index.php>

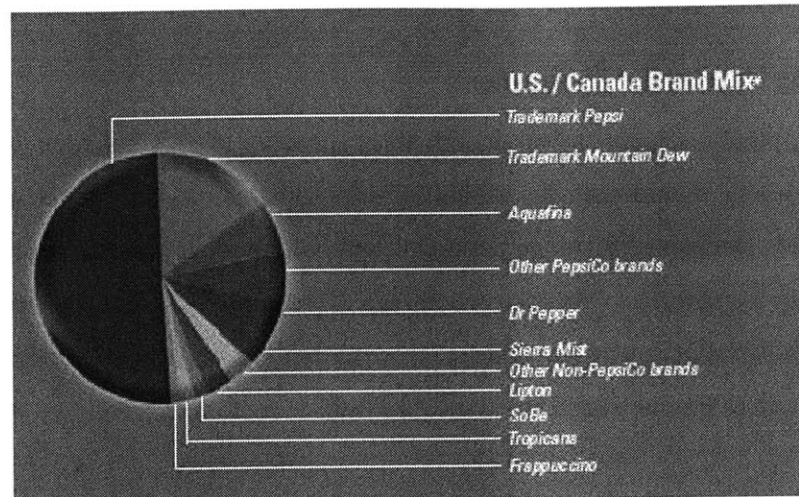


Figure 6: U.S./Canada brand mix⁷

One major distinguishing factor amongst the flavors offered is carbonated (e.g., Pepsi) vs. non-carbonated (e.g., Aquafina) soft drinks. Another distinguishing factor is contracted vs. manufactured products. Some of the products listed in Figure 5 (such as Sobe and Tropicana Juices) are not produced in PBG plants – instead, they are purchased from contract manufacturers.

The packages are broken down into three main categories: cans, bottles, and fountain drinks. The cans and bottles are available in different sizes and configurations to address varying needs and price points. Fountain drinks are those dispensed from machines, as typically found in fast food restaurants. This type of product is delivered as a syrup in 3 or 5 gallon bags.

1.5 Pepsi Bottling Group Service Model

When the Pepsi Bottling Group was spun off from Pepsi-Cola in 1999, the intention was that it would focus on the operations and service aspect, while Pepsi-Cola would focus on the marketing aspect. This is made clear by the slogan adopted by PBG: “We sell soda”. The underlying goal of the company, however, is to achieve outstanding customer service. To that end, PBG has adopted a three phase service model. The three main phases identified in the service model are: before the store, in the store, and after the store.

⁷ Pepsi Bottling Group 2005 Annual Report, p. 2

1.5.1 Before the Store

The service model begins before the store. In this phase, a planner uses a software program to generate a demand forecast. The software utilizes future retail pricing and promotion plans among other inputs to determine this forecast. The forecast in turn becomes an input to another software application that is used to create a schedule for producing, ordering, and shipping products to sales and distribution warehouses for subsequent delivery to customers. At the warehouse, inventory levels are closely monitored and safety stock levels maintained to ensure all products are available to meet customer needs.

1.5.2 In the Store

The service model continues inside the stores. PBG essentially follows a vendor managed inventory model – sales representatives visit stores, check inventory levels, place orders for routine customers, and provide in store merchandising service. These representatives travel with wireless handheld computers (similar to the one shown in Figure 7) that contain data about delivery dates, in store inventory, displays/promotions, and retail pricing. This information, when combined with relevant sales history, is used to create customer orders that will satisfy local market demand until the next delivery occurs.



Figure 7: Wireless Handheld Computer⁸

1.5.3 After the Store

The third phase of the service model occurs after the sale. Each year PBG makes over 600,000 equipment moves and 2 million service calls. When PBG receives a customer service request,

⁸ Symbol's website: <<http://www.symbol.com/PDT8100/>>

they employ a “solve by sundown” policy. The goal is to respond to all requests by the end of the day the customer call is received. Each year, PBG surveys more than 5,500 customers to ensure they are meeting all expectations.

1.6 Project Motivation

The Pepsi Bottling Group supply chain is quite complex, with an ever growing portfolio of SKU’s. Currently, there is no robust method of determining the optimal sourcing strategy – in which plant(s) to produce each product. The goal is to develop an approach that allows PBG to determine where products should be produced to reduce overall supply chain costs while meeting all relevant business constraints.

1.7 Thesis Structure

This thesis is organized into seven chapters, described below:

Chapter 1, Introduction and Overview: This chapter provides background on the Pepsi Bottling Group, and describes the project which led to the research in this thesis. It also outlines the structure of the thesis.

Chapter 2, Supply Chain Optimization Background: This chapter provides a framework for analyzing the capabilities that drive supply chain excellence. It additionally provides some background on sourcing optimization, and more detail on the type of problem that is being addressed at PBG.

Chapter 3, Developing a Model for Sourcing Optimization: This chapter demonstrates the development of the supply chain model by describing the model inputs and the formulation of the objective function.

Chapter 4, Analysis of Model Output: This chapter describes the results of the baseline assessment and optimization scenarios.

Chapter 5, Implementation of Optimization Tool: This chapter describes the process for implementing the optimization tool into the existing PBG infrastructure.

Chapter 6, Organizational Change Analysis: This chapter examines the thesis work from the three perspectives of organizational processes: strategic design, political, and cultural.

Chapter 7, Conclusion: This chapter summarizes the findings in previous chapters and provides a series of lessons learned.

Chapter 2: Supply Chain Optimization Background

This chapter establishes a framework for the capabilities that promote supply chain excellence. It further provides some background on sourcing optimizations. It goes on to examine in detail the problem within PBG that is being solved. The chapter concludes by analyzing the specific area within this framework that is addressed in this thesis, and the motivation behind it.

2.1 Layers of Supply Chain Excellence

The competitive nature of the soft-drink bottling industry requires the need to develop advantages wherever possible. To get ahead, companies must continually make decisions that reduce cost and increase profits throughout the supply chain. Figure 8 describes four layers of capabilities that drive supply chain excellence.

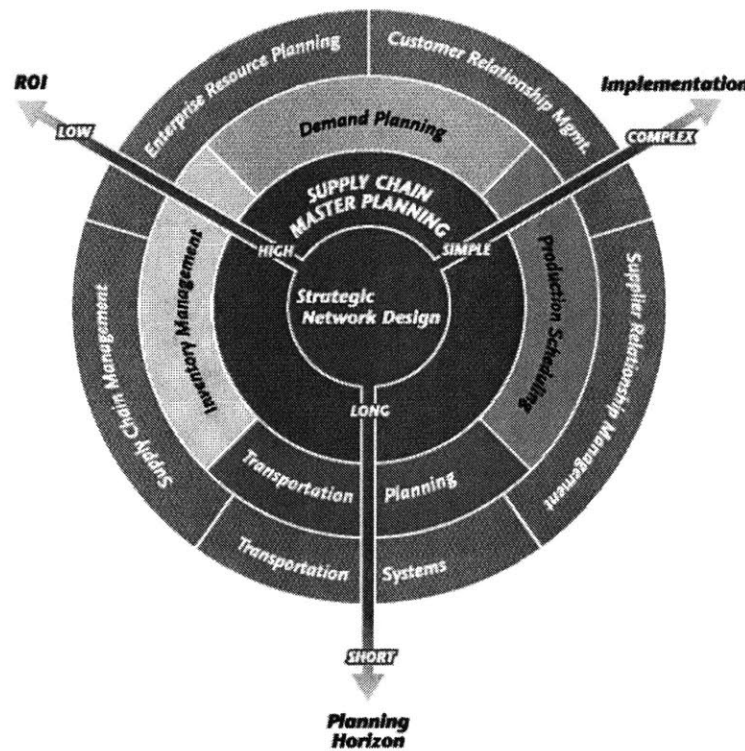


Figure 8: Capabilities required to achieve supply chain excellence⁹

⁹ Simchi-Levi et al, *Designing and Managing the Supply Chain: Concepts, Strategies & Case Studies*, 2nd ed., p. 284

These four layers, starting at the core, are:

Strategic network design: This layer features two types of strategies: network configuration and sourcing strategy. Network configuration involves determining the optimal number, location and size of warehouses/plants. Sourcing strategy involves determining which plant/vendor should produce which product. The objective of this layer is to minimize total costs (sourcing, production, transportation, inventory) by evaluating optimal trade-offs.

The BASF corporation¹⁰, a chemical company, provides an example of a network configuration project. The BASF supply chain network includes a fragmented network of distribution centers. A network optimization model was developed with the objective of determining the optimal number and location of distribution centers. As a result of the optimization, a more efficient network with fewer, more consolidated distribution centers was implemented. Savings of millions of dollars were reported, in addition to dramatic improvements in customer service.

Supply chain master planning: This layer involves coordinating production, distribution strategies, and storage requirements by allotting supply chain resources in a manner emphasizing profit maximization or cost minimization. Master planning gives companies the ability to plan ahead for seasonal effects, potential promotions, and restrictive capacities.

An example of a supply chain master planning project can be seen in a project undertaken at the 7-Eleven corporation in Taiwan¹¹. 7-Eleven operates over 3,000 stores throughout Taiwan, and all of these stores require a daily replenishment. This highly complex network, combined with factors such as crowded roads and increased competition required 7-Eleven to develop a planning solution that would increase efficiency and reduce costs. They implemented software that helped determine a master plan for routing schedules (how much to deliver and when) over an extended time period. Prior to the implementation, the various distribution centers decided their own delivery schedules independently. The master plan helped avoid the otherwise

¹⁰ Lee, Young, "Supply Chain Optimization Models in a Chemical Company." BASF Corporation. February 27, 2002.

¹¹ Manugistics: [e-journal] <http://www.manugistics.com/documents/collateral/0841_0105_7-11_casestudy.pdf>

common conflicts in delivery schedules between the different distributors, ensuring prompt delivery of goods to each store. The immediate results were a reduction of the miles driven in transporting goods, thus reducing transportation costs.

Operational planning: This layer is much more tactical, with planning horizons typically weekly to daily. The emphasis lies on developing feasible strategies, as opposed to optimized solutions. Operational planning systems include:

- Demand planning: generate demand forecasts based on historical data and other drivers such as promotions and new product introduction.
- Production scheduling: generate production schedules based on master plans or demand forecasts.
- Inventory management: generate inventory plan for warehouses based on average demand, variability, and lead times.
- Transportation planning: generate transportation routes and schedules.

The Luxottica Group, an eyeglass frame manufacturer, provides an example of an inventory management project¹². Luxottica distributes its products in 120 countries through 29 wholly-owned branches and 100 independent distributors. Their products have a wide range of seasonality and lifecycles – some are non-seasonal with long lifecycles (everyday frames), whereas others are highly seasonal (sunglasses). Each warehouse, however, had the same inventory policies for all products regardless of product mix. Luxottica thus implemented software that helped strategically determine the right inventory policies for each distinct product. As a result of this implementation, inventory levels were reduced by 10% while maintaining the same high service levels.

¹² Bodenstab, Jeffrey, “Consumer Products Industry Inventory Management Case Study.” [e-journal] <<http://logistics.about.com>>

Operational execution: These systems provide the data, transaction processing, user access and infrastructure for running a company.

- Enterprise resource planning: systems that integrate all facets of the business, including planning, manufacturing, sales, marketing, human resources, and finance.
- Customer relationship management: systems that track and update customer interactions.
- Supplier relationship management: systems that provide an interface for suppliers for transaction exchanges.
- Supply chain management: systems that provide tracking of activities in plants and warehouses.
- Transportation systems: systems that provide for tracking of goods in transport.

Creative Closets Ltd. designs and installs custom storage systems. Through their early years, Creative Closets primarily used a paper-based system to manage their daily operations. As the company grew and the processes became more complicated, it became increasingly more difficult to use only paper to communicate information. Thus, a web-based ERP system was implemented, resulting in improved workflow and communications. They were able to reduce the staff by 15% while increasing revenue by over 10% in the same period.¹³

The focus of the internship at the Pepsi Bottling Group was on the core of Figure 8, strategic network design. Within this core, the specific focus of the internship was on sourcing strategy. A secondary focus of the internship was on the second layer, supply chain master planning.

¹³ Exact Software: [e-journal] <www.exactamerica.com/macola/customer.html>

2.2 Sourcing Optimization Background

The key question addressed in a sourcing optimization is where to make each particular product. Arriving at optimal sourcing solutions involves evaluating a number of tradeoffs while considering the constraints inherent to the process. One of the tradeoffs involves the number of products produced at a location. From a manufacturing perspective, it would be ideal to minimize the number of products produced at a plant. This will minimize changeover costs and setup times, and the longer runtimes for each product will help take advantage of scale economies. From the transportation perspective, it would be beneficial to maximize the number of products at each facility. This will bring products closer to consumers, thus minimizing transportation costs. Additionally, it will allow for quicker response times to issues such as stockouts. Another issue to consider may be proximity to raw materials. It may be advantageous to produce products near the relevant suppliers in order to reduce lead times. Additionally, there may be opportunities to receive backhaul credits from suppliers by using internal fleet to pickup and deliver raw materials.

2.3 Planning Problem at PBG

In the current process, an optimized sourcing matrix defining which plants provide which warehouses with the demanded products is created once a year for the North American operations of PBG. This is accomplished using a series of Microsoft Excel based models. The results of the Excel optimization are distributed to each business unit as a recommended sourcing plan, and it is at their discretion whether or not to implement the suggested sourcing decisions. Generally, only some of the recommended decisions are adopted when the plan is distributed. For the most part, sourcing decisions and changes are made independently within the various business units. The following are some of the drivers that dictate these decisions made by the business units:

Strategy: Some plants are more efficient than others, giving them a cost advantage. These efficiencies are monitored and occasionally decisions are made to move entire packages from one plant to another, typically within the same business unit.

Capacity: At various times of the year, some plants are far more utilized than others. If they encounter capacity issues, it may be necessary to source some products at other plants (again, typically within the same business unit).

Convenience: On occasion a certain plant will have excess raw materials for particular packages, and therefore that plant may produce those packages in lieu of other plants.

Downtime: If a line at a certain plant goes down, it is necessary to make adjustments to the sourcing plan to accommodate.

In effect, incremental changes are made to a base sourcing plan throughout the year. This method has a number of drawbacks. From a technology perspective, the Excel based model is an extremely labor intensive process. It is understood and executed by one individual in the company, which could cause problems should that individual move on to a different role. Due to the manual nature of the model, it is run only once a year. This requires a forecast horizon of a full year, for which the accuracy is extremely poor. An annual model also does not take into account the large seasonal effects seen in the business. Many of the inputs and constraints in the model could change through the year, and these changes are not accounted for. Lastly, the Excel model provides output in a format that is difficult to interpret.

All of these reasons have led the various business units to make sourcing decisions on their own, based on the drivers described above. This process has led to another set of problems. First, a lack of central control in the sourcing process can lead to inefficiencies. Multiple people have authority to make sourcing changes that may not necessarily be optimal. Second, allowing individual business units to make decisions independent of other units promotes local optimizations. Decisions are made that don't consider the supply chain network as a whole.

For these reasons, the Pepsi Bottling Group is in search of a more robust method for determining the sourcing strategy. A more integrated solution could provide numerous benefits over the existing Excel based methodology, including the opportunity for more frequent updates to the sourcing plan. This could help address the issue of seasonality effects, in addition to ensuring

that more current and thus more accurate data is reflected in the model. There is the additional question regarding the efficacy of the Excel based optimization engine. The PBG network contains an enormous amount of complexity, and it is possible that a more powerful optimization approach could reveal further cost benefits.

Chapter 3: Developing a Model for Sourcing Optimization

This chapter demonstrates the development of the supply chain model. It describes the model inputs and the formulation of the objective function.

3.1 Model Overview

The goal is to model part of the supply chain network described in Figure 2, specifically the portion shown in Figure 9. Featured in this model are PBG Plants, plant attached warehouses, satellite warehouses and contract packers. End customer demand is aggregated to the warehouse level, so the warehouses are in effect treated as customers. Contract products are shipped directly to customers (warehouses), impacting only transportation costs.

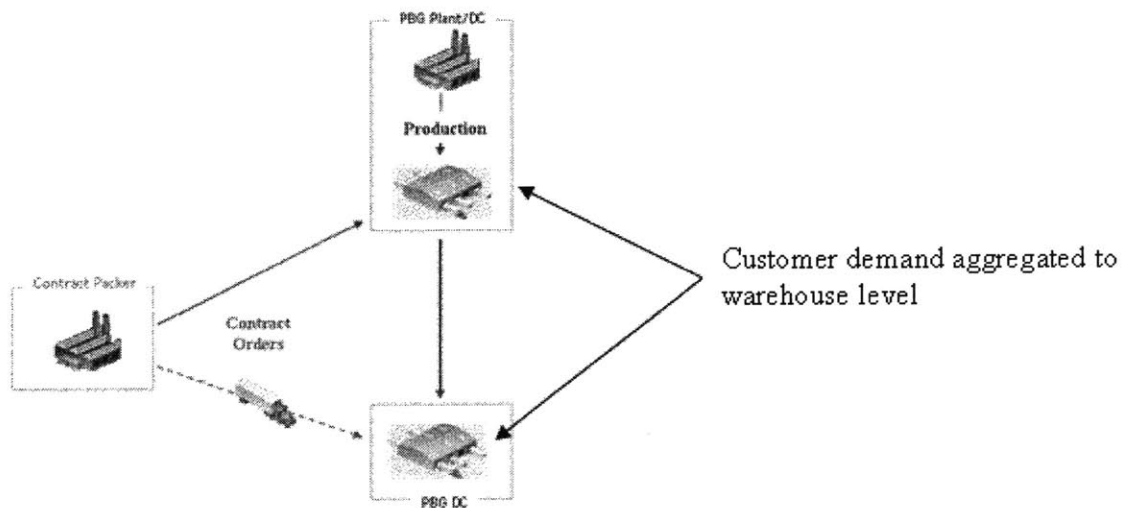


Figure 9: Portion of supply chain network modeled¹⁴

3.2 Model Inputs¹⁵

The following is a list of required data inputs:

- Products
- Plants

¹⁴ Figure adopted from Areté Inc.

¹⁵ "LogicChain®: User Reference Guide." LogicTools. 2005.

- Production
- Transportation
- Customers

The following sections will take a closer look at these key model inputs.

3.2.1 Products

The following list describes the product details required as inputs:

- **Weight:** Weight of one unit of product, used for trucking capacity. The unit of measure is defined by the user – for this model pounds were used.

3.2.2 Plants

The key required data inputs for the plants are the physical locations. Through a method known as “geocoding”, the necessary longitude and latitude values are determined to geographically model the location of the plants.

3.2.3 Production

The following list describes the production details required as inputs:

- **RT Available Hours:** Total number of “regular time” (i.e., non-overtime) production hours that are available for the selected production line during each time period.
- **RT Production Cost:** Per unit production cost associated with Regular Time production hours for each time period.
- **Min Lot Size:** If a particular item is produced, the minimum number of units that the selected production line must make during each time period.
- **Lot Increment:** Incremental number of units that must be produced by each production line when the **Min Lot Size** is exceeded during a time period. The actual number of units produced will be a multiple of the **Lot Increment**.

- **Capacity Required:** Number of hours required to create one unit of the selected product on the selected production line during the selected time period.

3.2.3.1 Plant Variable Cost

Production costs per unit were created for each package at each plant. PBG records aggregate production cost data at the plant level – it was therefore required to disaggregate these costs down to the package level. Historical manufacturing cost figures were obtained for 14 cost categories at the plant level. Table 1 summarizes the cost categories used to develop the plant variable costs:

Table 1: Production variable cost categories

Cost Category
Production Line Labor
Other Production Labor
Production Benefits
Product Liability Insurance
Production Breakage
Prod Materials & Supplies Act
Pallet Purchases
Production Utilities
Rep & Maint M&E Act
Production Hicone Usage
Trash Removal
Yields – Ingredient
Yields – Packaging
License/Taxes

Costs were allocated to the package level from the plant level using four categories, summarized in Table 2:

Table 2: Variable cost allocation categories

Category	Description
A	Employee Hours Used to Produce Package
B	Production Line Hours Used to Produce Package
C	Cases / Gallons Produced
D	Pallets used for Production

Table 3 summarizes how each of the 14 cost categories were allocated to the package level using the four allocation categories.

Table 3: Variable cost allocation basis

Category	Cost Type	Allocation Basis
A	Production Line Labor	Allocated Based On % of Employee Hours Used To Produce Package
B	Other Production Labor	Allocated Based On % of Production Line Hours Used To Produce Package
A	Production Benefits	Allocated Based On % of Employee Hours Used To Produce Package
C	Product Liability Insurance	Allocated Based On % of Cases / Gallons Produced
C	Production Breakage	Allocated Based On % of Cases / Gallons Produced
B	Prod Materials & Supplies Act	Allocated Based On % of Production Line Hours Used To Produce Package
D	Pallet Purchases	Allocated Based On % of Pallets Used For Production
B	Production Utilities	Allocated Based On % of Production Line Hours Used To Produce Package
B	Rep & Maint M&E Act	Allocated Based On % of Production Line Hours Used To Produce Package
C	Production Hicone Usage	Allocated Based On % of Cases / Gallons Produced
C	Trash Removal	Allocated Based On % of Cases / Gallons Produced
C	Yields – Ingredient	Allocated Based On % of Cases / Gallons Produced
C	Yields – Packaging	Allocated Based On % of Cases / Gallons Produced
A	License/Taxes/Ins	Allocated Based On % of Employee Hours Used To Produce Package

Figure 10 and Figure 11 show an example graphically of how the plant variable costs were calculated. Hypothetical “Plant A” produces three packages (6, 12 and 24 pack of cans). Percentages for each cost allocation category were calculated for each package – the example highlighted is the 24 Pack Cube package. The total amount of employee hours spent at Plant A were 726, out of which 255 were spent on the 24 Pack. Therefore, the percentage of employee hours allocated to the 24 Pack is $255/726$, or 35%. The same process is used to obtain the percentage breakdowns for the other three cost allocation categories across all packages.

Package	Can Production Line					% Breakdowns			
	Line Hrs	Line Staffing	Emp Hrs	Cases Prod.	Pallets Prod.	% Line Hrs	% Emp Hrs	% Cases Prod	% Pallets Prod
Plant A	242		726	110,000	1100	B	A	C	D
6 Pack Cans	112	3	336	50,000	500	46%	46%	45%	45%
12 Pack Cans	45	3	135	25,000	250	19%	19%	23%	23%
24 Pack Cube	85	3	255	35,000	350	35%	35%	32%	32%

% Employee Hours (A) for 24 pk = $255/726 = 35\%$

Figure 10: Calculation of cost allocation percentage breakdowns

Figure 11 shows the next step, which is using the cost allocation percentage breakdowns to obtain the variable costs. The cost categories are listed in columns (not all categories are depicted in this example) for the same hypothetical “Plant A”. The example highlighted is the 24 Pack Cube package. In this theoretical time period, 35,000 cases of this package were produced. The first cost item in the figure (third column) is production line labor, and Table 3 above indicates that this cost category is allocated based on percentage of employee hours used. The example in Figure 10 showed that 35% of the total employee hours at Plant A were allocated towards producing the 24 Pack package. From Figure 11 we know that in Plant A a total of \$10,000 was spent on production line labor. Thus, $35\% \times \$10,000 = \$3,500$ allocated to the 24 Pack for production line labor. The same technique is used for all cost categories. These package level costs are then summed and divided by the total cases produced for the particular package of interested to obtain the variable cost per case.

		A	B	A	C	C	B	
Package	Cases Produced	Production Line Labor	Other Production Labor	Production Benefits	Product Liability Insurance	Production Breakage	Prod Materials & Supplies Act	Total CPU
Plant A	110,000	\$ 10,000	\$ 15,000	\$ 10,000	\$ 8,000	\$ 5,000	\$ 10,000	\$ 0.53
6 Pack Cans	50,000	\$ 4,600	\$ 6,900	\$ 4,600	\$ 3,600	\$ 2,250	\$ 4,600	\$ 0.53
12 Pack Cans	25,000	\$ 1,900	\$ 2,850	\$ 1,900	\$ 1,840	\$ 1,150	\$ 1,900	\$ 0.46
24 Pack Cube	35,000	\$ 3,500	\$ 5,250	\$ 3,500	\$ 2,560	\$ 1,600	\$ 3,500	\$ 0.57

Line Labor for 24 pk =
 $\$10,000 \times 35\% = \$3,500$

Figure 11: Calculation of variable cost per unit

3.2.4 Transportation

3.2.4.1 Carrier Types

Two main types of carriers were considered:

- **Internal fleet:** This fleet consists of trucks owned internally by the Pepsi Bottling Group. When sent out, these trucks must make a return trip to the originating location.
- **Common Carrier:** This is a fleet of trucks subcontracted to outside agencies. These trucks make one way trips.

There are certain rules in place that dictate which type of carrier is used to ship product to warehouses. At some plants, no internal fleet is available, and all product shipped out is done so via common carriers. At other plants, both carrier types are available, and either can be used. In these cases, the distance the truck needs to be shipped dictates the decision. Typically, a truck from the internal fleet will only be sent if it can fulfill its shipment and return in the same day. This translates to one-way distances of approximately 250 miles, or 500 miles roundtrip. Distances longer than this generally utilize common carriers.

3.2.4.2 Mileage Estimation

A key input required is an estimation of mileage between two locations. Defining the following variables:

ρ	circuity factor to correct for actual road distance
lon_a	longitude value of location “a”
lat_a	latitude value of location “a”
lon_b	longitude value of location “b”
lat_b	latitude value of location “b”
R	radius of the earth in miles
D_{ab}	distance from point “a” to point “b”

The distance between two points “a” and “b” can be defined as¹⁶:

$$D_{ab} = \rho \times \left(\frac{2 \times \pi \times R}{360} \right) \times 2 \times \arcsin \left(\sqrt{ \left(\sin \left(\frac{lat_a - lat_b}{2} \right) \right)^2 + \cos(lat_a) \times \cos(lat_b) \times \left(\sin \left(\frac{lon_a - lon_b}{2} \right) \right)^2 } \right)$$

The longitude and latitude values are obtained as described in section 3.2.2.

The formula is essentially calculating straight-line distances (accounting for the earth’s curvature) between points “a” and “b”, with the circuity factor correcting for actual road

¹⁶ Simchi-Levi et al, *Designing and Managing the Supply Chain: Concepts, Strategies & Case Studies*, 2nd ed., p. 31

distance. This value is typically 1.14¹⁷ for the continental United States. The term $(\frac{2 \times \pi \times R}{360})$ represents the number of miles per degree of latitude, and is used to convert the angular distance into miles. Databases within the PBG system had actual distances traveled by trucks for the existing lanes – for these, actual distances were used as opposed to calculated. For potentially new lanes, however, this formulation was utilized.

3.2.4.3 Transportation Cost Formula

Transportation costs in the model are calculated by developing a per unit per product cost for each lane. Defining the following variables:

<i>cpm</i>	cost per mile
<i>D_{ab}</i>	distance from point “a” to “b”
<i>w</i>	weight per unit of product
<i>u</i>	utilization of truck
<i>tc</i>	capacity of truck

The cost of shipping a unit of product can be defined as:

$$\frac{cpm \times D_{ab} \times w}{u \times tc}$$

The per mile cost was calculated using internal financial cost reports: dividing total transportation expenses for a given period by the total miles driven in that period. The truck utilization refers to the percentage of a truck’s capacity that is filled with product – for this model, 95% utilization was assumed. The truck capacities were calculated by taking the average payloads from a given period of time.

¹⁷ Ibid., p. 32

3.2.4.4 Pre-Defined Sourcing Matrix

For the baseline models, the existing sourcing matrix is a required input. This matrix dictates the flow of product through the network by assigning each customer (warehouse)/SKU combination with a specific plant. Table 4 below shows an example of this matrix.

Table 4: Baseline sourcing matrix

Source	Destination	Product
Cranston, RI	Albany, NY	12OZ CN PEPSI DEP 36/1CB
Cranston, RI	Albany, NY	12OZ CN MTN DEW 36/1 CB
Cranston, RI	Albany, NY	12OZ CN DT PEPSI DEP 36/1CB
Cranston, RI	Albany, NY	12OZ CN DR PEPPER 36/1 CUBE
Columbia, SC	Atlanta, GA	8OZ CN MTN DEW 6/4
Columbia, SC	Atlanta, GA	8OZ CN PEPSI 6/4
Columbia, SC	Atlanta, GA	8OZ CN DT PEPSI 6/4

For example, this table tells us that in the existing process, the Albany, NY warehouse receives its 12 oz Can 36 Pack package from the Cranston, RI plant.

3.2.5 Customers

For this project, the satellite warehouses were treated as the end customers. The main inputs to be considered were:

- Location
- Demand

The locations of the customers were specified via latitude and longitude coordinates, as described earlier. The demand input was given special consideration for the baseline scenario. Historical demand forecast data was available, but when taking into account the forecast error, this was not the best representation of “true” demand. Another input available was shipment data, and this was the best representation of the true historical demand. For satellite warehouses, the demand was simply the shipments received (satellite warehouses don’t act as hubs, and therefore product is not shipped out). Plant-attached warehouses were slightly more complicated. Of the production from the attached plant, some product remained at the warehouse, while the remainder was shipped out to other warehouses. Additionally, these warehouses could receive product from other plants. Therefore, demand at the plant-attached warehouse was defined by the following flow balance:

$$Demand = manufactured\ product + shipments\ in - shipments\ out$$

Figure 12 below graphically demonstrates this.



Figure 12: Customer demand in the baseline scenario

3.3 Formulation of Model

The objective of the optimization is to minimize total landed cost. Defining the following variables:

x_{kij}	amount in cases/gallons of product k produced in plant i and shipped to customer j
m_{ki}	cost in dollars of producing 1 case/gallon of product k in plant i
t_{kij}	cost in dollars of transporting 1 case/gallon of product k from plant i to customer j
mb	minimum lot size
LI	lot increment
P_i	capacity of plant i
D_j	total demand of customer j
a	number of plants
b	number of customers
c	number of products

The objective function is:

$$Min(Cost) = \sum_{i=1}^a \sum_{j=1}^b \sum_{k=1}^c m_{ki} x_{kij} + \sum_{i=1}^a \sum_{j=1}^b \sum_{k=1}^c t_{kij} x_{kij}$$

The goal is to minimize total cost, with the two main cost drivers being transportation and manufacturing (plant variable costs).

The objective function is subject to the following constraints:

$$\sum_{j=1}^b \sum_{k=1}^c x_{kij} \leq P_i \quad i = 1, \dots, a \quad (\text{capacity constraint})$$

$$\sum_{i=1}^a \sum_{k=1}^c x_{kij} \geq D_j \quad j = 1, \dots, b \quad (\text{fulfill demand})$$

$$x_{kij} \geq 0 \quad i, j, k = 1, \dots, a, b, c \quad (\text{produce positive amounts})$$

$$x_{kij} \geq mb \quad i, j, k = 1, \dots, a, b, c \quad (\text{minimum batch size})$$

$$\frac{x_{kij} - mb}{LI} \neq \text{fraction} \quad i, j, k = 1, \dots, a, b, c \quad (\text{produce multiples of lot increment})$$

This is a single period model, and the intent is to run the model over multiple periods to account for seasonality. Additionally, it should be noted that this model does not account for inventory. Optimization of various levels and locations of inventory is addressed by other PBG systems.

3.4 Modeling Tool Background

The analysis tool enlisted for this optimization was LogicChain®, developed by Logic Tools, Inc. The software provides two distinct types of solutions:

Multi-site Production Sourcing Solution: This aspect of the tool helps determine the optimal sourcing strategy when a firm has choices deciding where each SKU should be produced or purchased from.

Master Planning Solution: This aspect of the tool helps determine the optimal quantity and timing of production, storage and flow decisions.

As mentioned earlier, the primary focus of this study has been on the first solution the tool offers. The master planning solution aspect was evaluated in a secondary focus, and those results will be discussed in Chapter 4.

3.5 Methodology

Four key steps were identified to perform the sourcing optimization:

- Step 1: Build a model representing PBG supply chain
- Step 2: Evaluate a baseline: simulate actual product flow through the network for a given period of time, and compare theoretical costs to actual costs.
- Step 3: Optimize the baseline: determine potential opportunity for the given time period
- Step 4: Input forecast data for future periods to develop recommended sourcing strategies

Figure 13 below shows a graphical depiction of the Pepsi Bottling Group supply chain as modeled in the LogicChain® software. The color scheme indicates the different business unit classifications. The legend below the map describes the contents of the figure in full.

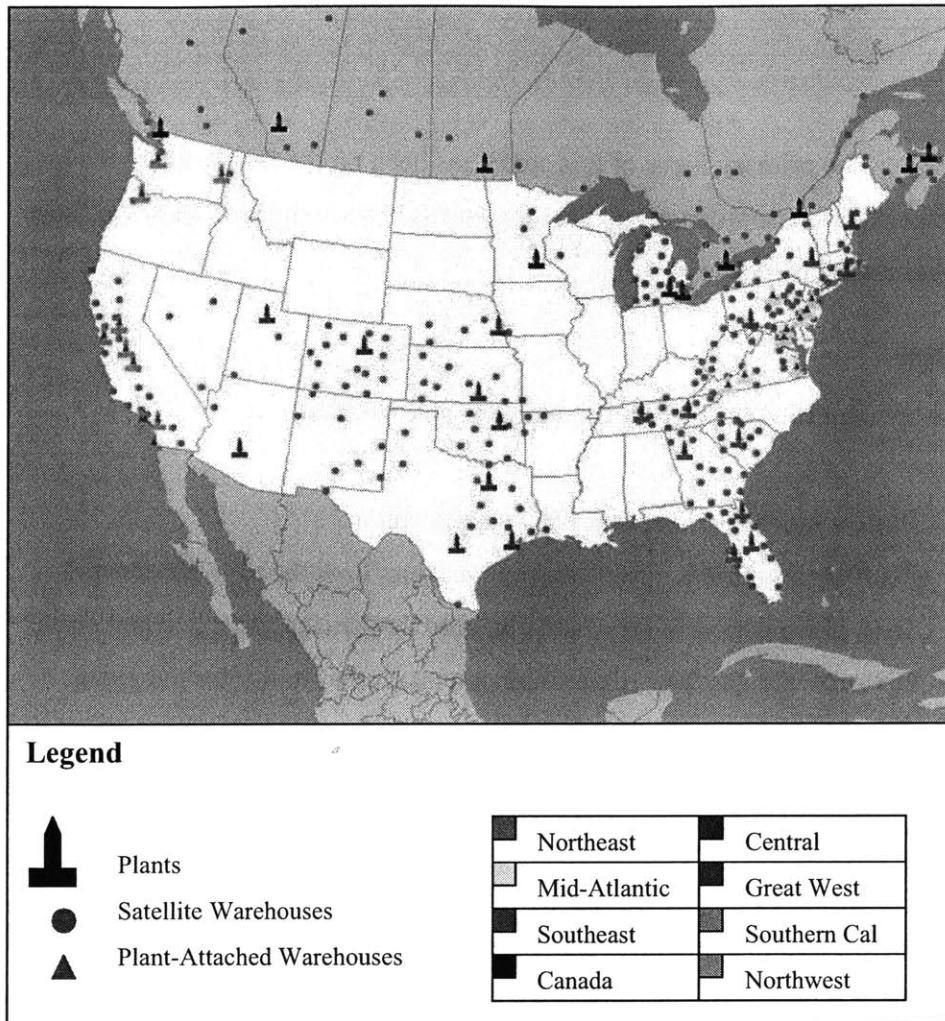
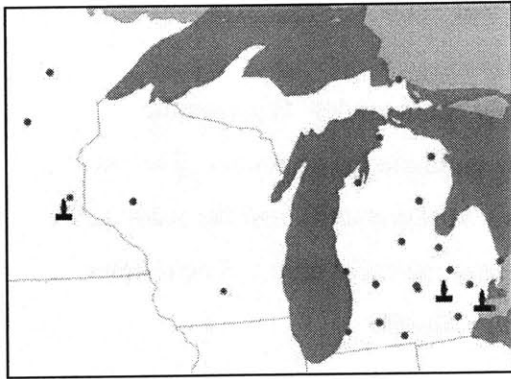


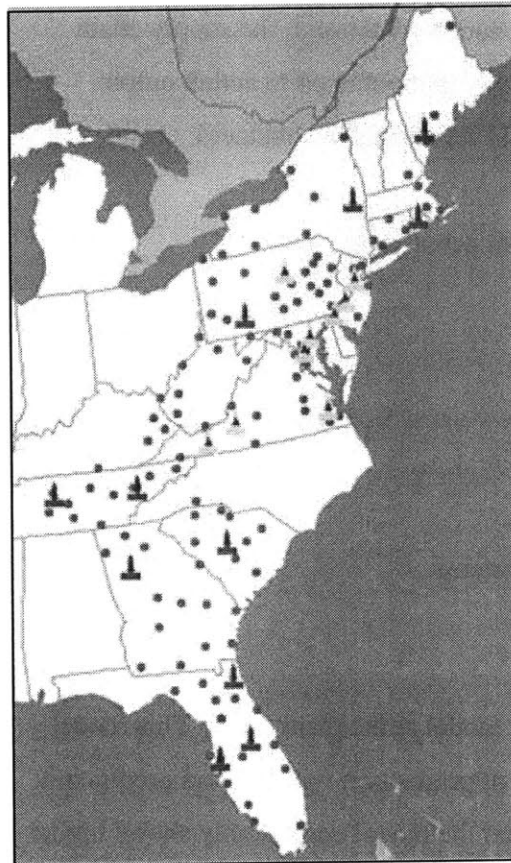
Figure 13: Pepsi Bottling Group supply chain network

The network as a whole is quite complex, containing millions of decision variables. To manage this complexity, the modeling and analysis for this project was broken down into two main stages, summarized in Figure 14. Stage 1 involved modeling the Central Business Unit, which contained 3 plants and 22 satellite warehouses. Stage 2 involved addressing the more complicated East Coast, which featured three separate business units containing a total of 20 plants and 149 total warehouses.



Stage 1: Central Business Unit

Plants: 3
 Warehouses: 22
 SKU's: 400



Stage 2: East Cost

Business Units: 3

Northeast Business Unit

Plants: 4
 Warehouses: 38

Mid-Atlantic Business Unit

Plants: 9
 Warehouses: 51

Southeast Business Unit

Plants: 7
 Warehouses: 60

Total

Plants: 20
 Warehouses: 149
 SKU's: 780

Figure 14: Stage 1 vs. Stage 2

Chapter 4: Analysis of Model Output

This chapter describes the results of the analysis of the supply chain model. It shows the baseline assessment and goes on to discuss the results of the optimization scenarios. The first part of the chapter looks at the results from stage one (central business unit), and the second part of the chapter moves on to the results from stage two (east coast business units). The chapter concludes with an analysis of a supply chain master planning scenario.

4.1 Central Business Unit Model Analysis

The purpose of the baseline model is to simulate actual product flow through the supply chain network for a given period of time, and compare theoretical output obtained to actual output. The goal is to establish confidence that the model accurately represents the business.

The following output from the model will be compared with actual data:

- Production Volume
- Production Cost
- Transportation Cost

The actual data is obtained from PBG internal reporting systems.

4.1.1 Central Business Unit Baseline Model

Table 5 below shows the baseline results from the Stage 1 model at the plant level. This model was based on one period (4 weeks) of data. Comparisons of production volume, and production/transportation costs are all within 3%. It can be noticed that the model consistently shows higher production numbers in comparison to the actual production numbers. This is likely due to the fact that in reality, some of the product demanded was shipped from existing inventory. The starting inventory numbers were not readily available and thus not included in the model, so all of the product demanded had to be produced. The model production costs are all correspondingly higher, reflective of the fact that more product had to be produced.

Table 5: Central Business Unit baseline results

Manufacturing Cost

Plant	Units Produced			Total Production Cost				
	Actual	Logic Chain	% diff	Actual	Logic Chain	% diff		
Burnsville	CONFIDENTIAL			CONFIDENTIAL			2	0.25%
Howell							2	3.06%
Detroit							5	1.04%
Total							8	1.63%

Transportation Cost

Plant	Total Transportation Cost			
	Actual	Logic Chain	% Diff	
Burnsville	\$	CONFIDENTIAL		-1.19%
Howell	\$			-1.01%
Detroit	\$			2.69%
Total	\$			0.27%

4.1.2 Central Business Unit Optimized Model Analysis

After gaining confidence from the baseline model, the next step was to run an optimization scenario. This was done by removing the baseline sourcing strategy and allowing the tool to determine the most optimal sourcing. Table 6 below shows the financial impact of this optimization. It specifically highlights an opportunity to save 9% on the transportation cost. There was a very small savings shown on the manufacturing side, and the overall savings found came to 2.6%

Table 6: Central Business Unit optimization results

Category	Baseline	Optimized	Difference	% savings
MFG Cost	\$	CONFIDENTIAL		0.6%
Trans Cost	\$			9.0%
Total Cost	\$			2.6%

Table 7 shows where the tool shifted product to. A clear shift of production from Detroit to Howell can be seen, with Detroit production down 14% and Howell production up 8%.

Table 7: Central Business Unit optimized scenario production breakdown

Plant	Units Produced		
	Baseline	Optimized	% change
Burnsville	CONFIDENTIAL		1%
Howell			8%
Detroit			-14%

Figure 15 shows an example of some of the decisions the tool is making that is resulting in this production shift¹⁸. Specifically, much of the production of the 12 oz Can 12 Pack and 2 liter bottle was shifted from the Detroit plant to the Howell plant. In fact, the software recommended moving all of the 2 liter bottle production in Detroit to Howell.

Detroit, MI Plant				
Line	Package	Baseline Prod	Optimized Prod.	% diff
Can Line	12OZ CN 12/2 FM (12PACK)	628,430.00	525,200.00	-16%
Bottle Line	2 LITER PL 1/8 SHELL (LOOSE)	67,908.00	-	-100%
	16.9OZ PL PK 12/2 (12PACK)	44,955.00	44,955.00	0%

Howell, MI Plant				
Line	Package	Baseline Prod	Optimized Prod.	% diff
Can Line	12OZ CN 12/2 FM (12PACK)	730,425.00	839,034.00	15%
Bottle Line	2 LITER PL 1/8 SHELL (LOOSE)	763,576.00	826,668.00	8%
	24OZ PL PK 6/4 SHELL (6PACK)	118,405.00	117,726.00	-1%

Product Shift

Figure 15: Production comparison between Detroit and Howell in optimized scenario

Table 8 helps to explain why this shift may have occurred. The first two rows of this table show a comparison of the variable production costs of these two packages in Detroit, relative to Howell. The 12 oz Can 12 Pack package costs \$.20 more per case to produce in Detroit, and the 2 liter bottles cost \$.17 more per case. Thus, it is more costly to produce both of these packages in Detroit versus Howell. The last row of Table 8 shows the average distance of each of these plants from the customers (satellite warehouses). The Howell plant is on average 105 miles from its customers, whereas the Detroit plant is on average 140 miles from its customers. This fact is highlighted by Figure 16, which points out the Howell and Detroit plants on the central business unit map. The Howell facility is clearly more centrally located in the state of Michigan.

¹⁸ Actual data is disguised

Table 8: Cost comparison of Howell and Detroit plants

Category	Howell	Detroit
cost per unit (12OZ CN 12/2 FM (12PACK))	-	\$ 0.20
cost per unit (2 LITER PL 1/8 SHELL (LOOSE))	-	\$ 0.17
average distance from customer (miles)	105	140

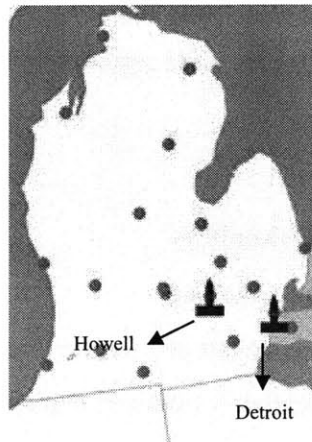


Figure 16: Location of Howell vs. Detroit

4.1.3 Stage 1 Validation Analysis

A study was done to analyze whether or not the types of savings shown in the Stage 1 optimization scenario would be sustainable from period to period. This was done by first developing an optimized sourcing plan for a future period by using forecast demand data as the input. This period featured lower demand and less complexity than the period simulated in the sourcing study. The existing sourcing strategy was used in actual production, and at the end of the period a “post-mortem” analysis was conducted. The period was simulated, using the optimal sourcing plan instead. The actual production and transportation costs were compared with the model’s predicted costs using the optimized sourcing strategy. Table 9 shows the results of this analysis.

Table 9: Results of Stage 1 validation analysis

Category	Model-Actual Sourcing	Model-LC Optimal Sourcing	Savings	% Savings
Trans		CONFIDENTIAL		4%
MFG		CONFIDENTIAL		2%
Total		CONFIDENTIAL		2%

These results indicate that using the optimized sourcing strategy would have offered an opportunity to save 4% on the transportation costs and 2% on the manufacturing costs. This confirmed that the cost savings opportunities were sustainable from period to period, even when demand was not at its peak.

4.2 East Coast Business Units Model Analysis

4.2.1 East Coast Business Units Baseline Model

Similar to Stage 1, a baseline model was developed for the three business units in the East Coast. Modeling these three business units together introduced significantly more complexity. It was necessary, however, in order to accurately simulate the baseline model since a certain amount of sourcing across business unit lines occurred. The existing sourcing plan was locked, and once again any sourcing outside of these three business units was ignored. A historical one-month period was simulated in the model, and actual results were compared to the model results. Figure 17 below shows the results of the manufacturing comparison. Each plant was compared side by side, and then the totals at the BU level were compiled. At the plant level, production and costs numbers in the model were within 3% of actual numbers. At the BU level, these numbers were within 1%.

BU	Plant	Units Produced	LC Units Prod	% diff	Actual Cost	LC Cost	% diff
Mid-Atlantic	Baltimore		CONFIDENTIAL	3.1%	\$	CONFIDENTIAL	1.6%
	Cheverly			-2.2%			-1.7%
	New River			-2.0%			1.6%
	Newport News			0.5%			-1.5%
	Philadelphia			1.7%			1.4%
	Piscataway			2.2%			2.2%
	Roanoke			4.1%			1.6%
	Willamsport			3.9%			3.2%
	Wilmington			-4.9%			-2.8%
MA Total			0.4%	\$		0.6%	
Northeast	Albany, NY		CONFIDENTIAL	1.4%	\$	CONFIDENTIAL	1.1%
	Auburn, ME			2.5%			2.1%
	Cranston, RI			-2.7%			-2.1%
	Johnstown, PA			-0.7%			-2.7%
	Laurel Packaging			0.8%			0.7%
NE Total			0.1%			0.0%	
Southeast	Atlanta, GA		CONFIDENTIAL	1.8%	\$	CONFIDENTIAL	2.2%
	Columbia, SC			1.1%			2.4%
	Jacksonville, FL			-4.4%			-3.1%
	Knoxville, TN			-1.4%			0.7%
	Nashville, TN			0.1%			-0.1%
	Orlando, FL			3.2%			2.7%
	Tampa, FL			0.8%			-1.5%
SE Total			0.4%			0.9%	
East Total			0.3%	\$		0.6%	

Figure 17: East Coast baseline model evaluation

A similar comparison was done for the transportation side. Figure 18 shows the results of this comparison. Again, the results are broken down by originating plant and then summarized at the business unit level. At the business unit level, the model costs are within 1% of actual costs.

BU	Plant	Actual Trans Cost	LC Trans Cost	% diff
Mid-Atlantic	Baltimore	\$	CONFIDENTIAL	2.7%
	Cheverly	\$	CONFIDENTIAL	-1.4%
	New River	\$	CONFIDENTIAL	-3.3%
	Newport News	\$	CONFIDENTIAL	2.3%
	Philadelphia	\$	CONFIDENTIAL	3.1%
	Piscataway	\$	CONFIDENTIAL	3.0%
	Roanoke	\$	CONFIDENTIAL	3.5%
	Willamsport	\$	CONFIDENTIAL	3.4%
	Wilmington	\$	CONFIDENTIAL	-2.5%
MA Total		\$		0.1%
Northeast	Albany, NY	\$	CONFIDENTIAL	1%
	Auburn, ME	\$	CONFIDENTIAL	5.4%
	Cranston, RI	\$	CONFIDENTIAL	-3.0%
	Johnstown, PA	\$	CONFIDENTIAL	-2.9%
	Laurel Packaging	\$	CONFIDENTIAL	-1.2%
NE Total				-0.6%
Southeast	Atlanta, GA	\$	CONFIDENTIAL	2.6%
	Columbia, SC	\$	CONFIDENTIAL	1.6%
	Jacksonville, FL	\$	CONFIDENTIAL	-1.4%
	Knoxville, TN	\$	CONFIDENTIAL	2.2%
	Nashville, TN	\$	CONFIDENTIAL	4.2%
	Orlando, FL	\$	CONFIDENTIAL	1.5%
	Tampa, FL	\$	CONFIDENTIAL	4.0%
SE Total				1.5%
East Total		\$		0.5%

Figure 18: East Coast model transportation cost comparison

The baseline model comparisons provided confidence that our model accurately predicted reality. The next step was to move on to the optimization scenarios.

4.2.2 East Coast Model Optimization Scenarios

Figure 19 shows the results of the optimization scenario run for the East Coast model. The optimization demonstrated an opportunity to save 7% on the manufacturing side and 3% on the transportation side.

Category	Baseline	Optimized	Savings	% save
MFG	\$	CONFIDENTIAL		7%
Trans	\$	CONFIDENTIAL		3%
Total	\$	CONFIDENTIAL		6%

Figure 19: East Coast model optimization scenario

In the optimization scenario, there was a significant increase in cross business unit sourcing. In practice, this does not happen as frequently since each business unit is essentially running as its own profit-loss center. There is a separate director for each BU, and they run their respective units quite independently. The software clearly found it advantageous, however, to source outside these boundaries. Figure 20 demonstrates the increase in cross business unit sourcing. In the baseline scenario, 19% of the product being shipped out of the Northeast BU was headed to a different BU. The Mid-Atlantic and Southeast BU's each shipped 1% of their products outside their respective boundaries. In the optimized scenario, the Northeast BU saw a 7% increase in product shipped outside their boundaries, and the Mid-Atlantic and Southeast business units saw increases to 4% and 5% respectively.

BU	Shipped Out	
	Actual	LC Optimized
Northeast	19%	26%
Mid-Atlantic	1%	4%
Southeast	1%	5%

Figure 20: East Coast cross Business Unit sourcing

A look back at the East Coast map shown below in Figure 21 can help explain much of the increased cross business unit sourcing. As a reminder, the magenta plants are a part of the Northeast business unit, whereas the yellow plants are a part of the Mid-Atlantic business unit. Highlighted in Figure 21 is a plant in the Northeast business unit that is geographically situated within the boundaries of the Mid-Atlantic business unit. In practice, many sourcing decisions were made to keep product flow within business units, and this clearly opens up opportunities for plants on the border of a business unit line.

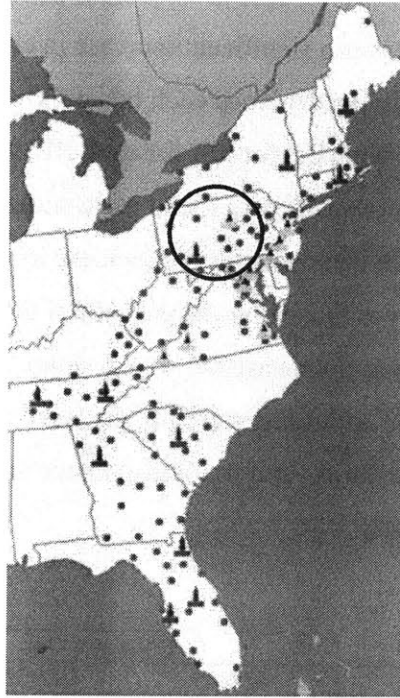


Figure 21: The case for cross Business Unit sourcing

4.3 Supply Chain Master Planning

The second layer of supply chain excellence from Figure 8 was examined as well: supply chain master planning. After determining *where* to produce each product, master production planning allows a company to determine *how much* product should be produced and *when* it should be produced. This becomes particularly relevant when seasonality effects are introduced. In the soft-drink industry, for example, there is a logical spike in demand in the warm summer months.

Beyond seasonal variation, demand for product can vary significantly within a one month period. Figure 22 demonstrates this point. In this figure, demand for a one month period is shown in weekly intervals. Demand ramps up to a peak at week 3, and subsequently drops off considerably in week 4.

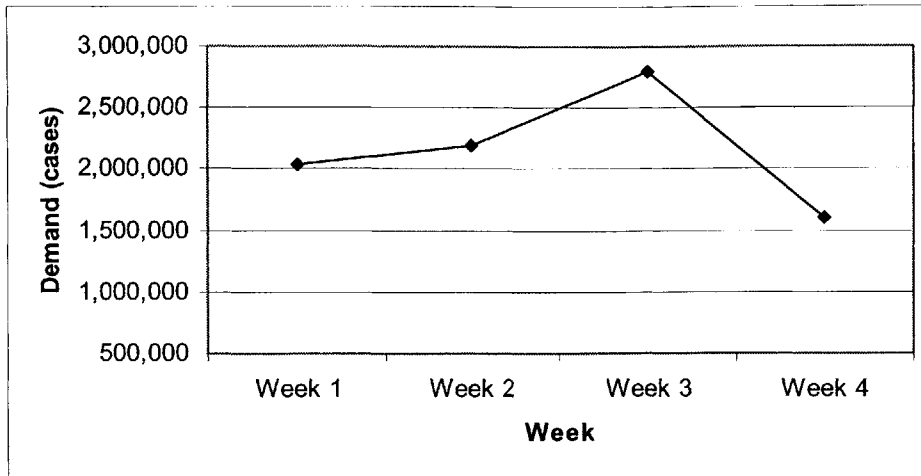


Figure 22: Sample PBG weekly demand¹⁹

Being able to respond to these variations in demand is imperative. If measures aren't taken to plan capacity, demand from the satellite warehouses may not be met for all products. Stockouts in the soft-drink industry are quite costly, as consumers can easily substitute other competing products.

In the current process at PBG, production schedules are produced (based on forecast data) for a one to two week time horizon. The current production planning tool will indicate if there is a potential capacity problem, but will not provide a solution. It is up to the supply planner to intervene at this point if the capacity problem is to be avoided. This dependence on manual intervention creates significant room for error in the planning process.

Figure 23 shows a snapshot of the output from the current production process. The demand and production are shown for one particular can package for a certain time interval and a particular plant. The utilization shown is for the entire can line at the specific plant. From the figure it is clear that week 3 presented a bottleneck for the production process. Utilization reaches 100% by week 3, and because of this not all demand could be met for the particular package displayed. This translates to a stockout on the shelves, and potentially lost customers.

¹⁹ Actual data is disguised

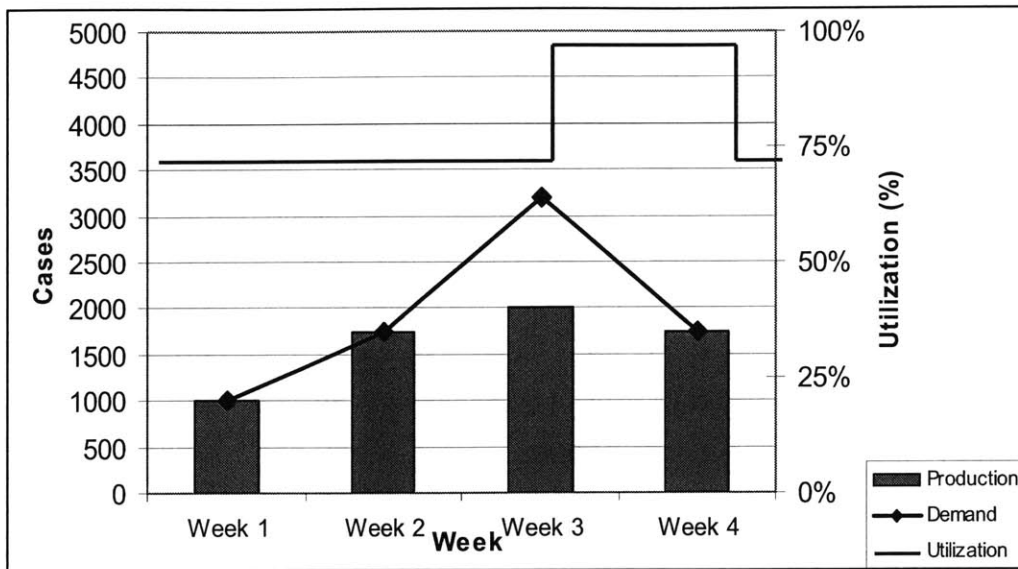


Figure 23: Production data for a can package¹⁹

Figure 24 shows the results of the optimized version simulating the same scenario described above. It recognized that demand reached a peak in week 3, and therefore pre-built product in week 1 when utilization was lower. Thus, product could be shipped from inventory in week 3 in order to meet all demand. Moreover, production was more level throughout the month. This helps mitigate the risk of potential line shutdowns.

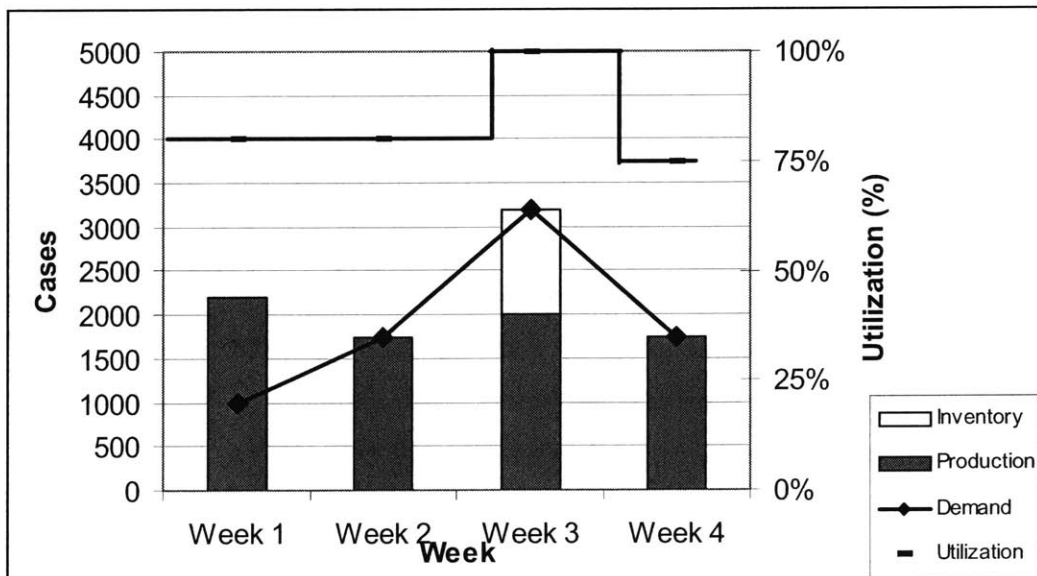


Figure 24: Optimized production data¹⁹

This simple example demonstrates the power of master production planning. By pre-building inventory, a costly stockout could have been avoided.

Chapter 5: Implementation of Optimization Tool

This chapter describes the process implications of implementing the optimization tool.

5.1 IT Infrastructure

Long-term use of the optimization tool will require successful integration of the tool with the existing IT infrastructure at PBG. Most crucial in this process is the development of automatic feeds for the data inputs described in Chapter 3. The nature of operations at PBG is extremely dynamic, resulting in frequent changes to the inputs. The most dynamic input to change is the customer demand information. From a broad perspective, there are large seasonal effects that can be observed. It was also shown that large variation can occur on a weekly basis. The SKU portfolio can change drastically from month-to-month, with new products being added and older products being deactivated. Production inputs can change frequently as well. Month-to-month, plants can change what they are capable of producing, either gaining complexity or cutting back on certain capabilities. Large changes can also occur in line efficiencies, and it is critically important to capture these changes. Changing less frequently is the transportation structure. It still, however, may be beneficial to update this input monthly as cost structures and average payloads may change. The input that perhaps changes least frequently is plant and customer (satellite warehouse) locations. Occasionally new plants/warehouses are acquired while others may be shutdown. Figure 25 shows a sample of what the system architecture might look like with the integrated optimization tool.

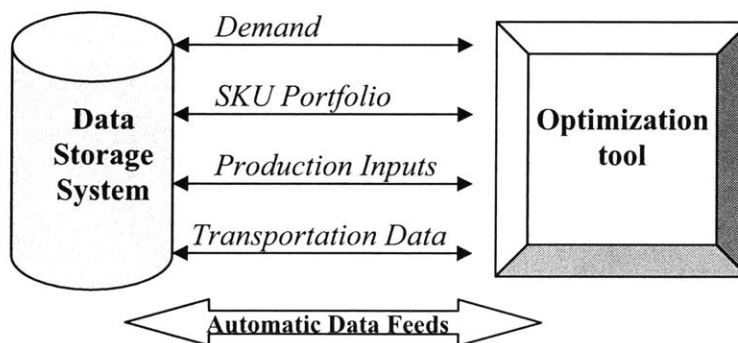


Figure 25: Optimization tool system architecture

5.2 Planning Horizons

One of the most critical factors to consider when implementing the tool is the planning horizon. This will determine how often the inputs need to be updated, and can have a significant impact on the usefulness of the results. Planning horizons will be discussed for the two aspects of the project, sourcing optimization and supply chain master planning.

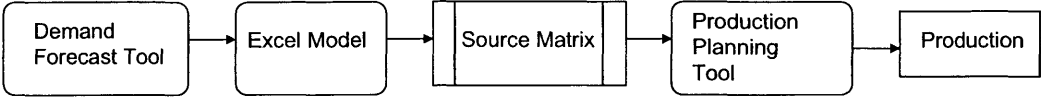
Sourcing Optimization: In the current process, the planning horizon for sourcing strategies is one year. This is mainly driven by the fact that the manual procedure is quite labor intensive. It has been shown, however, that the business can experience significant changes throughout the year. To produce the most efficient sourcing strategy, these changes must be accounted for. On the other hand, making changes to the sourcing strategy too frequently may cause problems. The system as a whole needs a certain amount of time to react and adjust to changes brought about with updates to the sourcing strategy. A potentially feasible horizon would be to update the sourcing strategy once every quarter. This horizon, however, can be adjusted to suit the needs of the system. The automatic data input feeds described in section 5.1 provide the flexibility to make adjustments to this horizon relatively easy. That is to say, it should not require a significant increase in workload to update the sourcing strategy more frequently, should that be desired.

Supply Chain Master Planning: As was demonstrated, demand can vary quite a bit from week to week. It thus makes sense to conduct strategic production planning plant by plant on a weekly basis. This is essentially the same horizon used in the current production planning process.

5.3 Process Implications

Figure 26 demonstrates the process changes involved with the implementation of the new sourcing optimization tool. In the new process, the Excel model is replaced by the optimization tool. Additionally, we notice a feedback loop between the tool and the production end. This loop refers to the automatic data input feeds associated with the tool, and emphasizes the fact that changes in the production data can be reflected in the sourcing optimization tool.

Old Process



New Process

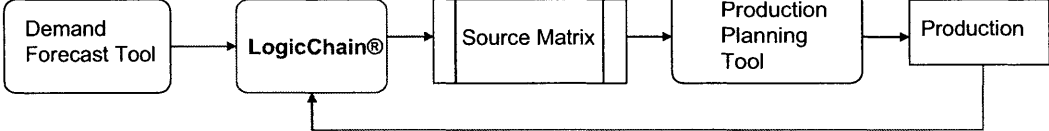


Figure 26: Sourcing process changes

Chapter 6: Organizational Change Analysis

This chapter examines the sourcing optimization implementation project from an organizational change perspective. The project will be analyzed from the three perspectives of organizational behavior – strategic design, political, and cultural.²⁰

6.1 Strategic Design

The strategic design perspective views an organization as a machine that is designed to achieve goals by carrying out tasks. The main goal of the Integrated Planning group is to ensure that customers are provided with the right product at the right time in the right quantity. The strategy to accomplish this goal focuses on four main aspects: technology, procedure, execution, and continuous improvement.

Technology: A main responsibility of the group is working with software vendors to be sure the PBG supply chain employs the right planning tools to help best meet the customer service goals. Members of the group spend a significant amount of time upfront researching potential vendors to determine the appropriateness of the fit within the existing IT infrastructure. Once a software package is selected, the group works closely with the IT department to successfully implement the software. In the past two years, new software technology was introduced to help improve demand forecasting, supply planning, and inventory policies.

Procedure: Another responsibility shaping the strategy of the IP group is the development of detailed procedures related to the execution of supply chain tasks pertaining to demand forecasting and supply planning. Detailed training sessions are setup with members of the field who are responsible for executing tasks involving the software. Teams from the IP group travel to each business unit location for extensive on-site sessions.

Execution: This aspect of the IP strategy involves monitoring field employees as they execute the various supply chain procedures. Members of the IP team observe remotely from their desks

²⁰ Carroll, John. "Introduction to Organizational Analysis: The Three Lenses." MIT Sloan School. August, 2001.

(via computer) as field employees navigate through the various software programs as a part of their daily tasks. Any deviations from the standard procedures are noted and discussed.

Continuous Improvement: The final aspect of the IP strategy involves continuously attempting to improve the supply chain operations in order to better meet customer expectations. The team is constantly engaged in projects with goals such as minimizing costs and reducing out-of-stocks.

As a whole, the sourcing optimization project fit quite well within the scope of the IP strategy. It offered a new technology in an attempt to promote continuous improvement. For this reason, tremendous support for the project was received within the home organization.

6.2 Political

The political perspective assumes that organizations are contested struggles for power among stakeholders with different goals and underlying interests. Organizations form combinations of stakeholders that advocate their side of important issues.

The sourcing optimization project featured multiple key stakeholders within the Pepsi Bottling Group. Figure 27 maps out these stakeholders with indications as to the extent of their support (indicated by the size of the plus sign) or opposition (indicated by the size of the minus sign) of the project.

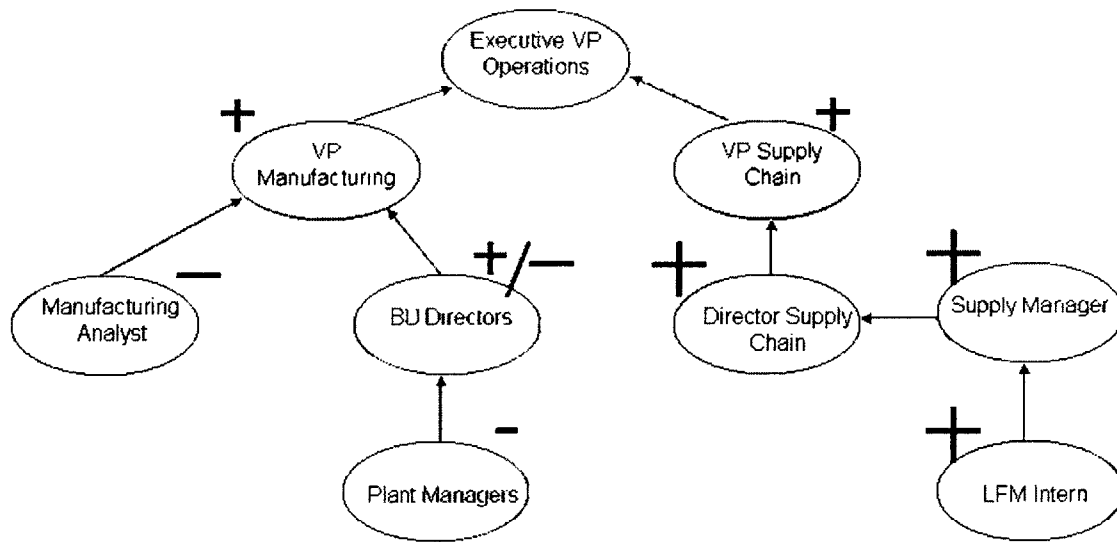


Figure 27: Stakeholder map of sourcing optimization project at PBG

The two main groups of stakeholders included supply chain management at headquarters and business unit directors in the field. Management at headquarters was concerned with maximizing value throughout the entire supply chain by reducing total landed cost. The business unit directors, on the other hand, were highly focused on numbers specific to their particular business unit. This is due to the fact that each BU is essentially set up as its own profit/loss center. Each director focuses on their own balance sheet as if they were a separate company. For this reason, the interests among these two major stakeholders were not entirely aligned. The optimization project was strongly supported by management at headquarters, while business unit directors approached it with more caution. They were fairly concerned about large swings in volumes, which would affect their business unit specific numbers. This posed a significant challenge, as support from the business unit directors was critical for long term success of the project.

6.3 Cultural

The cultural perspective takes the view that people in organizations take action as a function of the meaning they assign to situations. Cultures develop over time as organizations pass on their traditions and experiences. Within PBG, two distinct cultures were apparent: one for the manufacturing organization, and one for the supply chain department at headquarters.

The culture in the manufacturing organization was driven by a sense of urgency. The most critical goal was to ensure production lines were up and running to meet the aggressive demand requirements. Many of the manufacturing engineers spent their days “fire fighting”, frantically trying to fix problems on the line. This was extremely evident through the many conversations I attempted to have with these engineers – generally they did not have more than just a few minutes to spare. It is therefore not surprising that the manufacturing environment endorsed the following policy: “if it’s not broken, don’t fix it”. They did not embrace change, seeing as change is usually accompanied with a transition period.

The supply chain department at PBG headquarters was driven by a larger set of goals. While there was still a sense of urgency, the focus was additionally on bottom line growth. Those at headquarters recognized the fact that the soft drink industry is extremely competitive, and they were therefore much more interested in pursuing projects that offered opportunities to save money and develop advantages. Change was much more accepted amongst those at headquarters, especially if the net impact could be quantified. This differing culture between those “in the trenches” and those in headquarters provided an interesting backdrop for the sourcing optimization project. During the course of the internship, much time was spent with those in the field discussing the project and the progress. This gave them a chance to evaluate the assumptions, and at the same time sent the message that the project was a collaborative effort. Continued success with the project in the future will require those in headquarters to constantly recognize the differences in cultures and ensure measures are taken to promote communication.

Chapter 7: Conclusion

This chapter brings together the results and discussions from the previous chapters, and describes some of the major lessons learned.

The results of the project clearly indicate that there can be significant value in establishing a more robust approach to sourcing optimization and production planning. This value can take the form of cost savings, reduced stockouts, and better overall customer service. The suggested approach extracted the value by addressing the following areas:

- **Optimization Techniques:** A new optimization tool is introduced, capable of solving complex problems more efficiently than Microsoft Excel. The additional cost savings can in part be attributed to this more powerful optimization engine.
- **Frequency of Decision Making:** The approach suggests integrating the tool into the existing IT infrastructure, allowing for automatic feeds of the various data inputs. This will allow for optimizations to be run more frequently, helping to address the seasonality effects.
- **Planning Ability:** A more strategic approach to production planning is suggested. By planning ahead for potential capacity bottlenecks, it has been demonstrated that costly stockouts can be avoided.

Through the course of the project, the major lessons learned were:

- **Garbage in equals garbage out.** – The largest amount of time on the project was perhaps spent on building a baseline model that accurately reflected the PBG supply chain. A significant amount of effort was put into verifying data inputs and validating assumptions. This effort was reflected in the fact that the output from the baseline models matched actual outputs quite closely. This time was well spent for two main reasons. First, developing a starting point with the model allowed us to evaluate the financial impact of changes made to the sourcing strategy. Second, the time spent validating the model and the assumptions gave us confidence that the financial gains

were realizable. These two facts provide the confidence to make the recommended changes. This facet is missing from the current Excel based procedure. There was no baseline assessment of the model, and it was clear that people questioned some of the inputs.

- **Easiest solutions can be hardest to see.** – Perhaps the most powerful aspect of a thorough, robust optimization is revealing the “easy wins”. A clear example of this was demonstrated in the Stage 1 optimization analysis. The results indicated that numerous packages were being produced in plants that were more costly than other plants, and located further from customers. Capacity was available in the more logical choice, and the switch was made. This seems like an obvious sourcing strategy decision, but when directors and planners are forced to deal with a multitude of other issues, these simple scenarios can get missed.
- **Local decisions can lead to non-optimal solutions.** – As we have shown, much autonomy exists in the decision making process. The individual business unit directors remain focused on their territories, and the decisions they make reflect this. The lack of cross BU sourcing reflected this localized focus, and led to significant lost opportunities.
- **Dynamic systems require dynamic solutions.** – A significant drawback in the current sourcing optimization process is the manual nature. The process is quite labor intensive, thus a strategy is developed only once a year. As we have discussed, however, data inputs in this industry can change quite frequently. Therefore, a solution today may not be a very valid solution in eight months from today. When an environment is quite dynamic like that of PBG, decision making tools need to be equally dynamic in order to be fully effective.
- **Delegate down, not up.** – In the current process, a manufacturing analyst performs the Excel based sourcing optimization, and distributes the results to various members of the company. The results are treated as recommended strategies, and more often than not the recommendations were not followed. It became clear that if the recommendations

were to take effect, mandates would have to come from the executive level. For this project, gaining support from upper levels of management was therefore always a priority. Continued success in implementing the strategies will require sustained support.

References

- Blaha, Dwight. *Designing a Strategic Sourcing Process for Low Volume, High Technology Products*. LFM Thesis. June, 2002.
- Carroll, John. "Introduction to Organizational Analysis: The Three Lenses." MIT Sloan School. August, 2001.
- Exact Software: [e-journal] <<http://www.exactsoftware.com>>
- Klein, Jan. Conference Call on Stakeholder Mapping and Analysis. July 23, 2005
- Lee, Young, "Supply Chain Optimization Models in a Chemical Company." BASF Corporation. February 27, 2002.
- "LogicChain®: User Reference Guide." LogicTools. 2005.
- Miciano, Miguel. *A Tool for Sourcing Decisions*. LFM Thesis. May, 1999
- Manugistics: [e-journal]
<http://www.manugistics.com/documents/collateral/0841_0105_7-11_casestudy.pdf>
- Pepsi Bottling Group 2005 Annual Report
- Pepsi Bottling Group's website: <<http://www.pbg.com>>
- Pepsi's website: <<http://www.pepsi.com>>
- Pidd, Mike. "Just Modeling Through: A rough guide to Modeling." *Interfaces* 29, no. 2, March-April 1999.
- Simchi-Levi, David, and Philip Kaminsky and Edith Simchi-Levi. *Designing and Managing the Supply Chain: Concepts, Strategies & Case Studies*. 2nd ed. New York: McGraw-Hill, 2003.
- Symbol's website: <<http://www.symbol.com>>