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I am submitting herewith a thesis written by Malcolm Roger Shrimplin entitled "An Electronic Pull System for Scheduling Production and Distribution in the Soft Drink Industry." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Management Science.

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AN ELECTRONIC PULL SYSTEM FOR SCHEDULING PRODUCTION AND DISTRIBUTION IN THE SOFT DRINK INDUSTRY

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Malcolm Roger Shrimplin
December 1997

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DEDICATION

This thesis is dedicated to

my parents Malcolm and Marilyn Shrimplin

who both showed me HOW,

to the Rev. Karen Thompson

who told me WHY,

and to

my advisor Ken Gilbert

who taught me WHEN.

Each of you have touched my

life in ways words cannot describe.

ACKNOWLEDGMENTS

No work involving an application of a manufacturing philosophy to the "real world" would be possible without the assistance of those who run the daily operations. I am indebted to the following people who graciously assisted me while I tested my ideas: Ty Brannon, Jim McCune, Larry Maso, Jimmy Mount, and Kevin Sullivan from the Knoxville Pepsi-Cola Bottling Facility and Chris Haley, Mike Jensen, Greg Miller, Cindy Swain, and Rex Thompson from the Pepsi-Cola Bottling Company of Ft. Lauderdale-Palm Beach, Inc. Further, no work of this nature is possible without financial support. I am indebted to Ed Stack and the Pepsi-Cola Company for the many semesters of support they provided me while I was pursuing my degree. I am also indebted to Mike Caudill and the management team of Central Investment Corporation. The professional and personal experiences I had while working for them and living in Palm Beach Gardens, Florida gave me means to create some of the best memories of my life.

Without the help of many people at The University of Tennessee my work would also not have been possible. In particular I would like to acknowledge John Riblett and the staff of The Management Development Center. They have all contributed to creating an environment in which graduate students can excel. I am also grateful to the members of my committee, Dr. Melissa Bowers and Dr. Kenneth Kirby, for their valuable input and willingness to serve. Finally, the patience and understanding of my committee chair, Dr. Kenneth Gibert, cannot be overstated. His support and encouragement during this time in my life was absolutely crucial. I am forever in his debt.

ABSTRACT

Over the last half of the twentieth century there has been increased interest in the application of just-in-time, lean, or pull production techniques to many industries which produce nonperishable goods within The United States. More recently, however, companies that produce perishable goods, particularly foodstuffs, have started to apply these techniques to their manufacturing and distribution operations. This study highlights the application of these techniques to the soft drink industry. There is perhaps no better industry suited for such a study. The proliferation of the product line in both package size and flavors in recent years has been exponential in nature and there is every indication it will continue to grow in such a manner. (At one company in the study the number of cases sold between 1980 and 1995 increased from five to 16 million, while the number of stock keeping units increased from 40 to 240.) To further complicate the situation, the market which these bottlers serve is volatile and the margins they earn from it are not getting larger. Bottlers must meet consumers' demands for new products and retailers' demands for more efficient service with low cost products and sophisticated promotions. All of this is occurring while bottlers try to operate with equipment and performance measures that are designed to accommodate none of these objectives. Long gone are the days of two main competitors each selling one similar product to an inexhaustible market.

A new production and distribution scheduling methodology was applied and refined at both companies in this study. The pull production system operated by scheduling production and distribution based on the previous day's route truck loadouts. (Loadouts are the amount of product which is removed from a delivery truck and placed

in a retail outlet.) This system replaced one in which production and distribution decisions were scheduled weekly, based on a forecast of future demand. As a result of the new scheduling methodology, inventory at both companies fell dramatically and out-of-stock and out-of-date product were made virtually nonexistent. This was very impressive considering that virtually no changes in operational procedures, except for scheduling methodology, were used.

Predictably, key manufacturing performance measures, which are based largely on mass production assumptions, did not indicate improvement. Among the major concerns were yield loss and number of package and flavor changeovers. Each of these problems, however, could be traced to using equipment for purposes for which it was not designed.

Management at both locations was pleased with the results of the study. All agreed that in the future a production and distribution scheduling system like the one used would become essential because it reduced the amount of inventory, while avoiding stockouts. Most importantly, the study was deemed beneficial because it pointed management in a new direction for investments in capital improvement projects. One facility in the study was so impressed with the new system that it used the results as part of its entry for a company wide quality control award. The facility won the award and continues to use a version of the system introduced in the study.

PREFACE

This thesis represents the culmination of four years of consulting work with two facilities which bottle the same brand of soft drink products. One facility, called a COBO (company owned bottling operation), is part of a larger corporation which owns several bottling facilities. The other facility, called a FOBO (franchise owned bottling operation), is owned by a private individual who has an investment in one other bottling operation in addition to the one studied. While both facilities are located in the southeastern part of The United States, the markets they serve are vastly different. One serves a mature market with limited growth, while the other serves a market which is growing at a much faster rate. The mature market has the seasonal demand that one would typically expect to witness for soft drink products. The other, due to its geographic location, has much less of a seasonal demand. Further, the marketing strategy that both organizations used is necessarily different due to the aforementioned factors and management style. A better scenario for the comparison of "mass" versus "lean" production and distribution philosophy would be hard to find. Further, the contrasts between the two markets and the operations which served them made for an interesting test of the potential use of pull production and distribution methods.

One would be remiss to not mention what is happening in the markets which both these operations serve. Throughout the grocery-industry there has been a movement towards adopting a new way of operating. Broadly this has been called Efficient Consumer Response (ECR). It is defined as "a grocery-industry strategy in which distributors and suppliers are working closely together to bring value to the consumer. By

jointly focusing on the efficiency of the total grocery supply system, rather than the efficiency of individual components, they are reducing total system costs, inventories, and physical assets while improving the consumer's choice of high quality, fresh grocery products." (12) The estimated savings for the traditional grocery-industry supply chain is estimated at $30 billion with 41% less inventory. Needless to say, these figures have caught the attention of all those who participate in the industry. Within this industry, however, the soft drink manufacturers occupy somewhat of a unique position. Unlike other manufacturers who distribute their product through a multi-tier distribution system, the product they sell is shipped directly from the production facility to the retail outlet. This has two implications for soft drink manufacturers as the grocery-industry evolves. Much of the projected savings of ECR in both money and inventory does not apply directly to making soft drinks. Further, unlike the other major players in the traditional grocery-industry supply chain, soft drink manufacturers control much more of the supply chain for their goods. The combination of these two facts imply that it is crucial that soft drink manufacturers understand where the grocery industry is headed and how the ECR movement will affect them. As one industry commentator has noted, "(F)or the consumer products industry to achieve the vision of efficient consumer response (ECR), manufacturers need to radically redesign their management processes and organizational structures." (10) The author's intent is to add to the body of knowledge needed to foster this redesign.

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CHAPTER 1:

REVIEW OF THE LITERATURE

Terminology

For the purpose of this review, various production systems will be defined as follows:

Pull: a system in which each workcenter is allowed to work on incoming jobs only when the need for such jobs is signaled by the workcenter immediately downstream from the workcenter in question.

Push: a system in which each workcenter is free to work on an incoming job as soon as it approaches.

CONWIP (constant work in progress): a system in which jobs are released into the system based upon a need from one of the downstream workcenters. However, unlike a pull system, workstations from the initial workstation to the downstream trigger are allowed to work on jobs upon approach.

Hybrid: a system which is a combination of both a push and pull system, but not a CONWIP system. Typically this refers to a system which operates predominately in a pull mode, but switches to a push mode for a specific period of time.

General Description of Pull Production Systems

The origins of pull production systems are in the Toyota Production System, see for example Monden (15). Kitney (11) describes the basic concepts of a pull system. He highlights how the system can be used effectively in administrative processes. In

contrast, Mori and Kuriyama (16) describe the basic concepts of a pull system in a manufacturing environment. In particular, they highlight how to use pull production and CIM (computer integrated manufacturing) to respond to market changes.

Theoretical Aspects

Spearman et al., have written excellent papers on the theoretical aspects of pull production systems. When comparing push production systems to pull production systems (18) they note that pull systems have less congestion and are easier to control than push systems. They also note that this is due largely to the fact that the WIP (work in progress) is bounded, rather than being pulled through every stage of the manufacturing process. Using this knowledge, they propose a control strategy called CONWIP which outperforms both a pull and push system. They also claim that CONWIP is more broadly applicable than traditional pull production systems.

Several papers have been written on the advantages of CONWIP and hybrid systems. Spearman et al., have one work (19). It describes a CONWIP system in relationship to a pull system. Papers by both Hirakawa (6) and Takahashi et al., (20) describe models which illustrate the benefits of a hybrid system. Hirakawa et al., (7) outline theoretical arguments for a hybrid system. They construct models to support the performance of such a system. By choosing specific demand and forecasting models, they contrast the performance of the hybrid system to pull and push systems.

Customer service in both pull and push systems is considered in another paper by

Spearman et al., (17). In a push system "good" customer service is defined as taking no more than the allotted lead time to finish a job. From this such measures as fraction of jobs on-time and average tardiness are computed. Because the lead time in a pull system is theoretically zero, the notion of "good" customer service is different. The performance measures which indicate the level of customer service in a pull system are probability of a stockout, expected time to fill demand, and expected backlog of orders. They show a CONWIP system has better service than a pull system and that it also solves specific implementation problems.

A paper by Hopp et al., (9) highlights the idea of using excess capacity (called "safety capacity") in a pull system to meet demand and to buffer against the randomness of demand. (This is analogous to the situation when excess inventory is utilized to meet demand in a push system.) The authors also explore the tradeoff between lost revenue opportunity and overtime costs associated with the excess capacity or lack thereof. Finally, as pull systems are rate based, the authors also discuss how to set economic production quotas to meet demand.

Lee (13) describes the use of a computer model to quantify the difference in several performance measures common to both pull and push systems. By varying the level of demand, he concludes that pull systems outperform push systems on virtually all performance measures considered- mean daily job completion rate, process utilization, job queue time, and job lead time.

Practical Aspects

In order to change a push system to a pull or hybrid production system, lead time reduction is inevitably part of the implementation process. Hopp et al., (8) have determined there are three key points upon which one must focus to achieve lead time reduction. Flow time must be reduced. This can only be accomplished by working on its two major components: queuing time and waiting time. Since WIP is proportional to flow time, excessive flow times can be traced to locations in the manufacturing process which have large inventories. Finally, not only must the average flow time be reduced, but the variability in flow times must also be reduced in order to shorten lead times.

Since a pull system is a rate based system which responds to demand, changes in demand must be detected and capacity adjusted accordingly. One way to monitor demand for an item produced in the system is to place it on a control chart. This way changes in both variability and average demand can be monitored. Watts et al., (23) suggest a similar approach when monitoring the performance of a reorder point system. They suggest charting the demand for a particular product, as well as inventory turnover, to diagnose the performance of the system.

Several papers have been published on the implementation of pull production systems and how the performance compares to push systems. Ding (2) describes the implementation of a pull system in a tractor plant. Venne and Ptak (21) describe the results of implementation in a medical device company. Lynch et al., (14) describe how to implement a pull production system in the semiconductor industry. Finkle (3)

describes the ten steps involved in implementing a just-in-time system as outlined by Bruce Harvey of Hewlett-Packard. Vrat and Pisal (22) describe the results of trying push, pull, and hybrid methods in a hard disk parts manufacturing company. Carlson and Yao (1) explore using simulations to predict how a pull system will perform in a low volume manufacturing environment- typically not where pull type systems are applied.

CHAPTER 2:

OVERVIEW OF THE PRODUCTION AND DISTRIBUTION PROCESSES OF THE GROCERY SUPPLY CHAIN

There are many entities in the traditional grocery-industry supply chain between the manufacturer of the perishable good and the final customer. These entities typically include distributors, wholesalers, and retailers. This means there are significant delays between the time when the product is produced and when it is purchased by the consumer from the retailer. Usually a decision must be made to produce a product, then there is a delay in receiving the raw materials to do so. After being produced, the goods are often stored at the manufacturing facility until they are ready to be shipped. Between the time the goods leave the manufacturer and the time they are placed on the store shelves, the goods are handled and stored several times at various warehouses and distribution centers. Likewise, there are delays and distortions in the information flow from the retailer back to the manufacturer. When the consumer purchases a product, this creates an empty space on the shelf and sometimes an electronic tally at the cash register. At some point accumulated purchases trigger the retailer to order more of the product from a warehouse or distribution center. This process is repeated throughout the supply chain. Thus, the timing of the actual purchase by the final consumer is often lost.

These delays in both time and information cause huge swings in inventory and production levels. This effect is sometimes referred to as pipeline whiplash. As this anecdote from the soup industry illustrates, marketing efforts usually make the situation even worse:

> " . . . the process of bringing Campbell's chicken soup to the shelves is full of 'gyrations' that add costs to the logistics chain, while adding no value whatsoever. Because Campbell offers supermarkets off-invoice deals in January to coincide with its 'Soup Month' promotions . . . most major retailers stockpile enough chicken soup then to last not only for the promotion but for four months beyond. To support that activity . . . Campbell begins running its poultry plants overtime in August, stockpiling deboned frozen chicken meat. Then it begins running its canning line overtime in October, stockpiling finished product in outside storage. In January, Campbell puts its shipping crews on overtime, and supermarkets put their receiving crews on overtime. In the meantime, employees of Campbell's boning plants and canning plants are laid off until the next spike in production." (4)

Fortunately, soft drink manufacturers do not face the same distribution dilemma that most other perishable food producers face. They have control over a considerable amount of the distribution system they use. From the time the raw materials enter the production facility until it is actually sold to the retailer (and in some instances the final consumer) they own the product and the space it occupies. Further, since the shelf life of soft drinks are much shorter than some perishable goods like soup, the rate at which soft drinks move through the distribution system is relatively quick. These facts make the production and distribution of soft drinks ideal for a pull system.

CHAPTER 3:

OVERVIEW OF THE PRODUCTION AND DISTRIBUTION PROCESSES OF THE COMPANIES IN THE STUDY

Production and Distribution

Both production facilities produce a wide range of flavors of soft drinks and other beverages. Those flavors are bottled and packaged in several forms on dedicated lines. The three major production lines at each facility produce a twelve ounce aluminum can in cases of six, twelve, and twenty-four, a one, two and three liter plastic bottle, and a ten ounce glass bottle and fountain tanks. To start the production process, flavored concentrate and additives are mixed in a small stainless steel tank to form syrup. The syrup is then pumped into a large steel tank and mixed with water and high fructose corn syrup. It is usually aged overnight and then tested to make sure it is within specification. Next, the syrup is pumped through a series of tubes to a line. At the line, the filler mixes the syrup with water and carbon dioxide and bottles the beverage. After being intermittently tested while being bottled, the packages are palletized and stored for shipment. Both facilities operate this process at least four days a week. The COBO chooses to use three eight hour shifts, while the FOBO uses two twelve hour shifts. In both cases, the first shift starts around 6:00 a.m.

Both companies in the study have virtually identical distribution systems. The only major difference between the two is the number of warehouses each production facility serves. Pallets of beverage leave the production facility in one of two ways. They are either shipped directly to major retail outlets or sent to regional warehouses for

delivery to smaller retail outlets. In the former case, the production facility serves as a warehouse for the product until it is delivered. In the latter case, pallets are stored at the regional warehouse until they are loaded onto trucks for delivery on certain routes. The distribution of goods to the warehouses usually occurs around the clock. Deliveries to retail outlets usually start around 6 a.m. with the trucks being loaded the afternoon of the day before the deliveries are to occur. Trucks that directly deliver product to large retail outlets are loaded according to orders from sales personnel. Trucks which deliver goods from the regional warehouses are loaded at each individual driver's discretion. Figure 1 illustrates the supply chain.

Production Scheduling and Raw Materials Acquisition

Each week the production scheduler makes a schedule for all of next week's production. The scheduling process is just as much art as it is science. Two factors drive the scheduling process: a forecast (or monthly budget) and manufacturing considerations such as minimizing changeovers. At the COBO production facility the scheduler uses forecast data from a sophisticated system which is driven by past sales and competitor and promotional activity. At the FOBO production facility the scheduler uses an aggregate monthly sales budget and information from weekly sales meetings. Regardless of the source, each schedule has to incorporate the many production constraints that currently exist. For example, some flavors must be run before others due to potential contamination or sanitation requirements. Also, package changeovers play a major role

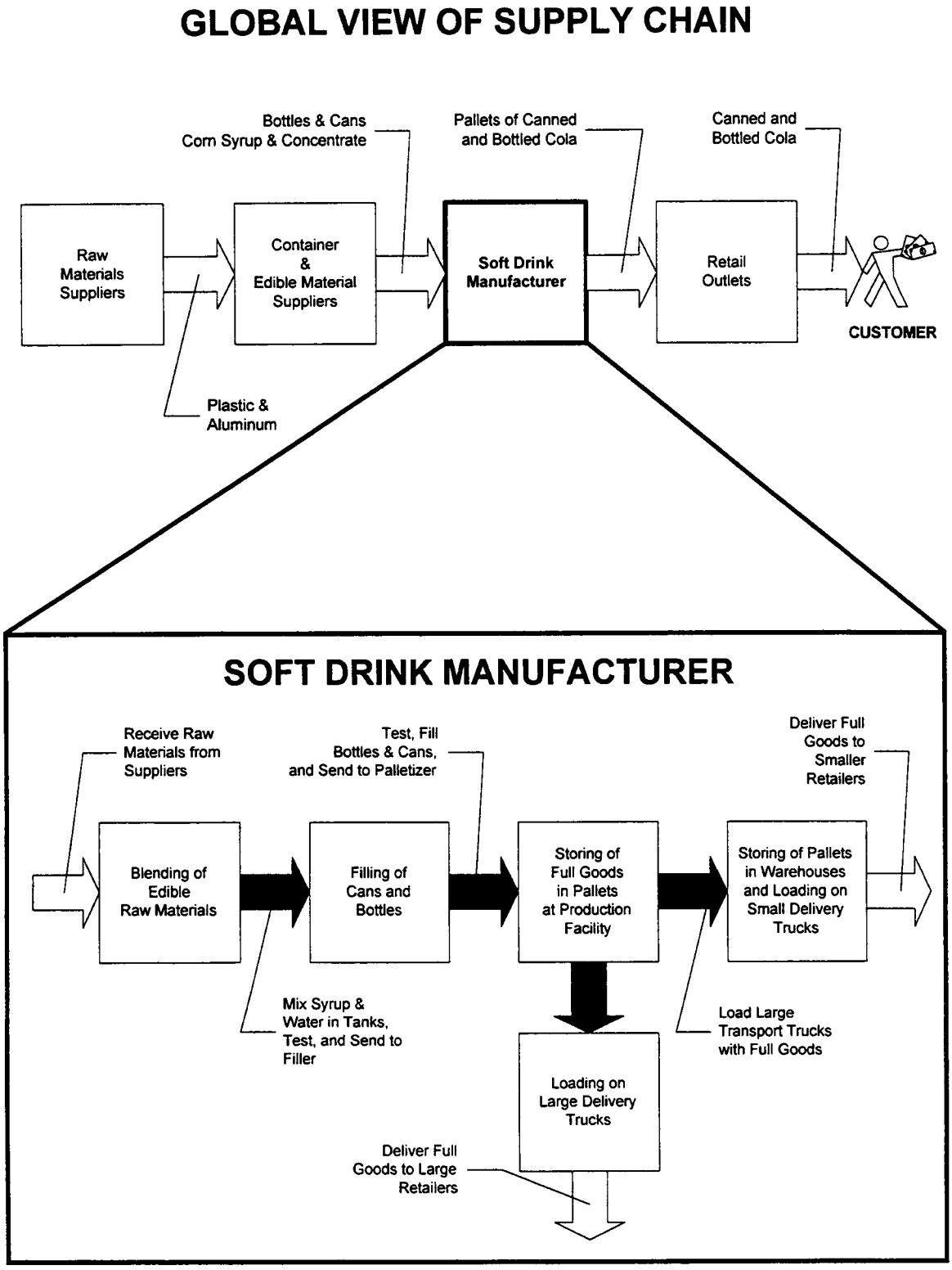


Figure 1: The Soft Drink Production and Distribution Process

in scheduling. For example, at both facilities changing from two liter bottles to ten ounce bottles requires an enormous amount of time. Because the equipment is not designed to do this easily, frequent changeovers are strongly discouraged.

From the schedule, next week's raw materials requirements are transmitted to suppliers. Notable exceptions to this process include seasonal or promotional items such as labels and cans. These requirements must be ordered well in advance of the date they are actually needed. Most raw materials arrive at the production facility the day of or the night before they are needed. Concentrate, however, normally arrives only once a week.

The distribution of finished goods between the production facility and the regional warehouses at both companies is mainly based upon the movement of product from the floor of the regional warehouses. Product is shipped based on a measurement called week's supply. Goods with a lower weeks supply tend to get replaced faster than those that are at a higher week's supply. What constitutes a week's supply is different at each company. At the COBO, a week's supply is based upon warehouse floor inventory and forecasted sales for the week. A week's supply is based upon warehouse floor inventory and the monthly budget evenly divided among the weeks in the month at the FOBO. In either case, space limitations at the production facility, on the transport trucks, and at the warehouses themselves often influenced the distribution decisions. Also, if there is not room on the production facility floor for all the day's production, it is often sent to regional warehouses based upon available warehouse floor space.

CHAPTER 4:

PRELIMINARY DATA ANALYSIS

Overview

A preliminary data analysis was done for two reasons. First, it was necessary to show management that the combination of product proliferation and current scheduling methodology were producing unintended consequences. Second, historical data was needed to establish a baseline by which the effectiveness of a new production and distribution methodology could be evaluated. The following historical data was relevant to management at one or both of the facilities: stockouts, inventory levels, exchanges between warehouses, forecasting error, and actual product demand at the regional warehouses and production run size and frequency at the production facility.

Stockouts

A stockout was defined as an inability to put product on a truck when it was requested by either a route truck driver or sales personnel. At the COBO this was a significant problem across all product lines. The number of days which a stockout occurred for a given month at a representative regional warehouse is shown in Table 1. The relatively high number of stockouts in the summer months is reflective of the seasonal demand experience by the COBO. At the FOBO stockouts were not considered a major problem. Therefore, they were not studied.

Table 1: Monthly Stockouts at a Chosen COBO Regional Warehouse

Month	Total Days Stockouts Occurred	Total Cases Unavailable for Loading
1992 February	4	589
March	18	1359
April	15	1905
May	20	9235
June	19	1930
July	22	7742
August	22	2396
September	18	874
October	18	1680
November	6	712
December	4	100
1993 January	13	964

Inventory Levels

At the representative COBO regional warehouse average inventory levels across all product lines was around a nine day's supply. This meant that the warehouse had enough product on the floor to supply nine days worth of route truck driver loadout requests. For some products, however, the amount was as great as 44 day's supply. At all the FOBO regional warehouses the total floor inventory for most products was about ten day's supply. There were also large swings in inventory levels at both companies. For one product alone at the COBO representative regional warehouse the inventory level range was an astounding 142,000 cases, which is a 37 weeks supply. At the FOBO regional warehouses, a typical product's inventory level had a range of 23,000 cases, which is a two weeks supply.

Exchanges between Warehouses

In a two month period there were several thousands of cases transferred between the representative COBO warehouse and the other warehouses in the system. Exchanges among the warehouses at the FOBO operation were minimal.

Forecasting Errors

At the COBO the production scheduler was given a weekly forecast which was based on past sales and competitor and promotional activity. When these weekly forecasts were analyzed, the correlation between the forecasts and actual product

movement from the regional warehouses was near zero. This meant that the forecasts explained none of the movement of product from the warehouses. At the FOBO a forecast was not used. Instead a monthly budget was set and the sales force tried to meet it. As a consequence, the product movement from the regional warehouses followed the typical hockey stick pattern. It was light at the beginning of the month and heavy at the end of the month when the salesforce tried to compensate for being under budget. This was particularly true for the twelve ounce can line of packages.

Actual Product Movement at the Regional Warehouses

At both companies the movement of product from the regional warehouses remained stable and predictable over a given period of time. If there was a seasonal trend to any movement, it usually followed a smooth rise and fall with the season for which it was associated. Exceptions included special promotional items and items such as tonics and other mixers which are particularly popular each year around Thanksgiving and Christmas. Control charts of regional warehouse loadout data for several different packages were constructed and analyzed. One consistency across all products at both companies was the relative stability of demand. Most control charts had an upper limit equal to approximately two to three days demand. Out of control points were easily identifiable and attributed to major promotions or holidays throughout the year. Figure 2 shows a typical control chart. The daily movement of 6 pack Pepsi from the regional warehouses is plotted over time. The out-of-control points correspond to the Fourth of

July and Labor Day holidays. Figure 3 shows the same movement with the out-of-control points removed. The average daily movement is 3493 cases. The upper control limit is 5928 cases or about a two day's supply. Figure 4 shows this same movement together with the actual aggregate inventory levels. This chart illustrates how large the swings in inventory were compared to the variation in product movement from the regional warehouses.

Production Run Size and Frequency

Table 2 summarizes other relevant statistics for the line in relation to the production of two liter products. Table 3 shows the size and frequency of runs for individual two liter products at one of the production facilities from January 17 to May 18, 1995. The only product which is produced with any relative frequency (every 2.1 days) is two liter Pepsi. During the same period, statistics were also kept on the line which was assigned to run all two liter packages. On average, the line ran at least one two liter package every 1.5 days.

Discussion

The data all point to problems with the old production and distribution system employed at both companies. When using mass production techniques based on forecasted demand to "push" product from the production facility towards the final consumer, these results are typical. In systems like these, small fluctuations in demand

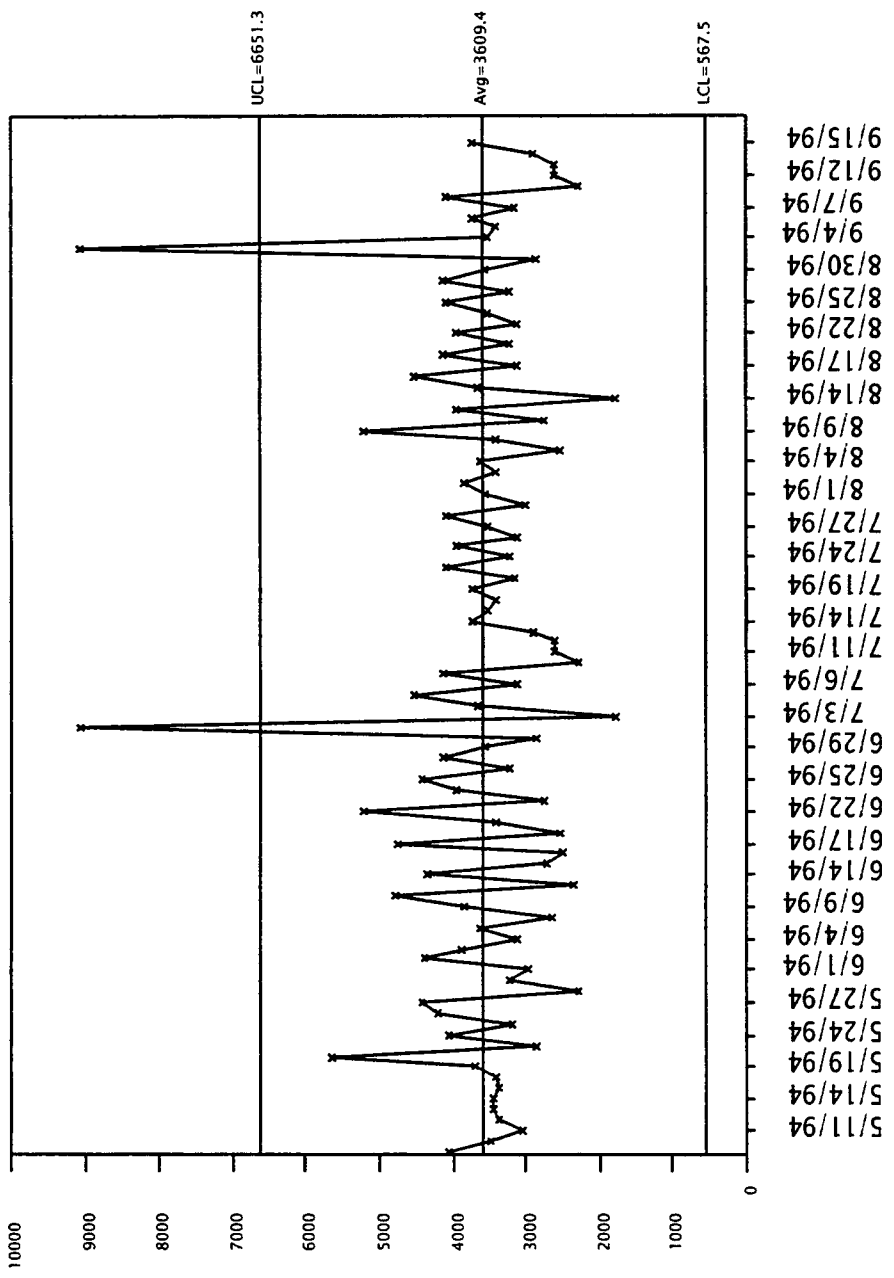


Figure 2: Out-of-Control Control Chart of Six Pack Pepsi Loadout Data in Cases

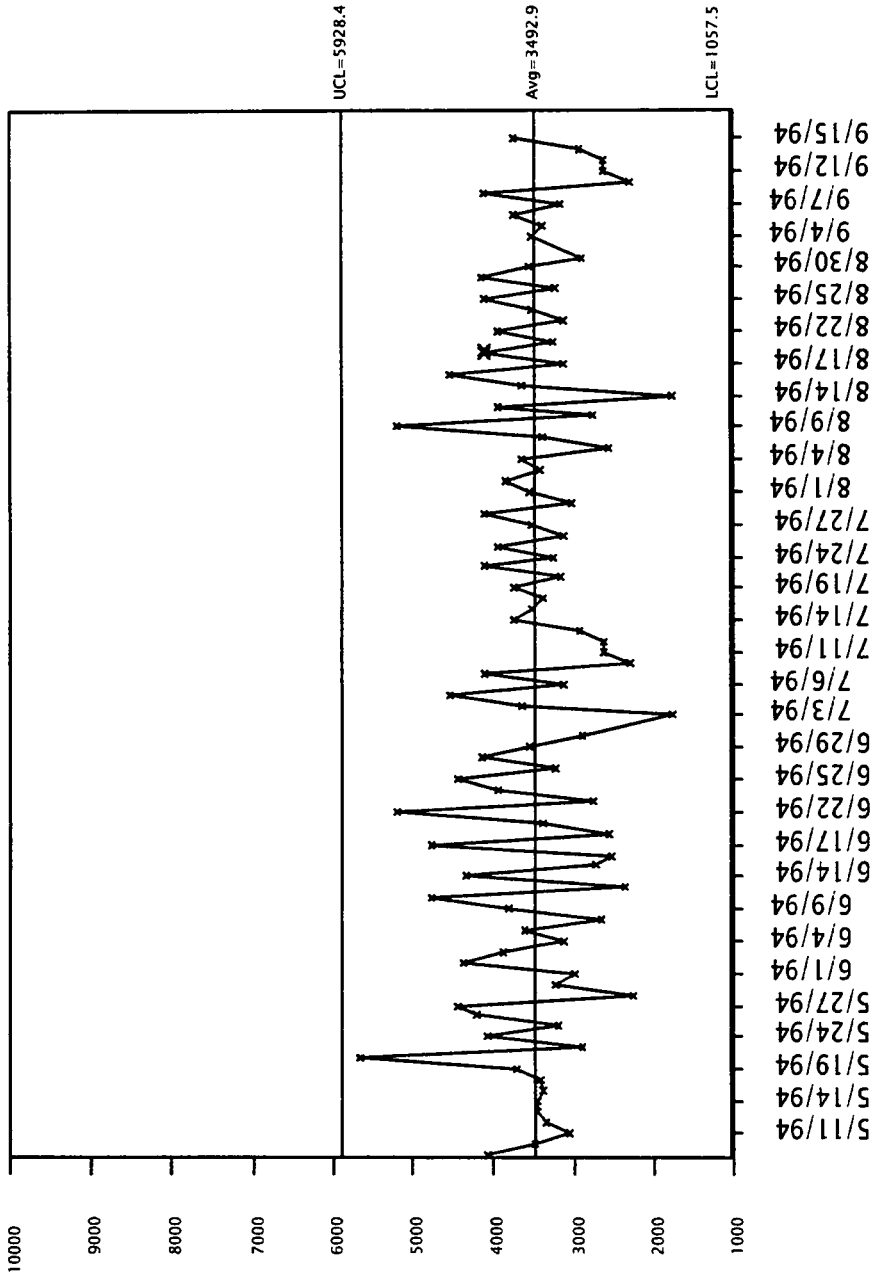


Figure 3: In Control Control Chart of Six Pack Pepsi Loadout Data in Cases

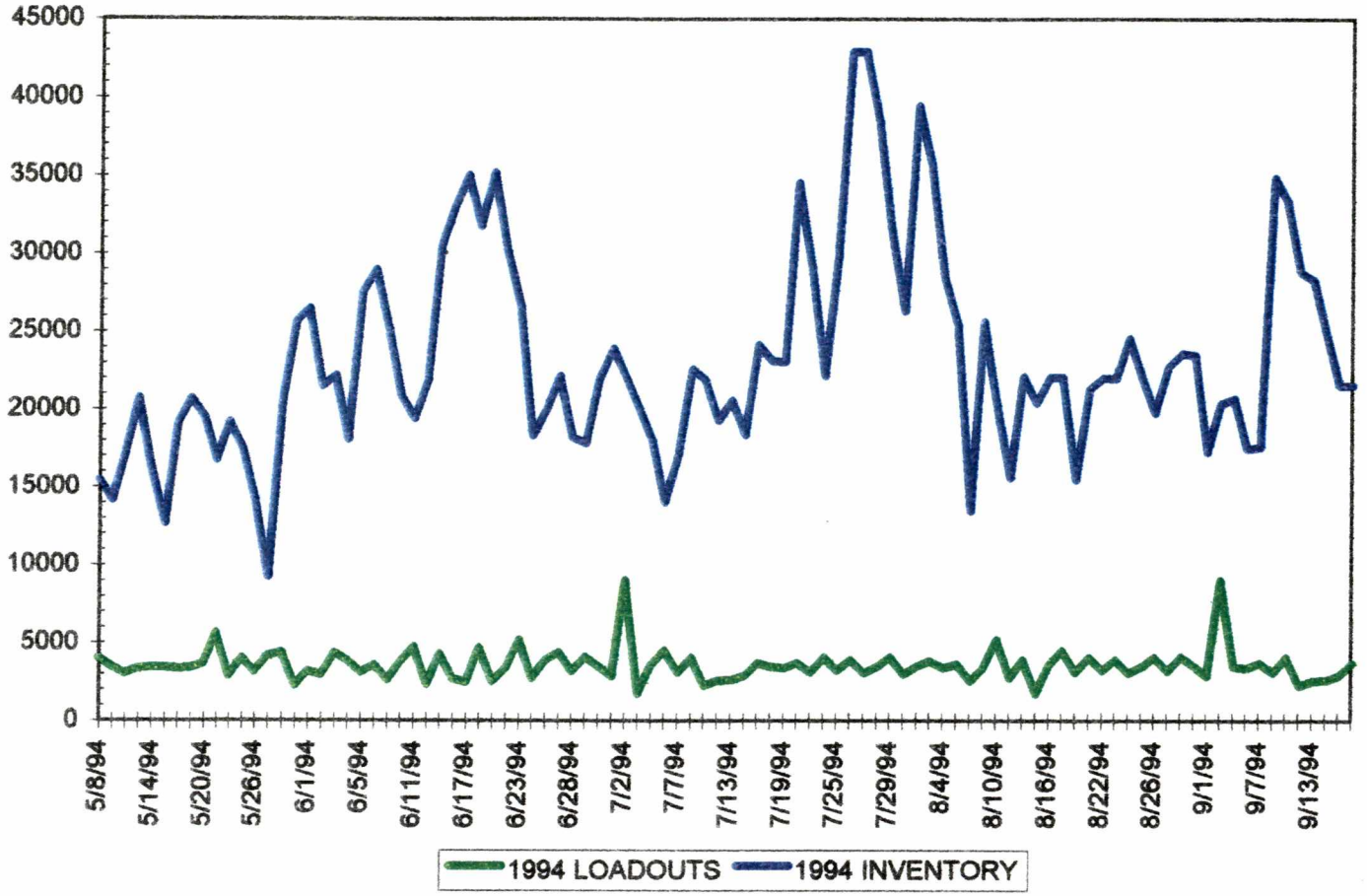


Figure 4: Six Pack Pepsi Inventory and Loadout Data in Cases

Table 2: 1995 Two Liter Production Statistics from the Production Facility

	Cases	**Flavors**
Maximum	19,619	6
Average	10,625	3
Median	11,279	3
Minimum	562	1

Table 3: 1995 Two Liter Production Summary by Flavor

FLAVOR	Pepsi	CF Pepsi	D Pepsi	DCF Pepsi	CH Pepsi	Pepsi XL	Mtn Dew	D Dew	Slice	D Slice	Or Slice	D Or Slice	Ale
FREQ	1.7	4.3	2.9	3.8	16.0	9.1	3.8	10.7	21.3	16.0	32.0	16.0	10.7
MAX	15093	3888	7127	3551	2746	1747	5316	1398	842	841	850	837	2443
AVERAGE	6856	2167	3431	2025	1970	1305	2596	1108	720	788	729	784	1851
MEDIAN	6360	2278	3519	1921	1918	1221	2684	1036	751	798	729	812	1629
MIN	572	1180	880	393	1299	1095	1133	954	568	715	608	676	1598
FLAVOR	D Ale	Ras Ale	D Ras Ale	Sunkist	AW RB	D AW RB	AW CRM	D AW CM	Tea	Ras Tea	Vernor's	D Vernor's	S Seltzer
FREQ	16.0	16.0	16.0		16.0	12.8	16.0	16.0	10.7	16.0			21.3
MAX	531	1058	517		2732	1840	1354	2225	1475	767			574
AVERAGE	497	760	480		2398	1477	1030	1665	1211	644			570
MEDIAN	514	763	497		2715	1369	949	1576	1288	608			570
MIN	428	457	411		1430	1009	869	1284	781	592			567

at the end of the distribution system tend to result in much larger swings in production and inventory levels. This is typically called pipeline whiplash and can be explained by the time lags in both information and product flow. This situation is further aggravated by basing a weekly production and distribution schedule on forecasted demand while using long, infrequent production runs. Further, both regional warehouse managers and production managers commented that as the number of products in the production and distribution system have increased over the years, the worse the highlighted problems have become.

CHAPTER 5:

SIMULATION OF AN ALTERNATIVE PRODUCTION AND DISTRIBUTION SYSTEM

The Ideal Pull Production System

Theoretically, pull production systems allow the final consumer to trigger the production of more goods in the system. In the soft drink industry this would literally mean a bottle of soft drink is produced only when one is sold to a customer. In reality, however, this rarely happens. Currently in the soft drink industry product is produced and "pushed" into the market ahead of consumer demand. This is very typical, especially during holidays or heavy promotional periods.

The Pull Production System Used at the Two Companies

Neither of the two companies currently has access to actual retail sales on a timely basis. However, both do have timely access to daily regional warehouse truck loadout data. This means that each day the goal of the production and distribution system should be to produce and place back on the individual regional warehouse's floor as much as possible of what was loaded on the trucks the night before. Therefore, an ideal daily production and schedule for each individual product would look like the following:

$$\text{Production} = \sum_{\text{Warehouses}} \text{MAX}(0,\ \text{Target Inventory Level} - \text{Yesterday's Ending Inventory})$$

where at each warehouse,

Yesterday's Ending Inventory =

Yesterday's Beginning Inventory - All Loadouts + Yesterday's Shipments Received

and

Target Inventory Level =

Desired Day's supply to be Kept * Exponentially Smoothed Aggregate Daily Loadouts

Theoretically, the target inventory level for each product at each regional warehouse should be the least amount of inventory needed to meet one days worth of expected aggregate loadout. Control charts of aggregate daily regional warehouse loadouts by individual product were constructed to determine this amount. Regardless of the product size or flavor, the vast majority of charts had an upper control limit equal to roughly two times the average aggregate daily loadout. This meant that if every product could be produced and distributed every day to each regional warehouse, the ideal target inventory level for each regional warehouse (or amount of product needed to cover daily aggregate loadouts 99.9% of the time) would be equal to approximately twice the average aggregate daily loadout. To track the average aggregate daily loadout, an exponential smoothing model was employed with a conservative smoothing factor. This model allowed for the figure used as the "average" to rise and fall with seasonal trends in aggregate product loadout.

The Results of Some Initial One Product Simulations

Using a scenario of a single production facility producing and distributing only one product to a number of regional warehouses highlighted how dramatic an improvement there could be in warehouse inventory levels. The aim of these simulations was to produce and distribute a single product and see what effect changing certain production parameters would have on the magnitude and variability of regional warehouse inventory levels and other performance measures. For example, at one company, two products were chosen for this type of simulation. One product, two liter Pepsi, has a high volume of sales relative to the other, two liter Diet Orange Slice. A spreadsheet program was used to simulate several scenarios for several weeks of production. Each scenario had the option of manipulating the the following parameters:

- **Target inventory level** - measured in day's supply, this equals average aggregate daily loadouts times the number of days inventory to be held on the warehouse floor. In the simulations the values ranged from 2.5 to 7.5 day's supply.
- **Run size** - the limiting factor to the size of a run of soft drink is the amount of concentrate that must be mixed to make a run. An unlimited run size of one case or more and a positive integer multiple of the minimum batch size, in cases, was used.
- **Run frequency** - different plants choose to operate on certain days of the week. Two scenarios were used. Neither used Sunday as a normal production day. One scenario used all other available days of the week, while the other used all other available days except Wednesday and Saturday.

- **Lead time** - how long does it take from when the loadouts are recorded until they are replenished. This is largely a function of the time it takes to procure the necessary raw materials and the time it takes to transfer the product from the production facility to a regional warehouse. Two days and one day were used in the simulations.

It was decided that one simulation would be judged better than another if it lead to smaller, less variable inventory levels, while avoiding a stockout of product. For the first four simulations, the target inventory level was set as low as possible without causing a stockout after the other parameters were fixed. For the fifth simulation, the target inventory level was set at the theoretical minimum based on a control charts of loadouts.

One quarter's worth of historical aggregate regional warehouse loadout data was used in the simulations. For each of the five scenarios inventory levels and production decisions were recorded and relevant statistics were computed. Figures 5 - 10 and Tables 4 and 5 summarize the results of the simulations. The formulas described earlier were used to determine the daily production quantities of each product. For reference, the historical inventory levels are also included.

On each chart, the green line represents the daily aggregate loadouts (simply called sales). The inventory that was left on the warehouse floor at the end of each simulated day is represented by the red line. The target inventory level is represented by the dashed black line. The solid black line represents the exponential smooth of the loadouts. The dark blue line represents the actual inventory from the same period as the daily aggregate loadouts. Finally, a blue dot represents the amount of a day's production.

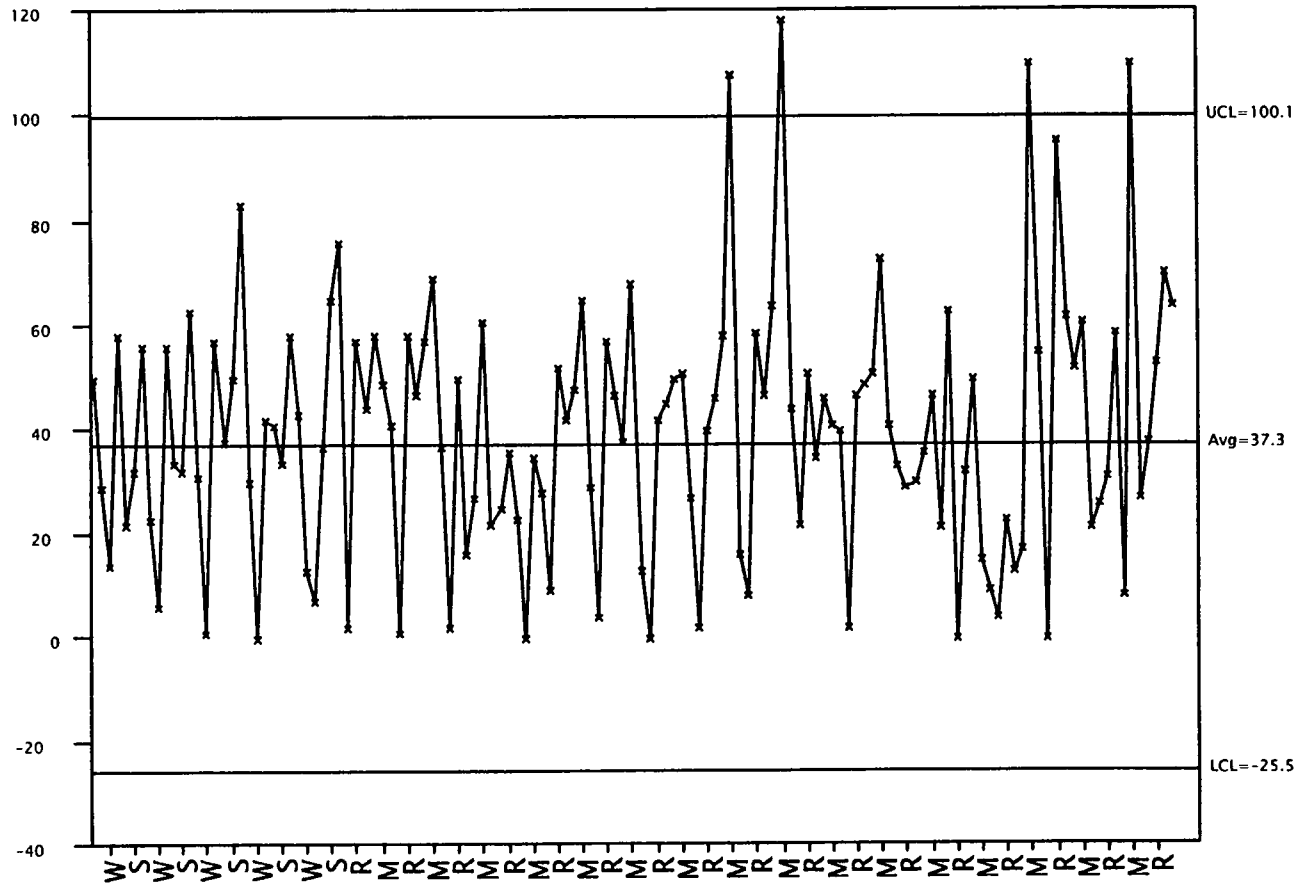


Figure 5: Control Chart of Two Liter Diet Orange Slice Loadout Data in Cases with Out-of-Control Points

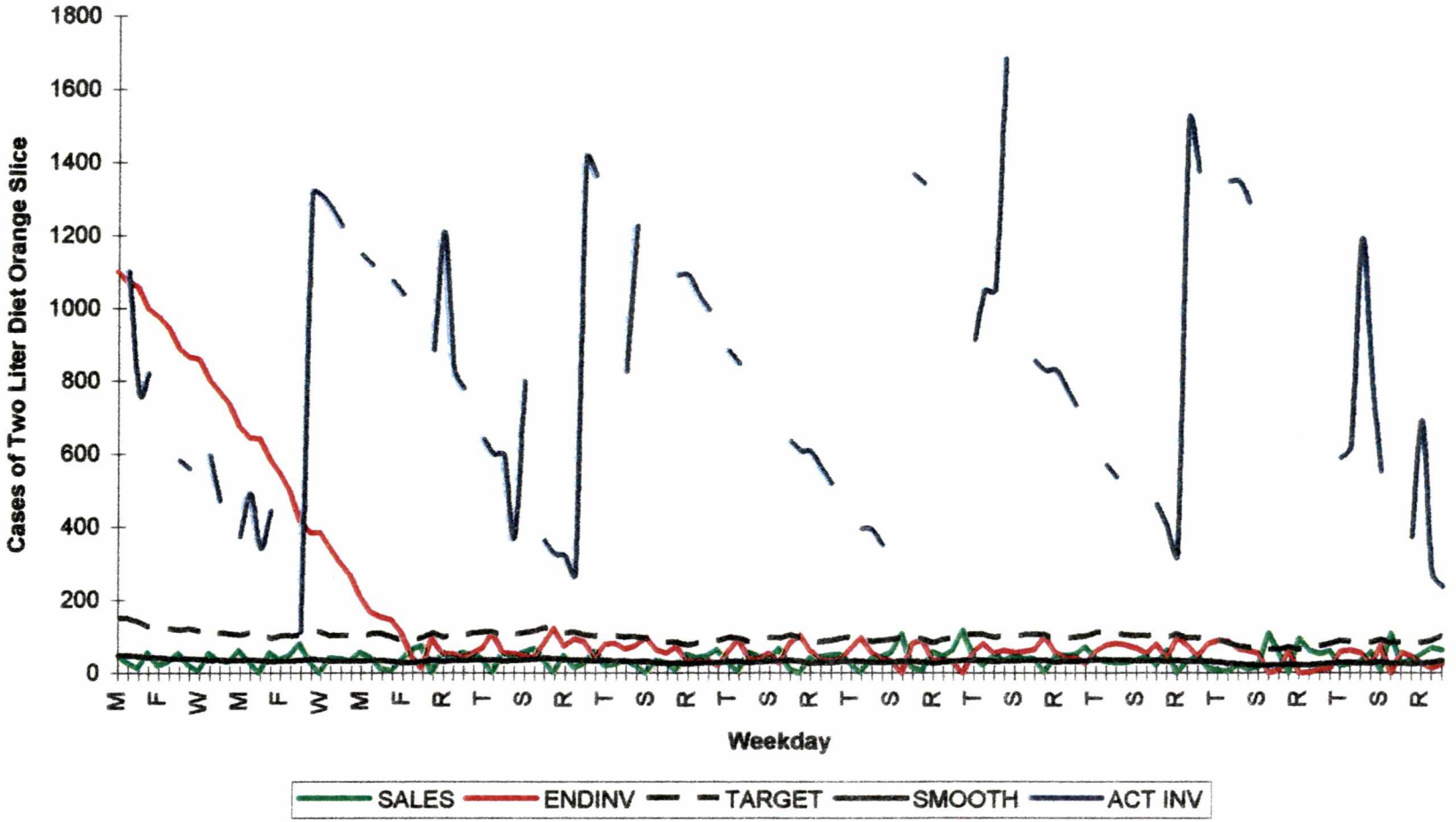


Figure 6: Two Liter Diet Orange Slice Simulation - Scenario 5

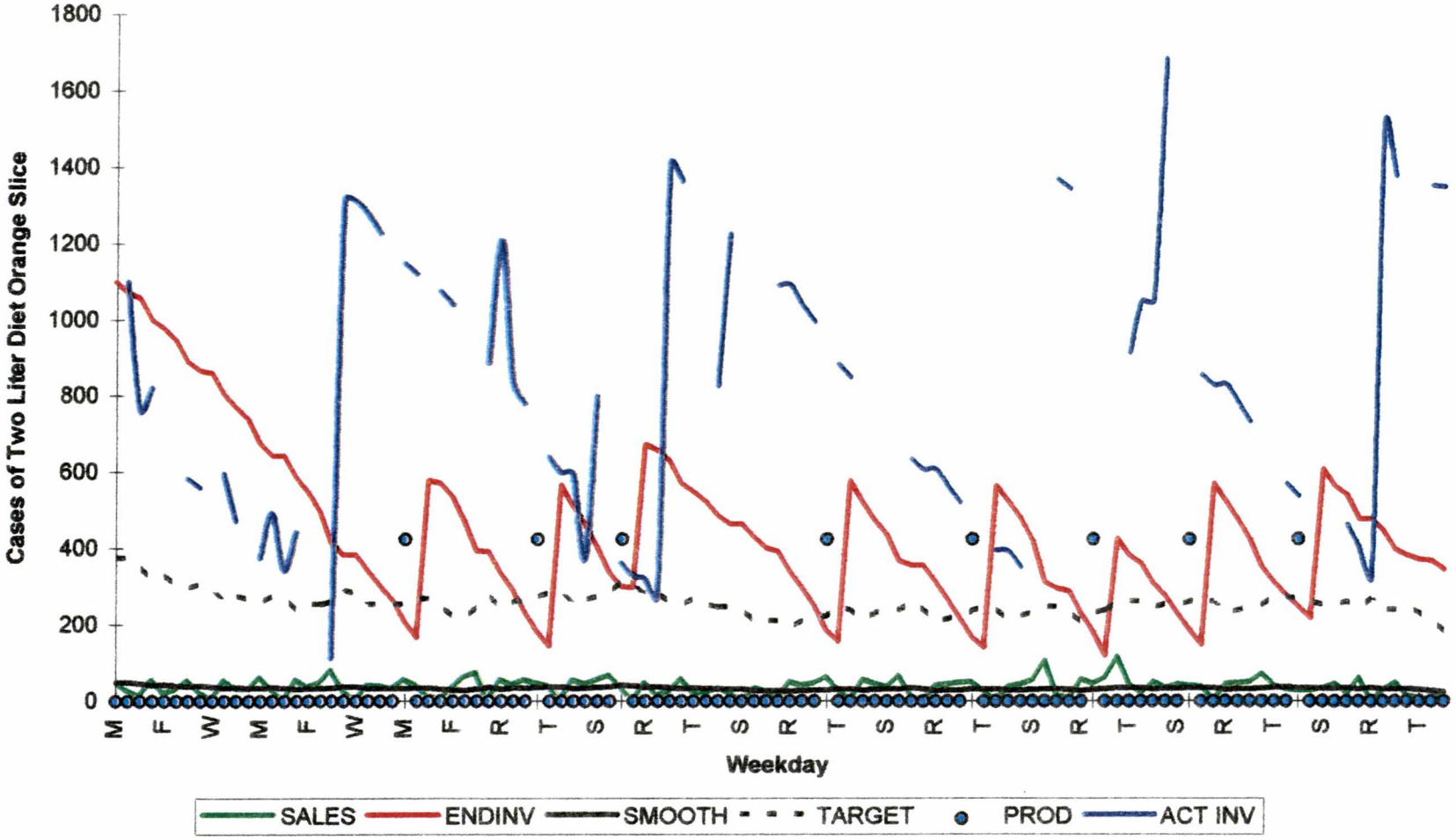


Figure 7: Two Liter Diet Orange Slice Simulation - Scenario 1

Table 4: Two Liter Diet Orange Slice Simulation Summary

ASSUMPTIONS- **Using 1994 Data**	**Sim #1**	**Sim #2**	**Sim #3**	**Sim #4**	**Sim #5**	
Alpha	0.1	0.1	0.1	0.1	0.1	
Target Inventory Level	7.5	7.5	4.0	3.5	3.0	day's supply
Run Size	426	426	426	426	1	case(s)
2 Day Lead Time	Yes	Yes	No	No	No	
No Production on Wed & Sat	Yes	No	Yes	No	No	
RESULTS- Inventory						
Actual Inventory Max	29754	29754	29754	29754	29754	cases
Actual Inventory Min	2986	2986	2986	2986	2986	cases
Range Actual Inventory	26768	26768	26768	26768	26768	cases
Simulated Inventory Max	726	726	571	550	126	cases
Simulated Inventory Min	52	52	120	111	63	cases
Range Simulated Inventory	674	674	451	439	63	cases
Actual Inventory Variance	135991	135991	135991	135991	135991	$cases^2$
Sim Inventory Variance	19280	19030	15208	14770	169	$cases^2$
Sales Variance	642	642	642	642	642	$cases^2$
Act Inv/Sales Var Ratio	211.82	211.82	211.82	211.82	211.82	
Sim Inv/Sales Var Ratio	30.03	29.64	23.69	23.01	0.26	
Median Sales	41	41	41	41	41	cases
Actual Median Inventory	796	796	796	796	796	cases
	20.58	20.58	20.58	20.58	20.58	day's supply
Simulated Median Inventory	394	400	338	316	98	cases
	10.38	10.74	8.69	8.15	2.48	day's supply
Inventory Reduction	402	396	458	481	698	cases
	51%	50%	58%	60%	88%	
RESULTS - Run Size						
Median Run	0	0	0	0	42	cases
Run Variance	14344	14344	14344	16175	535	$cases^2$
Run/Sales Var Ratio	22.34	22.34	22.34	25.19	0.83	
RESULTS - Stockouts & Out of Control Points						
Stockouts	0	0	0	0	5	day(s)
OOC points	4	4	4	4	4	day(s)

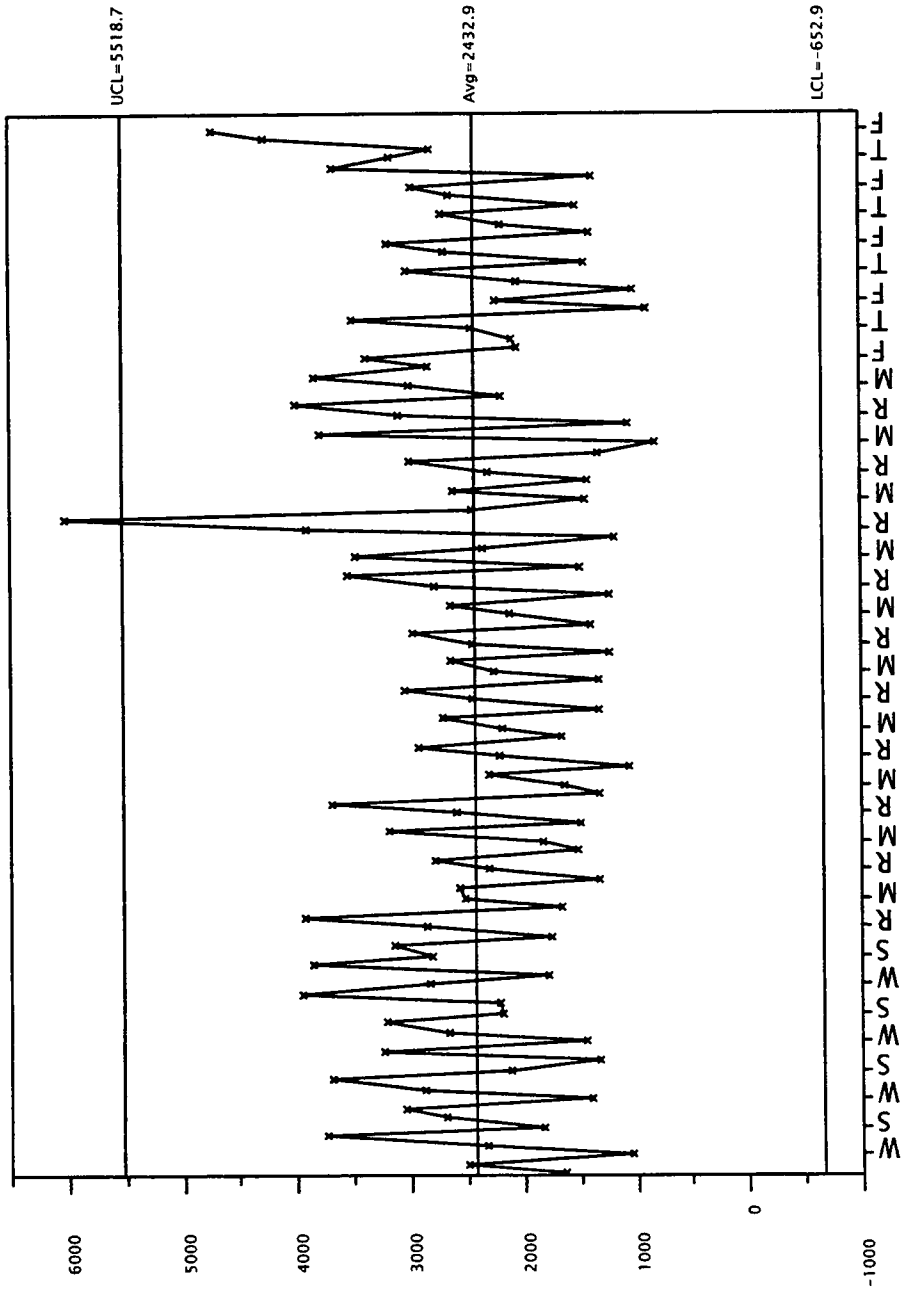


Figure 8: Control Chart of Two Liter Pepsi Loadout Data in Cases with Out-of-Control Point

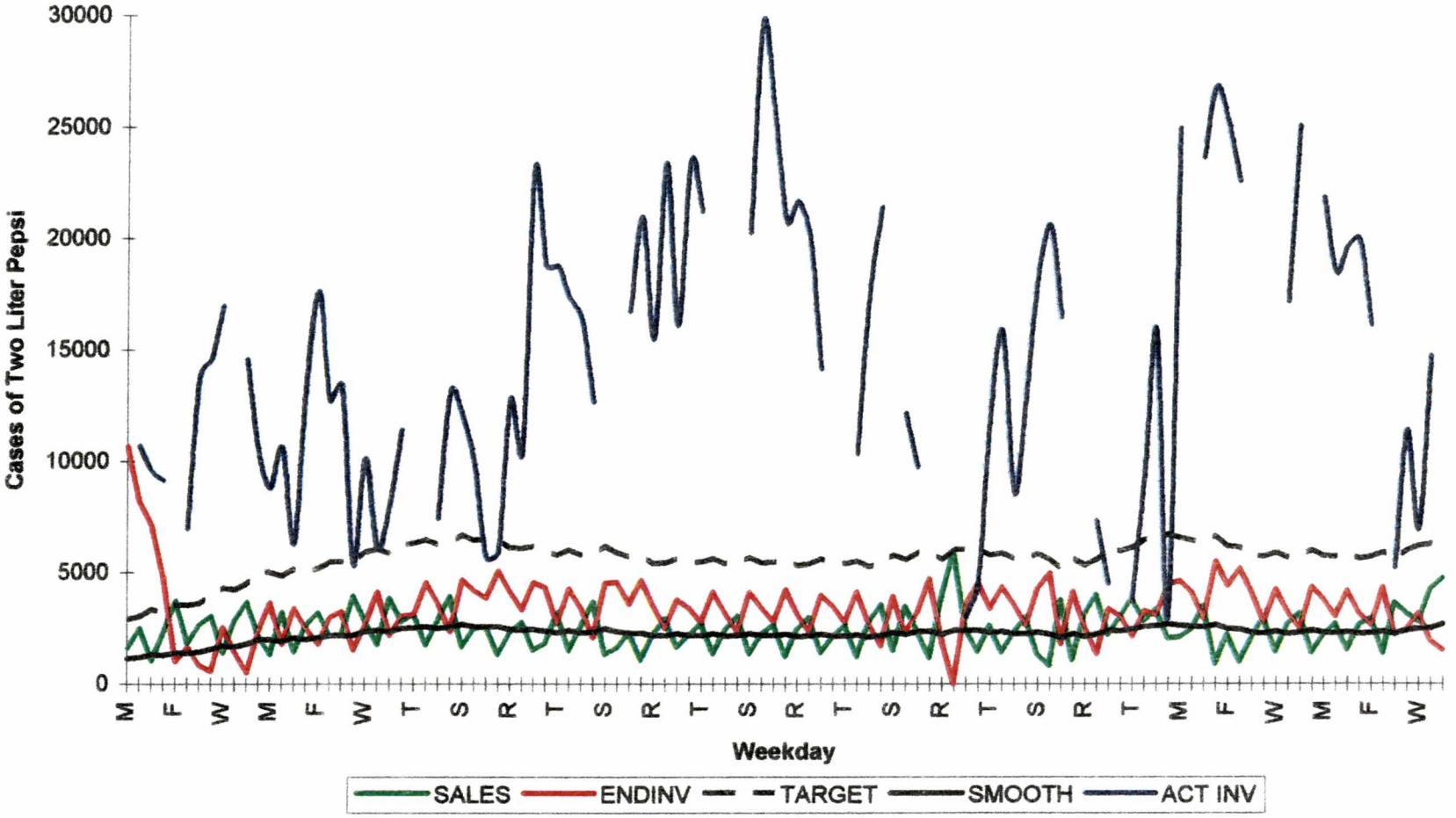


Figure 9: Two Liter Pepsi Simulation - Scenario 5

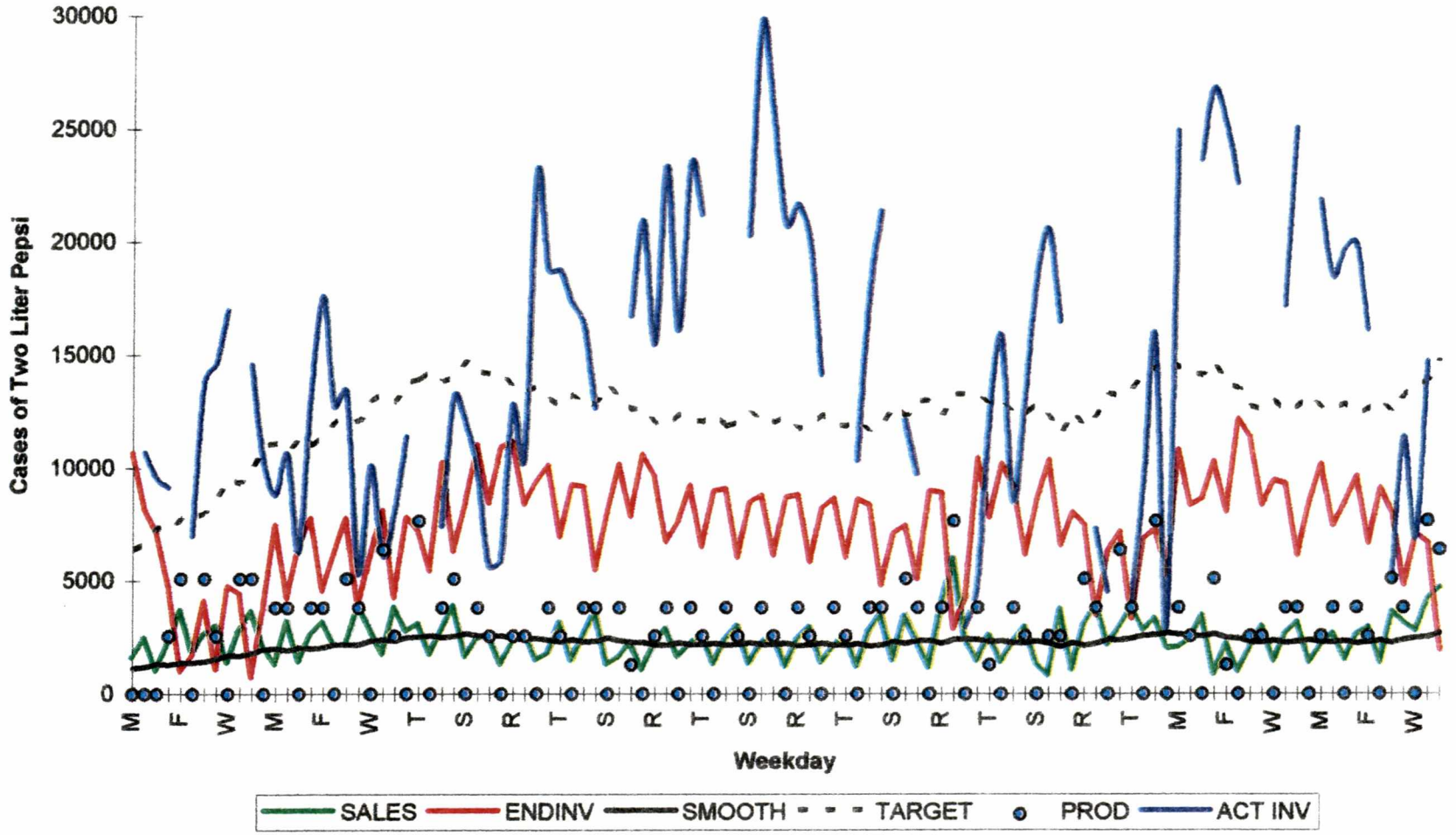


Figure 10: Two Liter Pepsi Simulation - Scenario 1

Table 5: Two Liter Pepsi Simulation Summary

ASSUMPTIONS- Using 1994 Data	**Sim #1**	**Sim #2**	**Sim #3**	**Sim #4**	**Sim #5**	
Alpha	0.1	0.1	0.1	0.1	0.1	
Target Inventory Level	5.5	4.0	3.0	2.5	2.5	day's supply
Run Size	1278	1278	1278	1278	1	case(s)
2 Day Lead Time	Yes	Yes	No	No	No	
No Production on Wed & Sat	Yes	No	Yes	No	No	
RESULTS- Inventory						
Actual Inventory Max	29754	29754	29754	29754	29754	cases
Actual Inventory Min	2986	2986	2986	2986	2986	cases
Range Actual Inventory	26768	26768	26768	26768	26768	cases
Simulated Inventory Max	13603	10348	9070	7845	6755	cases
Simulated Inventory Min	3595	2317	3024	3595	3545	cases
Range Simulated Inventory	10008	8031	6046	4250	3210	cases
Actual Inventory Variance	40847	40847	40847	40847	40847	$cases^2 / 10^3$
Sim Inventory Variance	4148406	2589162	1833197	1087875	1055979	$cases^2$
Sales Variance	883595	883595	883595	883595	883595	$cases^2$
Act Inv/Sales Var Ratio	46.23	46.23	46.23	46.23	46.23	
Sim Inv/Sales Var Ratio	4.69	2.93	2.07	1.23	1.20	
Median Sales	2459	2459	2459	2459	2459	cases
Actual Median Inventory	13990	13990	13990	13990	13990	cases
	5.69	5.69	5.69	5.69	5.69	day's supply
Simulated Median Inventory	10176	7522	7213	6464	5792	cases
	4.14	3.06	2.93	2.63	2.36	day's supply
Inventory Reduction	3814	6468	6777	7526	8198	cases
	27%	46%	48%	54%	59%	
RESULTS - Run Size						
Median Run	2556	2556	2556	2556	2402	cases
Run Variance	4762876	1607601	4274897	1227973	1058653	$cases^2$
Run/Sales Var Ratio	5.39	1.82	4.84	1.39	1.20	
RESULTS - Stockouts & Out of Control Points						
Stockouts	0	0	0	0	1	day(s)
OOC points	1	1	1	1	1	day(s)

Discussion

For both products, the same five scenarios were used. Simulation one most closely represented the way both companies operated before the implementation of pull production- fixed run size, two day lead time, and no production on Wednesday and Saturday. Simulation two differed from simulation one by allowing production six days a week. Simulation three differed from simulation one by assuming a one day lead time instead of two. Simulation four differed from simulation one by assuming both a one day lead time and production six days a week. Simulation five represented the theoretical pull system- totally variable run size, one day lead time, and production six days a week. As the simulations progress from the first to the fifth, they more closely resemble a pull production system. As a general rule, the more closely a simulation resembled a pull system, the better the chosen performance measures became. The only time stockouts occurred were during the fifth simulation. This corresponded to times when the aggregate loadout was unusually large, normally corresponding to an out-of-control point on a control chart. Situations like this are more than likely predictable. In each case, product would have to be pushed into the warehouse in anticipation of loadouts in order to avoid stockouts.

Each simulation highlighted points unique to each product, as well. The Diet Orange Slice simulations indicated that a huge amount of inventory was currently being held relative to loadout volume. From the charts it appears as if the company held nearly 1700 cases of product at one time or about one and a half month's worth of product.

Also, judging from the way the historical inventory spikes, the product was produced in a large run relative to its loadout volume. These simulations indicated the absurdity of producing a relatively large amount of product at one time and then occupying warehouse space with it. More subtly, however, simulation three indicated that by simply producing the minimum batch size the production scheduler could watch the daily inventory level gradually approach the conservatively set target inventory level. The approach of the inventory level towards the target would then trigger the production of more product. The simulations clearly indicated it was possible to schedule production based upon actual loadouts instead of a forecast or budget.

The Pepsi simulations again pointed out that a large amount of inventory (one to two week's worth) was being held relative to loadout volume. It also pointed out that production could be scheduled using loadout data. Further, since Pepsi is a product which is used in many packages across many lines, it is possible to schedule a run which is to the case what was loaded yesterday. Simulation five pointed out that, in theory, this would work.

Conclusion

These initial simulations were significant because they gave a first indication about the potential for improvement using a pull production system. For both products, the more often it was produced with smaller production runs and less lead time, the better the simulated inventory level data. In the end, senior managers at both the

companies decided that something close to scenario three was most likely what they would follow in an actual implementation. They thought that it was realistic to acquire the raw materials and put the product back on the warehouse floor within one day. However, they chose not to produce every day of the week and to limit run sizes to multiples of existing batch sizes. At the time this was viewed as a good compromise between the old mass production system and rules they were following and a pure pull system.

After considering the preliminary data analysis (as outlined in Chapter 1) and the simulations just described, there was a major mental shift in the senior management teams at both companies. Initially both teams were doubtful that a system which utilized real-time route truck loadout data in order to make daily production schedules would succeed. Too many times managers at both facilities had been caught off guard by large promotions. Further, both management teams had watched years of large fluctuations in warehouse inventory and assumed that unstable and unpredictable sales were the cause. Now, for the first time, there was a recognition that the production schedules and distribution plans based upon timely route truck loadout data might work.

CHAPTER 6:

RUNNING BOTH PRODUCTION AND DISTRIBUTION SYSTEMS IN PARALLEL

Introduction

Although they were limited in scope, the simulations presented in the last chapter gave a good initial indication of the impact of a pull production system. Based on these simulations, a fully operational pull production and distribution system software package was designed using a popular spreadsheet package. This software was tested and refined over a period of months at both companies. The testing was conducted by running the pull system parallel to the production and distribution system software currently in use by both companies. By using the pull scheduling software to make simulated daily schedules for production and distribution, a more accurate estimate of the potential of the pull production system could be made. Further, during the testing phase, there were many issues which surfaced with which management would have to deal before an actual implementation would be possible.

The management teams at both companies decided it would be best to test the new system on all the products produced on a single line. Both teams chose two liter, one liter, and ten ounce products for several reasons. Most importantly, this group of products was one for which they thought the loadout data would be the most stable and predictable over time. The raw materials were judged easiest to acquire since the containers came in only two colors, clear and green. Label storage was not a problem

since a large amount could be stored in a relatively small space. Further, the designs on the labels of these packages changed infrequently. Finally, the packages were relatively easy to produce. Since the packages were labeled after being filled, the crucial raw materials sourcing question each day would simply be how many clear bottles and how many green bottles were needed and in what size.

Scheduling Production and Distribution Using The Pull Software Package: Daily Activities

The pull production process has five steps which are repeated daily:

1. Gather Yesterday's Loadout and Yesterday's Actual Production and Shipping Data and Enter into Scheduling Program
2. Create an Ideal Pull Schedule for Tomorrow Based Upon Those Loadouts
3. Modify the Schedule Based Upon Manufacturing Constraints and Promotions
4. Schedule Shipment of Products to Warehouses
5. Monitor Inventory of Raw Materials and Place Orders

Scheduling Production and Distribution Using The Pull Software Package: Weekly Activities

At the beginning of each production week, it was necessary to get a floor count of all inventory in the regional warehouses. Also, towards the middle of the production week, it was necessary to make a best guess at what production would look like for the

upcoming week. This was accomplished by replacing each day's actual aggregate regional warehouse loadout data with the daily average and then scheduling each day's production for the upcoming week. The projected schedule was then used for ordering raw materials and concentrate and as a preliminary guide for production personnel who were accustomed to a weekly schedule which did not change.

Example of a Daily Production Schedule

After entering the previous night's loadouts into the program, the program generates a list of products grouped in columns by package and ordered within the columns by day's supply. An example of what is called a priority sheet is contained in Figure 11 . This sheet is used to make production decisions. The first column contains the name of the products available for production. The next two columns contain the day's supply of the product at each warehouse. The next column contains a number which indicates how far below or above the inventory target the warehouses are. If one warehouse is over its target and one is under, the program indicates how far under its target the one warehouse is. For example, the number -2.69 indicates that the worst warehouse is about two and a half day's supply below its target. If both warehouses are over or under the target, the column indicates an appropriately weighted combined day's supply figure. The next column is the actual number of cases corresponding to the day's supply in the previous column. The next two columns were not used on this printout.

After generating the priority list, the production scheduler then uses this

MONDAY'S PRIORITY SHEET						
2 LITER	2 LITER	2 LITER	2 LITER	2 LITER	2 LITER	2 LITER
	<====== Dayssupply ======>			<======== Cases =======>		
Flavor	Whse 1	Whse 2	Pure Pull	Pure Pull	Rec Prod	Act Prod
Mtn Dew	6.73	1.31	-2.69	-777		
DT AW R	1.40	1.35	-2.63	-208		
DT Pepsi	1.80	2.70	-1.64	-1480		
AW RB	2.56	4.58	-1.44	-56		
Pepsi	3.20	3.18	-0.81	-2294		
CF Pepsi	7.69	3.40	-0.60	-162		
DT AW C	3.52	4.04	-0.48	-13		
AW CRM	6.75	4.00	0.83	44		
DCF Pepsi	8.07	4.15	1.61	779		
DT Dew	7.10	4.77	1.73	168		
DT Rasp	6.54	5.38	1.82	62		
DT Or Slic	8.15	4.52	1.94	99		
DT Tea	10.57	4.21	2.06	99		
Ale	8.13	7.22	3.51	509		
Vernor's	12.37	6.86	5.09	239		
DT Ale	9.91	10.65	6.39	198		
Tea	11.54	9.87	6.44	451		
DT Slice	11.09	13.20	8.31	216		
Rasp Tea	21.23	7.68	8.71	305		
Or Slice	15.92	13.89	10.70	321		
CH Pepsi	18.71	14.35	11.89	1046		
DT Vernor'	24.53	15.04	14.79	562		
Rasp Ale	25.92	18.05	16.97	594		
Slice	34.00	14.69	17.45	349		
Sunkist	12.50	36.44	20.71	1015		
S Seltzer	28.56	22.63	20.76	519		
D CH Pep	131.25	6.00	47.55	523		

Figure 11: Example of a Computer Generated Production Priority Sheet

information to generate tomorrow's production schedule. A screen similar to Figure 12 is used to make production decisions. The order of products on the screen was chosen by the scheduler and remains constant across the week. The next four columns are the same as they were on the priority sheet. The sixth column contains a recommended production number, if a product was to be chosen for production that day. It is the smallest allowable run which will bring the inventory level of the product at all of the regional warehouses past their individual target inventory levels. The next column shows the actual amount the scheduler chose to produce on this particular day. The next column shows the number of units of concentrate the scheduled production will require. The final column shows the new day's supply the production would generate across all the regional warehouses.

The cell at the bottom of the page to the right of the label "Pull Cs" indicates the number of cases an unconstrained pull schedule would produce. The cell to the right of the label "Pull Flvs" indicates the number of flavors the same schedule would produce. The cell above the label "Rec Cs" is the total number of cases a batch-size constrained pull schedule would produce. The cell to the left of the label "Cs Prod" is the actual number of cases the scheduler chose to produce. The cell to the left of the label "Flvs Prod" indicates the number of flavors the scheduler chose to produce.

After making production decisions, the scheduler must then make shipping decisions for each warehouse for each product produced. At this point, the scheduler is trying to spread the day's production evenly between the two regional warehouses.

MONDAY'S PRODUCTION DECISIONS								
2 LITER	2 LITER	2 LITER	2 LITER	2 LITER	2 LITER	2 LITER	2 LITER	
	<====== Dayssupply ======>			<======== Cases ========>				
Flavor	Whse 1	Whse 2	Pure Pull	Pure Pull	Rec Prod	Act Prod	Units	New DS
Pepsi	3.20	3.18	-0.81	-2294	2556	4723	3.70	4.86
CF Pepsi	7.69	3.40	-0.60	-162	639	1296	1.01	8.05
DT Pepsi	1.80	2.70	-1.64	-1480	1917	2531	1.98	5.16
DCF Peps	8.07	4.15	1.61	779	639	1250	0.98	8.18
CH Pepsi	18.71	14.35	11.89	1046	0		0.00	15.89
D CH Pep	131.25	6.00	47.55	523	0		0.00	51.55
Mtn Dew	6.73	1.31	-2.69	-777	852	1324	6.22	6.27
DT Dew	7.10	4.77	1.73	168	0		0.00	5.73
Slice	34.00	14.69	17.45	349	0		0.00	21.45
DT Slice	11.09	13.20	8.31	216	0		0.00	12.31
Or Slice	15.92	13.89	10.70	321	0		0.00	14.70
DT Or Slic	8.15	4.52	1.94	99	0		0.00	5.94
Ale	8.13	7.22	3.51	509	0		0.00	7.51
DT Ale	9.91	10.65	6.39	198	0		0.00	10.39
Rasp Ale	25.92	18.05	16.97	594	0		0.00	20.97
DT Rasp	6.54	5.38	1.82	62	0		0.00	5.82
Sunkist	12.50	36.44	20.71	1015	0		0.00	24.71
AW RB	2.56	4.58	-1.44	-56	455	1219	13.40	15.87
DT AW R	1.40	1.35	-2.63	-208	455	879	9.66	12.49
AW CRM	6.75	4.00	0.83	44	0		0.00	4.83
DT AW C	3.52	4.04	-0.48	-13	455	1356	14.90	20.60
Tea	11.54	9.87	6.44	451	0		0.00	10.44
Rasp Tea	21.23	7.68	8.71	305	0		0.00	12.71
DT Tea	10.57	4.21	2.06	99	0		0.00	6.06
Vernor's	12.37	6.86	5.09	239	0		0.00	9.09
DT Vernor	24.53	15.04	14.79	562	0		0.00	18.79
S Seltzer	28.56	22.63	20.76	519	0		0.00	24.76
			Pull Cs	5062	7968	14578	Cs Prod	
			Pull Flvs	16	Rec Cs	8	Flvs Prod	

Figure 12: Example of a Computer Generated Production Scheduling Sheet

Figure 13 contains an example of the screen used to facilitate the shipping decisions. The first column contains the name of the product to be shipped and all the regional warehouses to which it can be shipped. The next column contains the current inventory level at both regional warehouses and the size of the production run. The next column contains the average of the aggregate daily loadout from each of the warehouses. (This is the same value that is used to set the target inventory level.) The next column contains the current day's supply at both warehouses. This is calculated by dividing the current inventory by the average aggregate daily loadout. The next column contains a recommended shipping amount. This is the amount of product which will bring each regional warehouse to the same day's supply. (Since soft drinks must be shipped on pallets, the number is rounded to the nearest pallet.) The next two columns are filled by the scheduler. They contain the amount of product which will be shipped to the warehouses the same day as production or the next day. It was necessary to have this option, as sometimes product produced on one day would not be available for loading until the next. The final column reports the new day's supply of soft drinks at each regional warehouse based upon actual shipments.

Discussion

Running both systems in parallel bolstered the case even further for the use of the new system. At both companies the results of the preliminary simulations were confirmed during this test period. It was indeed possible to schedule production and

MONDAY'S 2 LITER SHIPPING DECISIONS									
Cases/Pallet =====>		50							
Pepsi	CUR INV	AVG SLS	DAYSSUP	TOT SHIP	**MON CS**	**TUE CS**	NEW DS		
Whse 1	3308	1035	3.2	1700	1723		4.9		
Whse 2	5702	1791	3.2	3000	3000		4.9		
Production	4723	Difference from Production ==>			0				
						Pepsi			

Figure 13: Example of a Computer Generated Shipping Sheet

distribution for an entire line using route truck loadout data. Further, the reduction in inventory and avoidance of stockouts were both verified. These simulations indicated that total inventory and production run sizes could be reduced by approximately 50%. Further, they indicated that the frequency of production runs for individual products would approximately double.

Working with the production and distribution scheduler and other key personnel on a daily basis during the test period, the author was able to assist senior management in highlighting many areas in the operation of both companies which were potential areas for process improvement. One major area was data acquisition. There were initial problems acquiring accurate regional warehouse inventory levels and route truck loadout data. Typically, inventories were only physically counted once a week. The rest of the week, rolling figures based upon loadouts and shipments from the production facility were used. While it would have been ideal to have had an accurate inventory count daily before producing a schedule, this was deemed impossible. Therefore, there was an effort made to make the weekly counts as accurate as possible.

In turn, this meant that rolling inventory figures (updated once a week with actual inventory counts) would have to be used when making daily production schedules. Because the rolling figures would depend upon accurate shipment and loadout data, acquisition of that data became an area of concern. Exceptional efforts were needed to make these numbers as accurate as possible. This meant that each day shipments to regional warehouses had to be verified. It also meant that timely, accurate daily loadout

data became crucial. Because the loadout data had previously been used for monthly loadout volume reports and salesmen bonus computations, there had to be a special effort made to get accurate loadout data on a daily basis. Traditionally, the daily loadout data went through a settlement process which could take anywhere from one day to a week after a driver completed a day's sales on a route. After analyzing the current system, which was essentially the same at both companies, it was decided that preliminary loadout data from that day's sales would be used in making the next day's production schedule. Then, after the loadout data was settled it would replace the potentially less accurate data in the program.

However, this was not the end of the effort needed to acquire timely loadout data. Since the loadout data was previously needed only on a monthly basis, this meant that physically getting the data once it was collected proved to be another challenge. Each sales day, the loadout data was downloaded from individual routes to a mainframe system. There, the loadout data stayed in holding until it could be settled. Once settled, it was complied into a monthly report. Since the data was needed on a daily basis as soon as all the route trucks for a particular regional warehouse had finished their routes, more changes in data handling needed to be made. The mainframe computer program which collected the data from the regional warehouses needed to run soon after all the route trucks completed their routes. Also once completed, access to the data needed to be timely. This required a priority status be given to data which previously did not have such status.

In other areas of operation, there were major changes which needed to be made, as well. The blending of ingredients to make syrup was the most notable. Under the previous scheduling system, the personnel in charge of syrup production knew at least three days in advance the blends for which they were responsible for an entire week. Initially under the new system, the blending personnel found out the night before which blends would be needed the next morning. This was a major problem. In some instances the turnaround time for some blends was more than the allotted time to prepare the blend. As mentioned earlier in the chapter, this made it necessary to compile a projected schedule for an entire upcoming week.

The projected schedule became useful in other areas, as well. The personnel who actually worked the production line felt more secure having some idea which products would be produced on which day for an upcoming week. The projected schedule was also a useful tool when explaining the new scheduling system to suppliers. Almost all suppliers were willing to incorporate the preliminary schedule into their production schedules and then adjust accordingly as the week actually progressed.

In some respects the easiest part leading to an actual implementation has just been mentioned. Showing historical data to senior managers, making daily production schedules off-line while the old system ran, and compiling the results were relatively easy. The hardest part was educating personnel from almost every facet of the organization about the reasons behind the change to a new way of producing and distributing product. When showed groups of preliminary schedules, blending personnel

questioned the need to produce product more frequently and in smaller quantities than had been done in the past. Even during the actual implementation there were several comments like the following: "We just produced that yesterday!", "Why are we producing it AGAIN today?", and "Can't we just combine the both runs into one large one and get it over with?". Personnel on the production line shared the same sentiments. When showed groups of preliminary schedules, they were concerned with the frequency of changeovers between both flavors and products. Many of the volume-based performance measures upon which they had relied for many years were going to reflect the changes negatively. Sales personnel were probably the hardest to educate. At both companies they were used to submitting monthly sales estimates or completing analyses of market conditions and promotions which lead to weekly sales estimates. They were very comfortable being able to walk into a warehouse at the beginning of a month or a week and see a huge pile of inventory waiting to be sold. Conversely, one group which did see a distinct advantage to using the new system were the regional warehouse managers. All too many times they had been caught without the product they needed or with product they didn't need. Most had spent unproductive time moving product around the warehouse to make room for more or shipping product to a sister warehouse. The notion of placing back onto the warehouse floor what was loaded out the previous day made perfect sense to them. (In fact, one manager was so enthusiastic about the system he papered his office with control charts of daily loadout data.) One of the best educational experiences during the whole study actually happened outside the meeting

room. About half way into the actual implementation, a COBO production line manager took a promotion and went to manage one of the regional warehouses. After seeing both the production and distribution operations, he became an instant convert to the new system. He now understood the contradictory relationship between the performance measures which encouraged long production runs of a single product and the performance measures which discouraged high inventory levels and encouraged quick product turnover.

Trying to produce and put back on the warehouse floor what was loaded yesterday also had large implications for the timing of production, shipments to regional warehouses, and loading route trucks. Each of the schedules for these activities was set independently of the other. As a result, even under the new system of production, this caused problems. At times, a transport truck would be ready to leave for regional warehouse, but would be held because a product had not come off the production line. Then, because route trucks were loaded in the afternoon right in the middle of deliveries from the production facility and the day's production run, some drivers were shorted on product even though it was in the system. Instead of coordinating the three activities, they still remain unconnected today. The solution to this problem is an operating plan which views the three activities as one which is connected in time in a circular fashion. Since most stores require deliveries during the morning and early afternoon, the circle would start with the loading of route trucks in the afternoon immediately after a day's deliveries. This in turn would trigger replenishment production at the manufacturing

facility in the evening. Finally, replenishment production would trigger shipments to the regional warehouses in the morning. Regardless of the production and distribution system employed, regional warehouses need to carry excess inventory to cover the lack of coordination.

CHAPTER 7:

THE THEORY OF CONSTRAINTS: A GUIDE TO PROCESS IMPROVEMENT AND PERFORMANCE MEASUREMENT

Introduction

In order to judge the effectiveness of the proposed pull production system, appropriate performance measures are necessary. Eliyahu M. Goldratt's Theory of Constraints (TOC) (5) provides a framework for such performance measures. TOC is a philosophy of continuous improvement that focuses on the identification of management constraints for global business goal achievement. The idea behind TOC is that for most businesses a handful of constraints govern the overall performance of the business. If these constraints can be identified and removed, then the business will enjoy a greater level of success. TOC forces a company to quickly move raw materials through its various systems in concert with market demand. Doing so will allow a company to quickly turn raw materials into sales.

TOC's Operational Measures

TOC uses three operational measures to guide a business:

Throughput (T)

The amount of money a company generates through sales over a specified period of time.

Inventory (I)

The amount of money that the system has invested in materials it intends to sell. (This includes the plant, property, and equipment.)

Operating Expense (O_e)

Money spent by the system to turn inventory into throughput over a specified period of time. (This does not include money spent on inventory purchases. It includes all costs except direct variable costs incurred in generating throughput.)

As illustrated in Figure 14, this makes sense when the company is thought of as a machine:

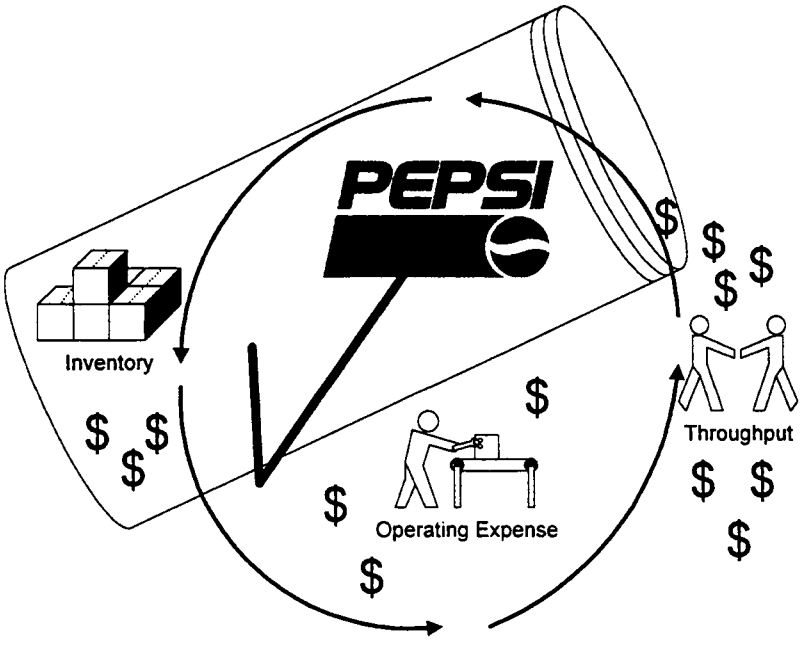


Figure 14: TOC Model of a Soft Drink Manufacturer

The company uses its production and distribution system like a crank on a money making machine. The question becomes how fast can it turn the crank - or - how fast can it turn inventory into throughput via operating expense.

Identifying the constraints to producing throughput faster is the goal. Once the constraints are identified, improvement in processes must be weighed against how they effect the three performance measures. For example, if the proposed action to alleviate a constraint will increase throughput while not increasing the sum of inventory and operating expense then the action is acceptable.

Application to Pull Production

By asking why every product cannot be produced every day (i.e. producing just enough to meet aggregate daily loadouts), a series of constraints can be identified. What is done to alleviate those constraints must be judged against what happens to the performance measures.

As the next chapter will indicate, pull production requires more flavor changeovers per day. Traditionally, flavor changeovers have been discouraged by soft drink manufacturers because they adversely affect traditional measures of operational efficiency. (Doing more changeovers on equipment designed for mass production increases yield loss and decreases the number of cans/bottles per minute which are produced.) Viewed in the context of TOC, more changeovers may actually be acceptable. If more changeovers don't cause throughput to decrease (i.e. lost sales) and

inventory levels fall (i.e. the money invested in finished goods and raw materials decreases), then this is good. The only question is what happens to operating expense? Are more workers required to implement pull production? What happens to yields? What about other operating expenses? As long as the changes offset each other or the company comes out ahead, then more flavor changeovers are acceptable.

CHAPTER 8:

APPLYING THE THEORY OF CONSTRAINTS: JUDGING THE PERFORMANCE OF PULL PRODUCTION

Introduction

In order to judge the performance of pull production, the impact on throughput, inventory, and operating expense must be quantified. In this chapter, an incremental analysis will highlight the changes which occurred in each of these measures as a result of pull production implementation at the production facility with two regional warehouses. (These changes are representative of the changes which occurred at the other facility in the study.)

Effect on Throughput (T)

Throughput remained virtually unaffected during implementation. Few, if any, stockouts occurred at the facility's regional warehouses. (At the other facility's regional warehouses an independent study by management actually reported that stockouts had decreased by 28%.) Therefore, assume that all sales were met during implementation.

Effect on Inventory (I)

As a result of the implementation of the pull production system, there was a dramatic decrease in median two liter inventory level. The overall range in two liter inventory levels decreased. However, the range at warehouse 2 increased. This was because it was necessary to increase the inventory level at this warehouse in order to

make both warehouses day's supply of two liter products equal. Figures 15 and 16 and Table 6 summarize this information. No charts for one liter and ten ounce products are provided, as there was little or no change in inventory levels for these products. This is because the minimum run size for these products was vastly larger than the monthly demand. Production under either system was enough to last for two to three months at a time.

Overall, the median two liter inventory was reduced by 32% (32,666 cases vs. 47,927 cases). This meant that inventory turned about one and a half times faster using a pull system. The median two liter Pepsi inventory level companywide was reduced by 27%. The inventory range for all two liter products fell by 37% (35,879 cases vs. 57,259 cases). Overall, for two liter Pepsi, the inventory range fell by 36%.

Using a per case materials cost of $4.10 which was provided by management, the inventory reduction represents a savings of nearly $62,500 ($4.10 x 15,261 cases). (Note that this cost does not include labor. Because there were the same number of employees after the implementation as there were before implementation, no incremental labor savings or expense occurred.)

Further, there was a significant reduction in full goods breakage at one warehouse. For the period from January to April of 1996, there were 1,966 cases damaged. For the same period in 1995, there were 3,500 cases damaged. While the addition of a newly installed racking system may attribute to some of this, a large portion of this is due to the dramatic inventory reduction. Using a per case cost of $4.25

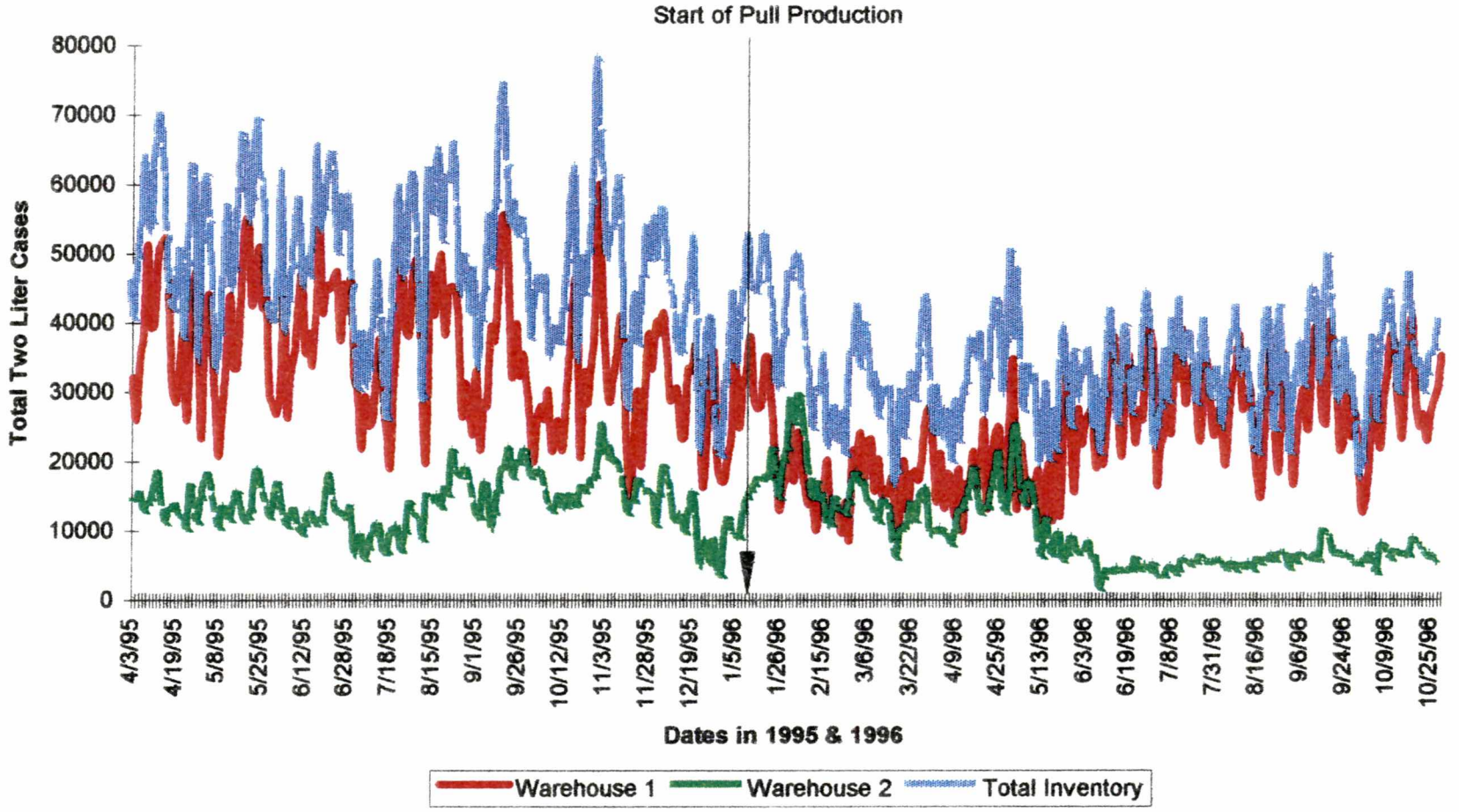


Figure 15: Total Two Liter Inventory Levels Pre and Post Implementation

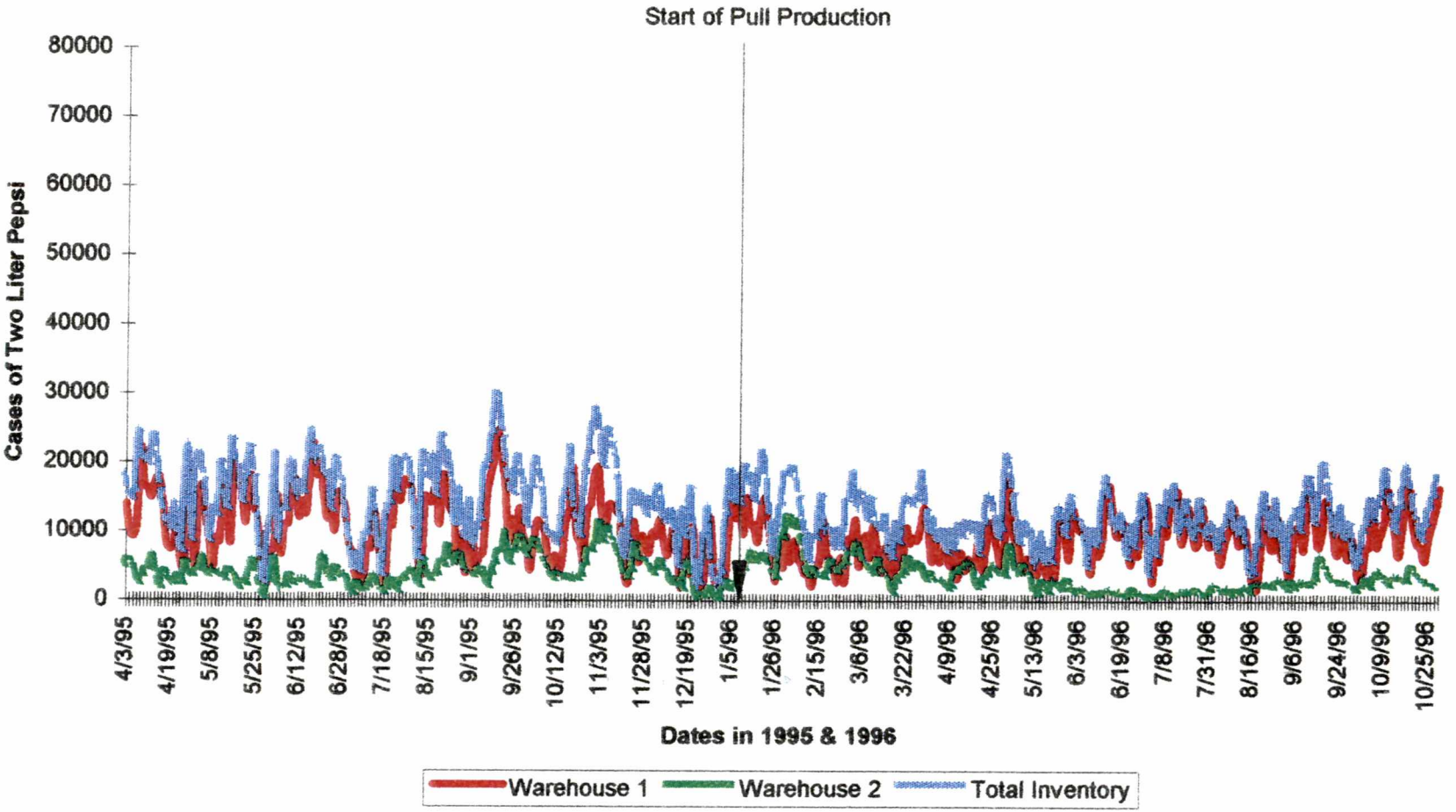


Figure 16: Total Two Liter Pepsi Inventory Levels Pre and Post Implementation

Table 6: Two Liter Inventory Statistics in Cases Pre and Post Implementation

	TWO LITER PEPSI INVENTORY			TOTAL TWO LITER INVENTORY		
	Whse 1	**Whse 2**	**Total**	**Whse 1**	**Whse 2**	**Total**
'95 MEDIAN	11115	3604	15378	33831	13373	47927
'96 MEDIAN	8470	2664	11191	23331	6784	32666
% CHANGE	-24%	-26%	-27%	-31%	-49%	-32%
	TWO LITER PEPSI INVENTORY			**TOTAL TWO LITER INVENTORY**		
	Whse 1	**Whse 2**	**Total**	**Whse 1**	**Whse 2**	**Total**
'95 RANGE	23480	11438	28139	44942	22060	57259
'96 RANGE	15811	12385	18109	32102	28211	35879
% CHANGE	-33%	8%	-36%	-29%	28%	-37%

provided by management, this represents a savings of just over $6,500. Also, as an added consequence of holding less inventory, both facilities noticed a significant decrease in out-of-date product.

Effect on Operating Expense (O_e)

Tables 7 - 10 illustrate the changes in production run sizes and frequency. For one liter and ten ounce products, there was virtually no change from the same period last year. Therefore, no information is provided.

When compared to the same period the prior year (see Table 2, pg. 20, Chapter 4), there were two more flavor changeovers performed on average each day two liter production was scheduled. On average, the line ran at least one two liter package every 1.2 days. Generally, each two liter product was produced 33% more frequently than it was in the same period last year. In addition, each flavor's run size was nearly one-third less than the size of the run made in the same period last year.

The yield losses associated with the change in run size and frequency (increases in the number of times the filler bowl was dumped, the lines were flushed, quality control tests were performed, etc.) should almost entirely explain any change in operating expense. (Note that because the workforce size did not change as a result of pull production, there was no additional labor cost or savings.) Computing the cost of yield loss proved to be a challenging task for three reasons. First, the yield loss data was only available in an aggregate form which combined all lines each month. Second, there was

Table 7: 1996 Two Liter Production Statistics from the Production Facility

	Cases	**Flavors**
Maximum	18,483	9
Average	9,889	5
Median	10,191	5
Minimum	429	1

Table 8: 1996 Two Liter Production Summary by Flavor

FLAVOR	Pepsi	CF Pepsi	D Pepsi	DCF Pepsi	CH Pepsi	Mtn Dew	D Dew	Slice	D Slice	Or Slice	D Or Slice	Ale	D Ale
FREQ	1.3	2.6	1.7	2.3	11.7	2.0	7.0	35.0	14.0	14.0	7.8	5.4	14.0
MAX	11230	1965	3844	2507	1300	2585	1131	607	362	400	809	1722	517
AVERAGE	5013	1221	1994	1479	1268	1376	732	555	356	379	419	1000	468
MEDIAN	4674	1274	1941	1255	1268	1290	690	555	358	390	375	1023	502
MIN	1295	574	567	825	1237	649	392	504	346	344	322	502	366
FLAVOR	Ras Ale	D Ras Ale	D WC Pep	AW RB	D AW RB	AW CRM	D AW CR	Tea	D Tea	Ras Tea	Vernor's	D Vernor's	S Seltzer
FREQ	17.5	14.0	23.3	5.8	8.8	8.8	8.8	14.0	14.0	11.7	14.0	14.0	23.3
MAX	1057	520	1229	1257	946	1356	860	1346	824	613	863	811	575
AVERAGE	636	498	696	865	829	673	517	1094	639	452	676	618	571
MEDIAN	501	500	431	771	874	505	415	1093	606	386	621	655	572
MIN	484	483	429	469	429	393	390	826	364	354	544	474	568

Table 9: Comparison of Two Liter Production Frequency

FREQUENCY IN DAYS			
FLAVOR	**1995**	**1996**	**%CHANGE**
Pepsi	1.7	1.3	-20%
CF Pepsi	4.3	2.6	-39%
D Pepsi	2.9	1.7	-41%
DCF Pepsi	3.8	2.3	-38%
CH Pepsi	16.0	11.7	-27%
Pepsi XL	9.1	--	--
Mtn Dew	3.8	2.0	-47%
D Dew	10.7	7.0	-34%
Slice	21.3	35.0	64%
D Slice	16.0	14.0	-13%
Or Slice	32.0	14.0	-56%
D Or Slice	16.0	7.8	-51%
Ale	10.7	5.4	-50%
D Ale	16.0	14.0	-13%
Ras Ale	16.0	17.5	9%
D Ras Ale	16.0	14.0	-13%
Sunkist	--	23.3	--
AW RB	16.0	5.8	-64%
D AW RB	12.8	8.8	-32%
AW CRM	16.0	8.8	-45%
D AW CM	16.0	8.8	-45%
Tea	10.7	14.0	31%
D Tea	--	14.0	--
Ras Tea	16.0	11.7	-27%
Vernor's	--	14.0	--
D Vernor's	--	14.0	--
S Seltzer	21.3	23.3	9%
		Median	**-33%**

Table 10: Comparison of Two Liter Median Run Size

MEDIAN RUN SIZE IN CASES			
FLAVOR	**1995**	**1996**	**% CHANGE**
Pepsi	6360	4674	-27%
CF Pepsi	2278	1274	-44%
D Pepsi	3519	1941	-45%
DCF Pepsi	1921	1255	-35%
CH Pepsi	1918	1268	-34%
Pepsi XL	1221	--	--
Mtn Dew	2684	1290	-52%
D Dew	1036	690	-33%
Slice	751	555	-26%
D Slice	798	358	-55%
Or Slice	729	390	-47%
D Or Slice	812	375	-54%
Ale	1629	1023	-37%
D Ale	514	502	-2%
Ras Ale	763	501	-34%
D Ras Ale	497	500	1%
Sunkist	--	431	--
AW RB	2715	771	-72%
D AW RB	1369	874	-36%
AW CRM	949	505	-47%
D AW CM	1576	415	-74%
Tea	1288	1093	-15%
D Tea	--	606	--
Ras Tea	608	386	-37%
Vernor's	--	621	--
D Vernor's	--	655	--
S Seltzer	570	572	0%
		Median	**-36%**

a concentrate price increase in February. (The cost of most Pepsi brand concentrates went up by 2%.) Third, yields had already been decreasing since the previous October. This makes it hard to justify contributing all the yield loss to pull production. Table 11 contains available yield data. (Some yields in the table are above 100%. This is because the actual yield is compared against a theoretical standard set by the suppliers of the concentrates used in a given month.)

The average cost per case of the products in the study for the three months before pull production was $0.7206 per case. The average cost per case for the three months after the start of pull production was $0.7432. This is an increase of $0.0226 per case or nearly $150,000. However, this does not take into account the price increase for concentrate. Depending upon how the costs per case for February, March, and April are adjusted for the concentrate price increase, the total cost increase due to yield loss varies. Table 12 outlines the costs given the adjustment for increase in concentrate price.

Regardless of the amount of cost attributed to yield loss from pull production, the larger point is that yield loss did occur both before and after pull production implementation. Since any amount of yield loss increases operating expense, yield loss needs to be minimized. The next chapter addresses this issue.

Table 11: Pre and Post Implementation Yield Loss Data

Production Method	Month	Cost per Case	Yield
Push	October 1995	$ 0.7177	100.93 %
Push	November 1995	$ 0.7274	100.50 %
Push	December 1995	$ 0.7243	100.63 %
Push	January 1996	$ 0.7113	100.03 %
Pull	February 1996	$ 0.7388	99.99 %
Pull	March 1996	$ 0.7462	99.10 %
Pull	April 1996	$ 0.7436	100.52 %

Table 12: Potential Cost Adjustment for Increase in Concentrate Cost

Percent Adjustment to FEB - APRIL Cost per Case	Adjusted Cost Per Case FEB - APRIL	Adjusted Increase in Cost Per Case	Adjusted Total Increase in Cost
- 2.0 %	$ 0.7283	$ 0.0077	$ 49,970
- 1.5 %	$ 0.7321	$ 0.0115	$ 73,935
- 1.0 %	$ 0.7358	$ 0.0152	$ 97,900
- 0.5 %	$ 0.7395	$ 0.0189	$ 121,866

CHAPTER 9:

APPLYING THE THEORY OF CONSTRAINTS: IDENTIFYING CONSTRAINTS

Introduction

In order to identify the constraints to greater levels of business success, the effect of pull production on the three performance measures was considered. There was no change in throughput. Inventory levels decreased. These are both favorable results. However, operating expense increased. This is not favorable. Therefore, the constraints identified during the implementation of pull production which caused the increase in operating expense are the most important. These must be identified and eliminated by senior management.

Effect on Operating Expense (O_e)

In order to reduce yield loss while doing shorter more frequent production runs, the production process must change. Therefore, the production process itself is the constraint. Equipment which will minimize yield loss must be purchased. This will make shorter more frequent production runs attractive.

When compared to the costs of full goods storage space associated with a potential warehouse expansion project, this appears to be a sensible alternative. By decreasing the potential two liter inventory by 32% or 15,261 cases, the effect for the operation is "buying" just over 2,400 square feet of warehouse space. This represents a savings of roughly $100,000. The money which would have been invested in warehouse

space could go towards the purchase of a equipment which would decrease the yield loss. Also, it should be noted that this is not a phantom savings. As the number of SKUs proliferate, bottlers will be faced with a choice of building more warehouse space or better using the currently available space.

By reducing the yield loss, operating expense will decrease. But, this is not the only one of the three performance measures which will be affected. It will also make doing production runs which are even more frequent and smaller more attractive, which will in turn drive the inventory levels down further.

Once yield loss is minimized, the next constraint should be the number of flavors/sizes that can be produced in a given day. This will pose yet another set of constraints to be broken by senior management.

This analysis raises a fundamental question: What will benefit the company more in the long run as the number of products continue to proliferate - adding additional warehouse space or acquiring equipment which will minimize yield loss and thus allow more flavor and package changeovers? All too often when management uses traditional performance measures fueled by a mass production mentality the answer is more warehouse space!

CHAPTER 10:

BROADER SYSTEMS ISSUES AND PRACTICAL IMPLICATIONS

The Production and Delivery Process: Improvements to Accommodate a Pull Production System

Implementing a pull production system provided many insights into how the production and delivery processes at both companies will have to change. Figure 17 illustrate those changes. It represents the "push" production and delivery system in a very broad sense, but is specific enough to highlight several systems issues identified by the pull production implementation.

Explanation of the Diagram

The clover shaped cloud at the far left of the diagram represents raw materials entering the production facility. The cloud on the far right of the diagram represents finished goods exiting the system via the final customer. Product flow is represented by the hollow arrows in the middle of the diagram. These arrows connect the boxes which represent the different inventory holding centers in the process. The circles represent decision points in the process. (Think of them as controls of product flow in the system.) Finally, the dashed arrows represent the flow of information in the process.

The Push Production and Distribution Process as Indicated by the Diagram

Both companies in the study operated at one time as a push system. Product was pushed from the production facility through the regional warehouses and route

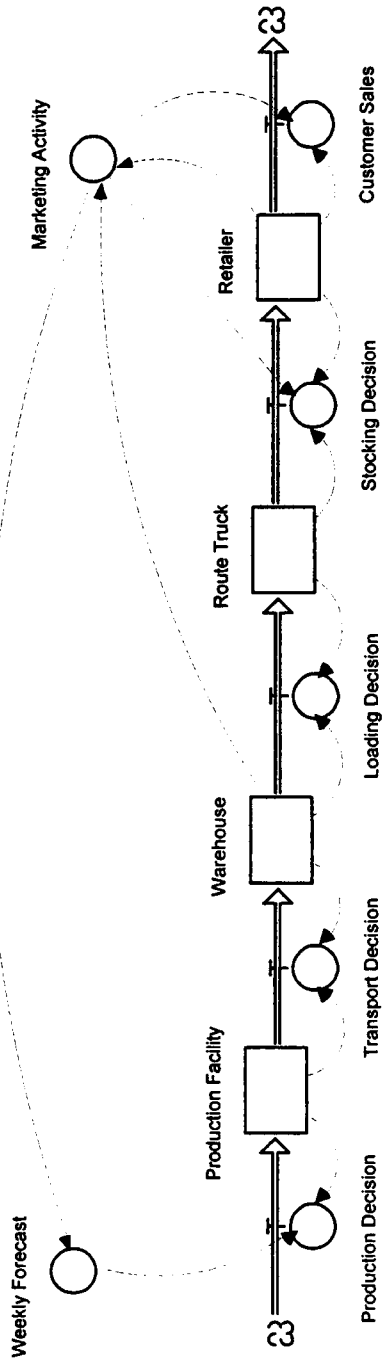


Figure 17: A Schematic of a Soft Drink Manufacturers' Push Production and Distribution System

trucks to the retail store and ultimately to the final consumer. The production schedule was made for one week in advance. This schedule was based on the weekly forecast, the inventory at the production facility, raw materials availability, and the manufacturing operating policies- polices which were a direct result of the incentive system. (For example, a plant manager's yearly bonus may be based on such things as yield loss and changeover times.) Product was transported to the regional warehouses based upon the current inventory level at the production facility and the regional warehouses and transportation restrictions (for example, no less-than-truckload shipments). Next, product was loaded onto route trucks. Ultimately, which products got loaded on a route truck depended upon product availability, space on the route truck, the current incentive system and loading practices. Each route truck made deliveries to retailers. Which product was placed in a retailers back rooms or on its shelves was a function of product availability, shelf space, the incentive system, and marketing activity. (Again, bulk deliveries were slightly different as orders are placed ahead of time). Finally, the customer purchased the product from the retailer's shelves. Customer demand was determined by product availability, marketing activity, and random influences. Back at the sales office each week/month, a forecast was made for next week/month's sales. This weekly/monthly forecast was a function of marketing activity, which in turn was a function of retail inventory and sales, current product availability in the warehouses, and the incentive system. After the forecast was made, the scheduling process was repeated.

In any system, the structure and incentives heavily influence the results. As was

highlighted in the study, this push system produced large swings in inventory, which in turn caused large swings in production. This was a function of forecasting errors, over-production, and under-production. With only a forecast, production decisions in a system like this tended to become manufacturing decisions. Decisions were made locally throughout the system. This is indicated by the information flows on the diagram.

The Pull Production Process: The "North Star"

The process previously outlined served both companies in the study well for years. However, with closer scrutiny of inventory levels and out-of-date product, a diversifying product line, and changes in the marketplace, the process needs to be improved. All companies which are successful at change have had a "North Star" to guide them in the process of change. A pull production system was just the guiding star these companies needed. The reasons and results were outlined in the previous sections. The following section gives a broad look at the pull production process and the areas for improvement two test implementations have identified. A discussion of the practical implications of implementing pull production follows.

The Current Pull Production Process: One Step Away from Retail Sales

The pull production process which was used in the two implementations is shown in Figure 18. It is very similar to the previous diagram, but there are some important changes. Trying to implement these changes lead to leverage points in the system for

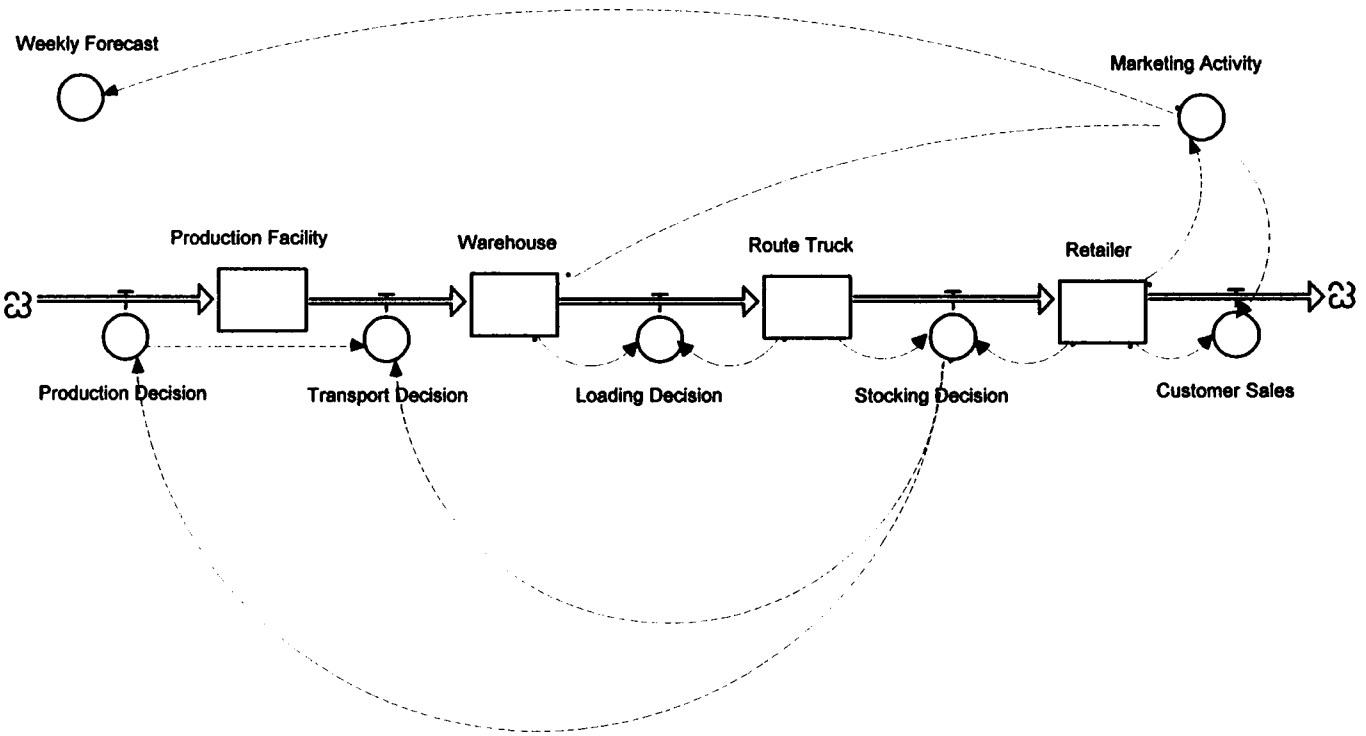


Figure 18: A Schematic of a the Pull Production and Distribution System Implemented in the Study

process improvement. Note that the production and shipping schedules are not based on the weekly forecast and available inventory at the production facility. Currently, both schedules are made daily using route truck loadout data. There is little inventory held on the production facility floor. Nearly everything produced is shipped the same day. By making these changes, the need to do the following proved most critical:

- obtain accurate daily route truck loadout data
- update production schedules and raw materials requirements daily
- produce each package in small run sizes more frequently

From a practical standpoint, many of these changes occurred inside the production facility. Flexibility was the key to the pull system. Many packages were run nearly every available day. Many more changes are needed, however. Concentrate sizes must decrease. The design of mix rooms and production lines must enable flexibility.

Further, due to variable route truck loadouts, the production runs which replenish them will not always be as long as the current shifts. This means the line may not be fully utilized each day. This is a result of using production capacity instead of regional warehouse inventory to buffer the variability in loadouts. The time it takes to make both package and flavor changeovers must be decreased in order to make smaller more frequent production runs. It will also become even more crucial for vendors to be able to accurately supply daily orders for materials as the companies move closer to a just-in-time system.

Due to the scope of the study, the rest of the system remained unchanged during

the implementation. In order to realize greater benefits, however, there will have to be changes. Cross-functional communication will need to be improved. Alignment of processes must occur. The next section discusses these changes.

The Ideal Pull Production System

As was illustrated by the preliminary one product simulations, the closer the system comes to a true pull system, the better the results. Compared to a push system, there is less inventory, less stockouts, and less out-of-date product. Figure 19 is a

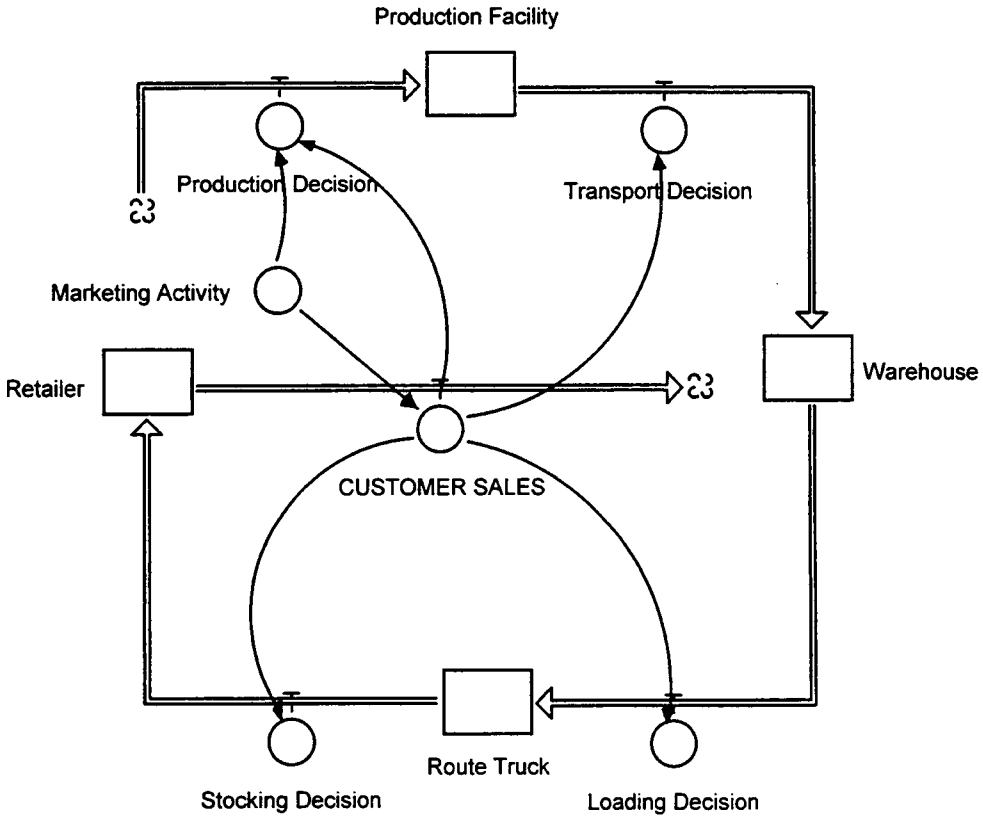


Figure 19: The Ideal Soft Drink Pull Production and Distribution System

diagram of the ideal soft drink pull production and distribution system.

Since customer sales are at the heart of the pull production system, the system is built around them. Every action throughout the system is determined by customer sales. As product is sold to the final consumer, product is produced to replace it at the production facility and then routed back through the system to the retailers' shelves. This means that localized decision making is eliminated from the system. (Note where the information flows are located in the diagram.) Further, each part of the system must be aligned. As mentioned in the discussion section of Chapter 6, production and distribution schedules should be coordinated with route truck loading. Alignment with marketing activity is also crucial, as it directly influences demand. If sales were stimulated significantly, thus producing an out-of-control point on a chart of daily loadouts, product would need to be pushed into the system in advance.

CHAPTER 11:

FUTURE WORK

This paper has focused on scheduling product on one line within a production facility. While the program developed to assist the production scheduler in making daily production decisions contained a wealth of information upon which to base decisions, the actual task of sequencing production on a line and between lines was left to the intuition of the production scheduler. To that end, integrating a pull production schedule on one of several lines proved to be a relatively simple task for an experienced production scheduler. Actually implementing pull production on more than one line, however, would pose a whole set of problems not introduced here with a new level of complexity. Developing a scheduling algorithm for the sequencing of product runs within a line and between lines would be crucial to the success of future implementations.

In the blend room, a scheduling algorithm for the order in which blends are made and the tanks to which they are assigned would be needed to assist the blender. Further, once such algorithms were developed, they could aid management in making decisions about where to allocate money for future capital improvement projects. Using historical data and the algorithms it would be possible to highlight where bottlenecks in the blending and actual production processes may lie and what the potential impact of relieving those bottlenecks may be. For example, by reducing production run size and increasing package and product changeovers, inventory levels would fall. This implies that less warehouse space would be needed. Another potential scenario would be an

increase or decrease in sales. In either case, simulations using the predicted change in sales would highlight potential effect on warehouse space and production and distribution equipment needs.

Within regional warehouses, truck loading and product storage locations could be better allocated by simply placing aggregate daily loadouts for each product on control charts. In such warehouses, full goods storage space and pick areas for product could be assigned based upon upper control limits for aggregate daily route truck loadouts for product. Within a route truck, aggregate sales for each product could be charted and the upper control limit used to set targets for replenishment. This would save the overloading and hoarding which leads to misallocation of product on many trucks.

Finally, formal training materials and sessions on the principles of pull production will need to be created for both bottling plants' and suppliers' employees. Within bottling plants, the mind set of mass production is understandably quite strong. Performance measures will have to be modified and, in some cases, invented to support pull production. Management will have to reformulate incentive systems, as well. Suppliers who are accustomed to monthly forecasts and firm weekly orders will have to respond to forecasts with shorter time horizons and orders that change daily. To that end, bottlers will have to learn to share more scheduling information with suppliers and update it more frequently.

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VITA

Malcolm R. Shrimplin was born in Mount Vernon, Ohio on April 28, 1970. He attended Fredericktown Local Schools in Knox County, Ohio. He graduated from Fredericktown High School on June, 1988 with several honors including being named valedictorian. While in high school he as active in all the offerings of the band program.

Malcolm entered Bowling Green State University in the Fall of 1988. He graduated cum laude in the spring of 1992 with Bachelor of Science in Business Administration with a specialization in operations research. While studying, he was inducted into several honoraries, actively involved in campus life, and lost 55 pounds. He was the only male named as one of ten finalist for the Outstanding Senior Award.

In the fall of 1992 he entered The Management Science Program at The University of Tennessee. While pursuing his Master's degree, Malcolm interacted with numerous businesses through The Management Development Center. For three years he lead a project at the Pepsi-Cola Bottling Company at The Forks of the River Industrial Park in Knoxville while working towards his degree. Malcolm left graduate school for one academic year to serve as an independent consultant to The Pepsi-Cola Bottling Company of Ft. Lauderdale-Palm Beach, Inc. While in Florida he began to run and lift weights. As a result, he lost an additional 35 pounds, bringing his life long weight loss to a total of 90 pounds. Malcolm will receive his Master's degree in December of 1997.