8-2005

The Use of Capacity and Inventory in a Rate-Based Planning and Scheduling System to Achieve Strategic Goals in Industrial Applications

Chad Aaron Toney
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Chad Aaron Toney entitled "The Use of Capacity and Inventory in a Rate-Based Planning and Scheduling System to Achieve Strategic Goals in Industrial Applications." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Industrial Engineering.

Kenneth E. Kirby, Major Professor

We have read this dissertation and recommend its acceptance:

Charles H. Aikens, Kenneth Gilbert, Dukwon Kim, Robert Mee

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Chad Aaron Toney
August 2005

Dedication

This dissertation is dedicated to my wife Kim, for being loving, supporting, encouraging, considerate, and very patient. To my newborn daughter who has taught me about what is really important in life.

Acknowledgments

When looking back on a research project such as this dissertation, I came to the realization that this research could not have been completed without the effort of many people. I would first like to thank Dr. Kenneth E. Kirby for opening the door to the PhD program for me. Throughout this collaborative work, I valued his expertise, insight, and constant encouragement. Dr. Kirby taught me about the Lean Enterprise and provided me with an education saturated with not only theory, but applicable experience. During the dissertation process, I appreciated his attention to detail, his astuteness, his honesty, and his willingness to provide time to talk when I required it. Dr. Kirby has provided me with an education that most could not comprehend.

I would like to thank Dr. Kenneth Gilbert who has also provided his support throughout my doctoral career. He always amazed me with his ability to apply theory to practice which greatly helped me to develop my research. I also appreciate his introducing me to the concept of Rate-Based Planning and Scheduling and his insight while developing the technique. Dr. Robert Mee's effort during my research is also appreciated. We spent hours in his office working through a multitude of information to ensure that the results are statistically conclusive. I valued Dr. Mee's time, knowledge, openness, and patience. I would also like to thank Dr. Hal Aikens, Dr. Hampton Liggett, and Dr. Dukwon Kim for their time, knowledge, and support and for complimenting my dissertation committee with a wealth of expertise.

I would also like to acknowledge everyone affiliated with the Center for

Executive Education at The University of Tennessee for providing a nurturing environment where a student can learn and grow. Everyone at the Center had an impact on my education, but I would like to single out a few. Rhonda Barton hired me to work during my PhD program and gave me an opportunity to work with many companies during my tenure; it was a unique and beneficial experience from which few students are able to benefit. She provided her trust and support which enabled an unparalleled education in an academic environment. Judy Snow's friendship and reinforcement provided a foundation that every student needs and that I cherished. Dr. Mandyam Srinivasan ("Srini") has been a great friend with whom I have enjoyed working. He can count on me whenever he is in need of help. Dr. Alex Miller has been one of my greatest teachers, not only academically, but also in life. I admire his relentless passion for everything he does. And to the rest of the professors for allowing an undeveloped student to train, advance, and benefit from the wealth of experience provided by themselves, and by associates in industry.

My friends and family have been patient, cooperative, and supportive through this enduring process. The doctoral education forces decisions that place a burden on those around the student. My family and friends have been very tolerant as I have not been able to help in all of the times that I should. I appreciate all of the jokes and jabs over the years regarding my education that in turn, provided motivation through the program.

But there has been no motivation throughout my program like that from my wife Kim. She has provided me with the enthusiasm, encouragement, support,

and love to maintain the desire to complete my PhD. To her I am the most thankful. There are not words to express ….

Abstract

In pull or lean manufacturing, the final production schedule is in the form of takt time (drumbeat). All internal and external suppliers are driven by pull signals to feed the production rate. However, variability can be a problem for this drumbeat as the plan should not change more than the ability of the suppliers' capability to respond. The supply chain should have sufficient flexibility to react quickly to changes in demand, while minimizing week-to-week production variability.

Current planning and scheduling systems do not produce a plan that minimizes fluctuations. If the schedule is frozen for several periods, they are slow to react to changes in demand, which eventually produces many changes in production and inventory (the bullwhip effect). When these systems do not freeze the schedule, variation in the forecast and demand yield nervousness, making the planning difficult.

Rate-Based Planning and Scheduling (RPBS) has been proposed as an alternative to current scheduling techniques. But for the most part, it has remained a concept rather than a method that can be implemented. The philosophy behind RBPS is to allow flexibility to adjust the schedule gradually for the near future, and more for periods farther into the future. If flexibility boundaries are defined strategically, the manufacturer will have the ability to respond to changes in demand, yet the schedule will be smooth and long term forecasts for the production rate will anticipate requirements from external suppliers.

This dissertation consolidates previous material on RBPS for the first time.

In addition, it introduces two algorithms (Retailer Smoothing and Production Smoothing) for RBPS. The Production Smoothing technique focuses on leveling production. Whereas, the Retailer Smoothing model allows the customer to create forecasted orders and then limits how much these orders may change. Through statistical experiments and simulations, the impact of the factors such as the standard deviation of demand, the length of the planning period, and the amount of flexibility in the plan are investigated. Irrelevant factors were eliminated as data from further simulations were compiled into tables. The goal of the tables is to allow practitioners to use one of the RBPS strategies with the appropriate levels of the RBPS factors by weighing the impact of capacity and inventory.

For the Retailer Smoothing technique, the closer production follows demand and the shorter the flex fences, less inventory is needed as production will shift more. But as demand varies more, production changes and inventory level will increase significantly. On the other hand, Production Smoothing minimizes production changes by constraining flexibility and lengthening the planning period. This will, in turn, increase inventory. Also, as companies update their plan more frequently, more variation is added to the system which will vastly increase the inventory needed to buffer the production swings.

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Chapter 1

Research Overview

1.1 Introduction

Rate-Based Planning and Scheduling has seldom been documented, and researched even less, with no defined procedure. The purpose of this dissertation is to provide a methodology for Rate-Based Planning and Scheduling, and to understand the impact of the most significant factors: lead time, flexibility, and demand variation. This chapter will provide a summary of the research in the dissertation. First, some background information is supplied to provide a foundation for the research. Then, the purpose of the dissertation is reviewed in the problem statement and objectives. This is followed by the experimental procedure of the research and some anticipated results.

1.2 Background Information

Companies are constantly trying to increase market share by reducing cost. One method is to gain a strategic advantage by importing their product from overseas and take advantage of cheaper labor (Grossman and Jones 2002). However, many did not estimate all of the costs incurred with this strategy. More inventory is necessary to flood the supply chain due to long lead times. Also, forecasts are more erratic with the long lead times as companies are forced to project their demand further into the future. Therefore, companies are compelled to order in large batches to buffer against the uncertainty and long lead times. Quickly, the bullwhip effect forms in the supply chain as the fluctuations in order sizes and frequency grow as the information is passed upstream to suppliers. Companies then put incentives in place which forces more expediting and inefficiencies.

A technique called Rate-Based Planning and Scheduling (RBPS) is introduced in this research. The goal of RBPS is to smooth production and the flow of the product through the supply chain to reduce the bullwhip effect, while still meeting the demand requirements with minimal inventory. The purpose of this research is to locate the equilibrium between limiting production and holding inventory to buffer against demand variation. This technique will support lean initiatives, as a flow or pull environment works better in a more repetitive environment.

The procedure, to limit the production flexibility, involves creating flex boundaries around the forecast. These bounds constrict production to protect the company from large oscillations in demand. Limits are calculated around the forecast, and narrow as the time frame approaches. For example, the customer may be allowed 15% flexibility 6 weeks out, 10% flexibility 4 weeks in the future, and 5% for the first two weeks as shown in Figure 1.1. Therefore, the manufacturer knows that production will not vary more than 15% from the forecast values 5 and 6 weeks ahead and they may plan accordingly. As the time nears, the projected demand will narrow, and so will the requirements on the production system. Implications for this technique

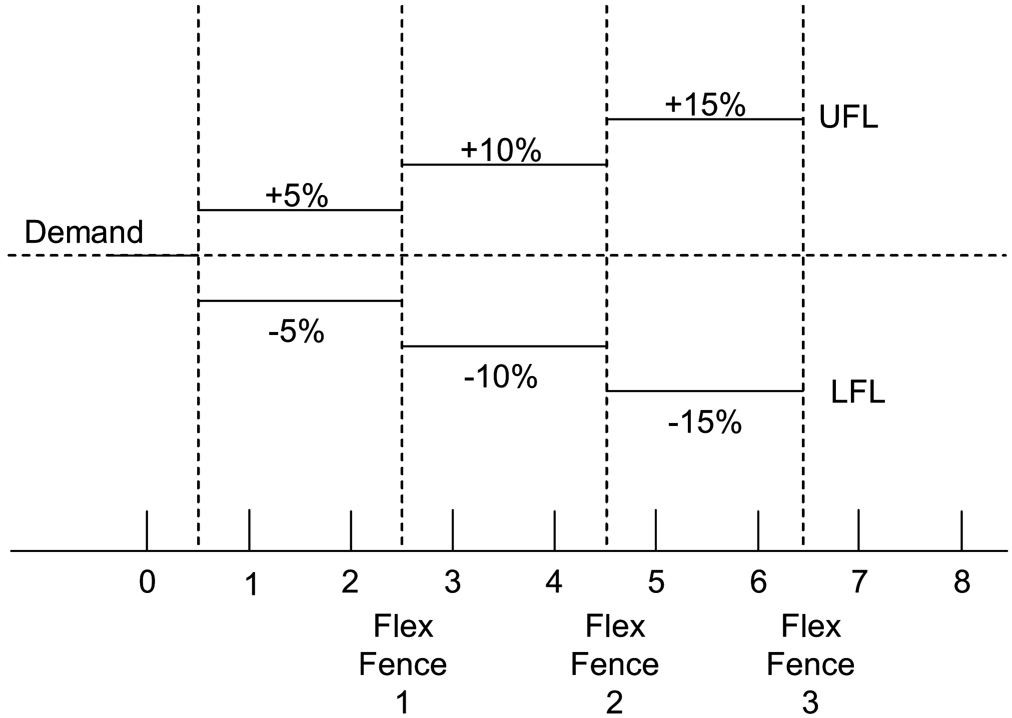

Figure 1.1 Three Flex Fences Increasing by 5% Each.

change as the lead time and the demand variation grow.

1.3 Problem Statement and Objectives

The major motivation for this study is the ramification of the bullwhip effect in the supply chain. As companies try to implement lean strategies within their company, a customer-focused strategy must be created as the basis for the implementation. However, companies often fail as a result of the variability in the supply chain. The overarching goal of this research is to develop a technique that will limit the burden on the manufacturer while meeting the customers' demands.

Very few authors have written about the RBPS technique, and no one has attempted to consolidate the RBPS ideas into a single discussion. As a result, this dissertation will attempt to unite all of these authors' views.

Finally, a simulation study will analyze the several factors in a RBPS system. The resultant significant factors will be simulated at many levels and accumulated into a reference table. The objective of this table is to provide the practitioner with a tool to understand the implications of the given factors in the study. As a result of the table, companies may perform a cost-based sensitivity analysis to understand the implications of lead time, flexibility constraints, and inventory on their system with the RBPS procedures.

1.4 Experimental Procedure

This study will simulate the scenario described in Figure 1.1 to test all possible factors that may influence a one demand fence and one flex fence system. The five factors that have been chosen are the standard deviation of demand, alpha used in the exponential smoothing model to develop the forecast, length of the flex fence, width of the flex limits or bounds, and RBPS demand strategy.

The initial goal of the research is to understand which of these factors should be considered when implementing RBPS through preliminary simulation runs. Statistical analysis will determine which factors are significant. Then, using the significant factors, tables will be built to provide guidelines for practitioners implementing the model. For instance, a page will provide all of the data to achieve a 99% customer service level, given a certain standard deviation for demand and alpha for the exponential smoothing model. This page will have a table listing the inventory required to buffer against demand for each set of flex limits and length of the flex fence. From this table, the practitioner may perform a cost-based sensitivity analysis for various levels of inventory and capacity changes.

Chapter 2

Literature Review

2.1 Introduction

This chapter will review research related to this dissertation. The concept of the bullwhip effect is explained since this concept is the motivation for this research. Next, the concept of Rate-Based Planning and Scheduling is reviewed to minimize the bullwhip effect and as a basis for the methodology in chapter 3. Lead times are discussed since they are such an important attribute of RBPS. And the last chapter primarily discusses Quantity Flexibility Contracts given that this is the most relevant literature for this dissertation.

2.2 Bullwhip Effect

Typically in a supply chain, the end consumer will purchase products from retailers. This forces the retailer to replenish their stock, and therefore, must order from the supplier. The supplier receives the order, processes it, schedules it, manufacturers the order, and then ships it to the retailer. However, there is often a lead time associated with this process. Therefore, the retailer must hold safety stock to ensure that when the consumer arrives to purchase the product, the merchandise will always be on the shelf. Hence, the retailer does not order according to the consumer demand. Instead, the retailer waits until the safety stock level is reached and then orders a larger or smaller amount than the consumer is actually purchasing to achieve the targeted inventory level. Meanwhile, the supplier receives these large and volatile orders and then requests even bigger shipments from the tier-2 supplier to buffer against the volatile demand. As the demand information is passed upstream, it will become more volatile and erratic as it is passed through each upstream stage as shown in Figure 2.1. This characteristic of supply chains is named the bullwhip, whipsaw, or whiplash effect (Simchi-Levi et. al. 2000, Lee et. al. April 1997, Metters 1997, Lummus et. al. 1998, Logic Tools 2003, Chen et. al. 2000, Reddy 2001, Lee et. al. Spring 1997). This phenomenon will have a significant impact on inventory, production scheduling, and delivery of product within the supply chain (Lee et. al. April 1997).

There are many cost implications associated with this occurrence. First, there are unwanted raw material costs to buffer against the customers' unpredictable demand. There are also manufacturing expenses from unused capacity while waiting for orders, followed by overtime to hurry and supply the order when it arrives as a result of the large, batched requisition. Extra costs are also incurred in warehousing and transportation costs from unplanned production and expedited shipping and the labor associated with these activities. Regardless of all of these expenses to buffer against the bullwhip effect, the most important cost is a result of stockouts and missed sales due to the inventory being in the wrong location at the wrong time. Poor product availability causes degradation in the relationship and trust between two stages in the supply chain (Lee et. al. April 1997, Chopra and Meindl 2001,

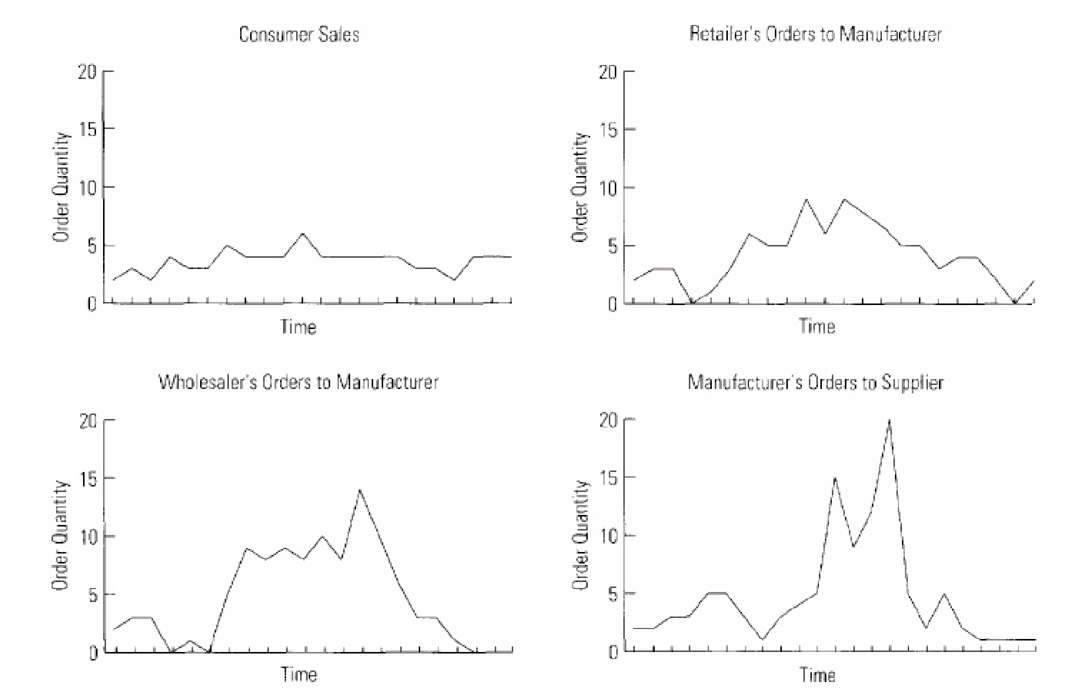

Figure 2.1. Seasonality and Variance Increases as the Bullwhip Effect Moves Upstream (Lee et. al. Spring 1997).

Donovan January 2002, Donovan 2002/2003). According to Metters (1997), if the bullwhip is causing seasonality and forecast errors, costs may increase by 15-30%. Also, the costs associated with monthly seasonality patterns far outweigh that of weekly seasonality shifts, especially in a capacitated environment.

There are many symptoms of the variation in the process that create the bullwhip effect. Excessive inventory is a result of erratic ordering and inconsistency in the sizes of the order. Inventory is also used to buffer against long lead times (Lee et. al. Spring 1997, Reddy 2001). Poor product forecasts also instigate the bullwhip phenomenon since a company is not able to accurately anticipate demand. Deficient forecasts cause uncertain production planning as the company is unable to predict demand. This often leads to excessive or insufficient capacity. During a lull in demand, a facility will appear to have unused capacity. However, when a large order suddenly arrives, the plant will not have enough capacity and will be forced into overtime while expediting shipments. These fluctuations result in poor customer service levels as the supplier is not able to predict the retailer's demand (Lee et. al. Spring 1997). The volatility also results in procurement cost overruns and additional warehousing and shipping costs as the supplier orders large batches of inventory, just to wait until the next order. Most importantly though, quality problems are often caused by the bullwhip effect. To expedite orders through the process, manufacturers often have to become lenient in their quality standards to ensure that the product will ship on time

(Reddy 2001). All of the before-mentioned symptoms have been attributed to incentive, information processing, operational, pricing, and behavioral obstacles in the supply chain (Lee et. al. April 1997, Chopra and Meindl 2001, Donovan January 2002, Donovan 2002/2003, Chen et. al. 2000). These sources of the bullwhip effect, and how to mitigate their effects, are discussed in the following sections.

2.2.1 Incentive Obstacles

There are two sources of incentive obstacles within supply chains. The first is a result of sales incentives. The sales force often changes the quantity of the forecast before the end of the planning period. One reason for this is the customer may forecast more than they actually need because they do not trust the sales force. Also, the sales force may skew the numbers on purpose for their own benefit. If they will not meet quota for the period, they may hold sales until the next period to guarantee themselves a lofty bonus (Donovan January 2002, Donovan 2002/2003). Conversely, when the sales personnel will run short of their target, they may rely on a retailer to increase their order when it actually is not needed downstream. The retailer will provide this order to ensure that the suppliers' sales personnel will reserve product for them during times of short supply. Incentives previously discussed often result in the "hockey stick phenomenon" as 70% of the orders arrive at the end of the incentive period (Lee et. al. April 1997). This fluctuation is enough to cause more significant ramifications upstream due to a disparity between planned production and the updated sales information (Reddy 2001). Thus, the sales incentives quickly distort the independent demand information to immediately start the whiplash within their own company. Then the fluctuations grow even more quickly as they are passed upstream (Chopra and Meindl 2001, Donovan January 2002, Donovan 2002/2003, Lee et. al. April 1997).

To alleviate the sales incentive problem, the incentives may be based on a rolling horizon program. Therefore, the sales force is not driven to increase the numbers at the end of a given period, which changes demand and burdens production. Another technique would be to measure the sales force over a longer time frame so they are incentivized on longer-term revenue generation (Chopra and Meindl 2001). Viewing this problem the opposite way, quota periods may be dramatically reduced. Therefore, the sales force is critiqued more often, which forces them to smooth the orders over time (Donovan January 2002, Donovan 2002/2003).

Another way to eliminate the problem is to reduce the fluctuations by forcing coordination through pricing. Lot size-based discounts may be used to incentivize longer-term relationships. This would be advantageous when selling commodity products since they may be purchased from a number of suppliers at any time. Lot-based discounts also help reduce the overall cost if both parties have large fixed costs associated with each batch. In addition, the use of buyback contracts and quantity flexibility contracts that provide the customer with pre-determined levels of product availability may be used. This technique provides an accurate inventory level for sales to market, which may improve the supply chain profits over time (Chopra and Meindl 2001).

The second incentive obstacle is from trying to optimize within a single stage of the supply chain. When controlling one area, without looking at the big picture, adjustments may be made that will impair the effectiveness of the whole supply chain. This is often a result of trying to minimize cost in one company. For instance, when a customer pushes the inventory back on the supplier to reduce inventory carrying costs, they are simply adding the burden on the supplier instead of trying to minimize the inventory between their two stages in the supply chain. This problem may be resolved by aligning incentives across the functions. Before one stage in the supply chain shifts their costs to a different stage, both parties must agree on the decision and compensate each other with the gained savings (Chopra and Meindl 2001).

2.2.2 Information Processing Obstacles

Lack of information sharing, demand forecasting, and demand signal processing are all causes of information processing obstacles. The problem with demand signal processing is that companies often use historical demand information to update forecasts. However, the demand may be nonstationary. Therefore, the historical demand is no longer relevant. Then, the incorrect forecast is sent upstream to suppliers making it so they cannot anticipate the independent demand. If long lead times are added to this supply chain, the demand information is distorted even more. With this warped information, the suppliers will never be able to anticipate the market implications on consumer demand causing inventory control and customer service levels to suffer. Note that in Figure 2.2, the volatility in the size of the orders varies greatly from the actual sales. Hence, the supplier makes their own forecast to anticipate production needs. This results in “double forecasting,” which sends an even greater shockwave rippling through the supply chain. Meanwhile, suppliers know that the forecast is inevitably wrong. Therefore, they use their own intuition to drive production. Again, this rational decision making skews the demand even more to create greater oscillations in the dependent demand (Lee et. al. Spring 1997, Simchi-Levi et. al. 2000).

To mitigate the effects of demand signal processing, a single member of the supply chain may be designated to develop the forecasts for the entire value stream. This way, everyone in the supply chain has the same information and may plan accordingly. Also, by eliminating channel intermediaries, there are fewer sources of variation (Lee et. al. April 1997, Chen et. al. 2000). One method to eliminate intermediaries would be to have the demand information bypass the retailer and deliver it directly to the supplier from the consumer. This option would remove one channel from distorting the information before it is passed upstream (Lee et. al. Spring 1997, Lee 2000). Another possibility, to reduce demand distortion, is to reduce the lead time in the supply chain. As the lead time is reduced, forecasting becomes much easier (Lee et. al. April 1997, Ryu and Lee 2003). These changes may require a great deal of effort. However, an easier solution would be to simply allow everyone in the supply chain to simply see

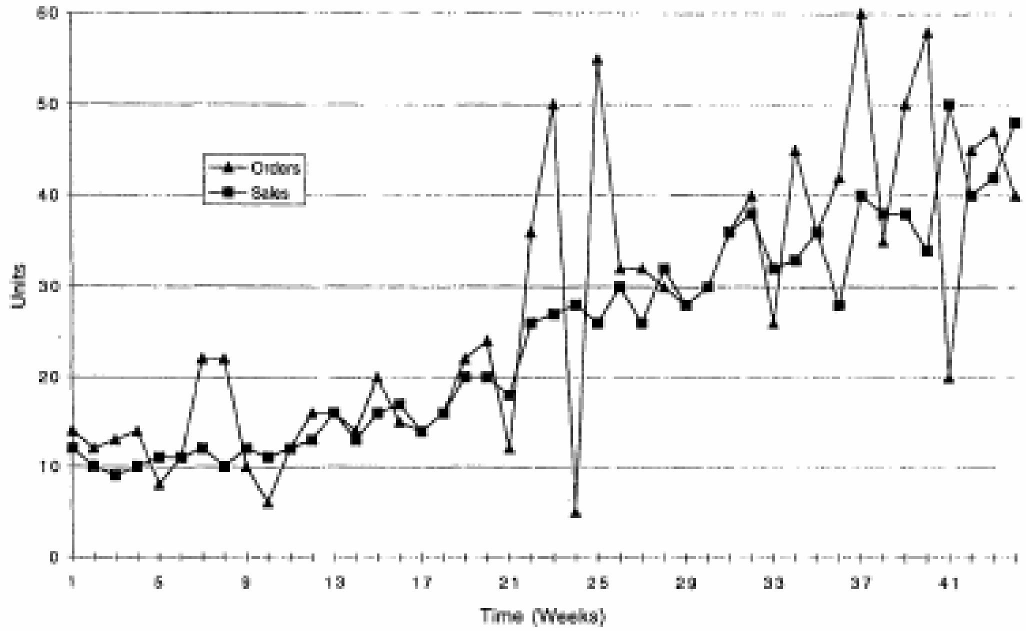

Figure 2.2. Bullwhip Effect Shown by Sales vs. Demand (Lee et. al. April 1997).

the consumer demand information from the retailer level. This way, all stages are assured that they are updating their forecasts with the same information as everyone else. However, they must ensure that every stage is using the same forecasting methods. If they are not, then the various techniques could again lead to the bullwhip effect (Lee et. al. April 1997, Lee et. al. Spring 1997, Chen et. al. 2000). One method to share this information would be the use of EDI (Electronic Data Interchange). Going a step further, the supplier may take on the activity of replenishment to the retailer. In order for this to work, the supplier must have access to all demand and inventory information from the retailer. The supplier would then be able to update the forecasts and resupply the retailer as needed. By using this technique, the retailer would become a passive partner (Lee et. al. Spring 1997, Lee 2000). Then, by using inventory to buffer against the demand volatility, the demand may be rationalized to reduce the bullwhip effect before being distributed to the upper stage (Reddy 2001).

The second information processing obstacle is a result of demand forecasting, which may be attributed to a lack of information sharing. Typically, companies forecast based on orders, not the independent demand. Part of the problem is that each stage in the supply chain views their role as to simply supply what is ordered without understanding the supply chain implications. Therefore, as orders are received, each stage will update their forecasts accordingly. Then as the forecasts are passed upstream, their magnitude in projections will increase dramatically (Chopra and Meindl 2001).

The more layers in the supply chain, the more that the demand information will be skewed, causing excess inventory, idle capacity, and higher manufacturing and transportation costs and resulting in upset customers (Lee 2000).

To diminish the demand forecasting issue, channels may share point-of-sale demand information. The supply chain must understand that the only demand that must be fulfilled is for the end consumer. With this in mind, passing the actual consumers' information would reduce errors in the data as it is passed upstream. However, passing along this information will only reduce the bullwhip effect, not eliminate it (Chen et. al. 2000). Another way to mitigate the demand forecasting problem is to implement collaborative forecasting and replenishment. If this technique is not used, the upstream stages will not be able to anticipate marketing initiatives such as sales and promotions, thus making point-of-sale data useless. Every stage must be able to anticipate the fluctuations in demand and understand why it occurred (Chopra and Meindl 2001). The last method to reduce the demand forecasting problem is by allowing one stage to control all replenishment decisions. Typically, these decisions would be controlled by the channel closest to the end consumer. Having one stage control all replenishment eliminates the need for multiple forecasts and provides coordination in the supply chain. By having one stage responsible, it is easier for supply chain performance measures to be formulated and used to control the system (Chopra and Meindl 2001, Chen et. al. 2000, Lee 2000). In summary, Logic

Tools (2003) claims that the only way to tame the bullwhip effect is by coordinating information and orders.

2.2.3 Operational Obstacles

There are many operational obstacles including long replenishment lead times, the rationing game, order batching, product proliferation, and product life cycles. Long replenishment lead times force companies to hold more inventory to buffer against the demand during the lead time. Therefore, suppliers produce in batches, since the orders are in batches, to replenish large amounts of safety stock at once. The obvious way to reduce the impact is to reduce batch sizes, which in turn will reduce the replenishment lead times. Managers would then be able to reduce the demand uncertainty in the shorter time frame (Chopra and Meindl 2001, Ryu and Lee 2003). Also, the lead time may be reduced by receiving advanced demand information. Basically, the earlier the supplier receives demand information, the sooner they can start producing the goods. Therefore, advanced demand information provides a substitute for inventory, and production and transportation lead times (Hariharan and Zipkin 1995, Ozer 2003).

Another operational obstacle is the rationing or shortage game. This refers to the ordering behavior of buyers when it is believed that suppliers will not be able to provide what is ordered. The shortage may be a result of supply problems or a deficiency in production yield. The rationing game may also be caused by a retailer anticipating peak demand periods. If they use the same supplier the competition uses, the retailer may order more to guarantee a production slot in the supplier's capacity. Increases in demand normally cause the rationing game (Lee et. al. April 1997, Lee et. al. Spring 1997, Chopra and Meindl 2001). Finally, from the rationing game, the retailer will probably order more than they need. If they receive the entire shipment, the retailer may want to return some of the product back to the supplier. A return policy simply aggravates the bullwhip effect (Lee et. al. Spring 1997).

To lessen the impact of the rationing or shortage game, suppliers may create different rules across the retailers. One method may be to allocate capacity to retailers based on their market share in previous periods. Therefore, the retailers may not skew demand with excessive orders. However, this technique does not anticipate the retailers' market share in the future. Therefore, suppliers may also allocate capacity as a percentage of the volume of the orders placed by the retailers when capacity is in short supply. However, the retailers will still overstate their orders to guarantee availability of the product. As a result, the supplier may increase capacity to achieve these heightened, but phantom, orders. The excess capacity will result in excess costs and risk for the supplier (Lee et. al. April 1997, Lee et. al. Spring 1997, Chopra and Meindl 2001). If the supplier simply communicates their capacity with the retailer, the retailer will have less anxiety given that they know exactly what will be produced and when (Lee et. al. Spring 1997). Also, by signing retailers into a contract to limit their ordering flexibility is another way to reduce the rationing game. The buyer may only be allowed to adjust their forecast by a given percentage over the planning interval. As the time nears, the buyer must narrow the range of potential orders (Lee et. al. April 1997, Lee et. al. Spring 1997). Also, stiff penalties must be agreed upon to ensure that the retailer does not return products unless they absolutely must in order to reduce their inventory (Lee et. al. Spring 1997). In the end, companies may smooth their orders by changing commission and incentive plans and by simply training the marketing and finance functions of the company regarding the costs of the bullwhip effect (Reddy 2001).

As stated earlier, order batching is another common operational obstacle. Order batching usually occurs as companies try to minimize their transportation and order transaction costs while improving the economies of scale by accumulating orders before making the batch (Lee et. al. April 1997, Lee et. al. Spring 1997, Chopra and Meindl 2001, Donovan January 2002, Donovan 2002/2003). These transaction costs could be minimized by reducing paperwork and the processing requirement for the order. An example would be to eliminate the need for purchase orders and the cost associated with this task. Also, transportation costs could be reduced by filling a truckload with various products rather than a batch of a single product, coordinating delivery schedules with the retailer, utilizing milk runs, or by using a third party logistics provider. Reducing these costs allows for ordering in smaller and more frequent batches which will more closely mimic the actual demand. However, the small lots create more pressure on the suppliers. Since there is less inventory at the customer, they rely on the supplier to provide accurate sizes of small batches in a consistent and repetitive manner (Lee et. al. April 1997, Lee et. al. Spring 1997, Chopra and Meindl 2001, Lummus et. al. 1998). Batching is also caused by the periodic review process. The periodic review process allows more demand variability as the timeframe lengthens. This issue may be mitigated by allowing direct access to all sales and inventory information (Lee et. al. April 1997, Lee et. al. Spring 1997).

As competition increases in a market, companies try to offer new and advanced products. These products typically have more options for the end user so consumers may purchase exactly what they want. However, there are supply chain issues associated with the wealth of new products. Forecasting, production planning, inventory management, and sales support become much more difficult as options are increased (Lee 2000).

Also, product life cycles are constantly becoming shorter. Technology innovations are a reason for the rapid life cycle. This causes significant supply chain concerns as more products are in the supply chain since the timeline of the product life cycles overlap (Lee 2000).

2.2.4 Pricing Obstacles

Intuitively, price variations skew the demand information. If prices are down, sales will increase. On the other hand, when prices increase, sales may decrease. It is the constant battle of varying price depending on supply and demand. When prices are down, buyers will normally purchase larger quantities to take advantage of the reduced cost. Also, companies use promotions such as price and quantity discounts, coupons, and rebates to increase demand without understanding the impact on the supply chain. These discounts cause rapid fluctuations in demand and cloud other factors that impact demand. Additionally, customers become trained to only buy when items are on sale, creating larger lumps in demand (Chopra and Meindl 2001, Donovan January 2002, Donovan 2002/2003, Lee et. al. April 1997, Lee et. al. Spring 1997, Reddy 2001, Lummus et. al. 1998). Many forward orders will be submitted during the incentive period, followed by a lull in buying (Chopra and Meindl 2001). Large amounts of overtime are also forced on the company as they try to catch up to the volatile demand created by the pricing benefits. If capacity may not be increased through overtime, the company may have to hold large stockpiles of inventory. Surges in premium freight could be forced on the company to ensure product availability for the customer. With the escalation in inventory and shipping, a growth in damage is likely to occur. It is evident that companies who cause price fluctuations end up hurting their value stream probably as much as the discounts help. (Lee et. al. April 1997, Lee et. al. Spring 1997, Reddy 2001)

To remedy the problem of pricing variations, companies may offer an Every Day Low Price (EDLP) to smooth demand. EDLP provides the customer with a constant reduction in price rather than sporadic discounts and promotions (Chopra and Meindl 2001, Lee et. al. Spring 1997, Lee et. al. April 1997). Also, limits may be placed on the amount that the customer may purchase. These limits are typically set for individual customers and are based on historical information (Chopra and Meindl 2001). Activity-Based Costing (ABC) systems are used in determining the actual cost of promotions. ABC takes into account all inventory, transportation, and other costs associated with discount campaigns to fully understand the implications of this activity. Using this technique, companies often realize that the costs outweigh the benefits of promotions (Lee et. al. Spring 1997, Lee et. al. April 1997). By also combining vendor managed inventory programs with a "rationalized wholesale pricing policy," suppliers can reduce the forward-buying benefits as most of the customers' costs are already reduced in this scenario (Lee et. al. April 1997, Donovan January 2002, Donovan 2002/2003).

2.2.5 Behavioral Obstacles

Typically, companies are only focused on their stage of the supply chain since they are measured on the goals of their own portion of the channel. They do not bother to understand why the value stream acts like a bullwhip. They are simply concerned with their local measures, especially since many of the measures in the channel conflict with each other. Usually, companies accuse the inefficiencies on others in the supply chain. The blame game then fosters negativity and ill-will between channels rather than a cooperative partnership. A vicious circle ensues where a company resolves a situation by creating a problem for another supply chain stage. Then that stage adapts by creating problems for someone else. This cycle will continue until the chain collaborates to solve their problems. The behavioral obstacle is one of the hardest to overcome since the chain has traditionally been antagonistic. All trust has been diminished as has all hope for shared responsibility to solve issues. Instead, all channels duplicate each others' efforts since they do not believe the information that they have received from each other (Chopra and Meindl 2001, Donovan January 2002, Donovan 2002/2003, Metters 1997).

The only way to solve the behavior issue is by creating trust within the supply chain. This is not easy to do. Companies will have to allow access to their proprietary demand information. They must share the demand information, inventory status, and forecast analyses so that every stage is in agreement regarding the status of the supply chain. Slowly, confidence will form as companies benefit from reduced costs. And vice versa, costs will decrease as companies start depending on each other (Chopra and Meindl 2001).

As stated earlier, a method to reduce the bullwhip effect is by smoothing production and the demands on the supplier. The technique of Rate-Based Planning and Scheduling is designed to use these benefits. The technique is thoroughly discussed in the next section, and is the primary basis for this dissertation.

2.3 Rate-Based Planning and Scheduling

Rate-Based Scheduling (RBS) and Rate-Based Planning (RBP) are techniques that have been discussed by several researchers such as Behera (1992), Woodhead (1992), Maskell (1994), Wei and Kern (1999), Reeve (2002), and Vollmann, Berry, and Whybark (1997). However, few of these researchers have presented a consistent methodology for this practice. This section will integrate the concepts of RBP and RBS into a common methodology of Rate-Based Planning and Scheduling (RBPS), and will discuss how to implement these concepts in Build-to-Stock (BTS) or Build-to-Order (BTO) environments. Also, this section will explain how RBPS may be implemented in a repetitive and stable environment, a repetitive environment with variation, and a seasonal environment.

2.3.1 Definition of RBPS

The Rate-Based Planning and Scheduling (RBPS) technique changes the plan, production requirements, and/or schedule into a rate rather than orders (NDS 2002). This rate will then allow a company to meet the customers' demands through changes in the rate and by utilizing the inventory to buffer against uncertainty.

Vollmann, Berry, and Whybark (1997) introduced the concept of Rate-Based Planning as they separated planning into two phases: time-phased, and rate-based. Time-phased planning refers to production preparation, which is based on orders. These orders are sent to the shop floor in batches to minimize changeovers, as discussed in Figure 2.3. The Rate-Based method develops a rate for each part that will be used. Rates are then passed through the planning bill of materials so they will be ready for execution when pulled by the customer. The assumption with this scenario is that the supply base is flexible and able to provide the parts in a short lead time.

Figure 2.4 helps explain how these planning approaches fit into manufacturing strategy and market requirements. The time-phased method is preferred for low volume, customized products that allow a wide variety of options. On the other hand, RBPS is for higher volume, standardized products (Vollmann, Berry, Whybark 1997).

Rating the production process is similar to using takt time. Takt time (also known as tackt or tact) is a German word that represents an interval of time and will designate how quickly a product must be produced to meet demand. The demand is simply converted into a demand or production rate for the day. For instance, suppose that demand is 100 units per day and there are 400 available work minutes in the day. Therefore, one unit must be produced at least every 4 minutes in order to satisfy demand. And if the demand rose to 200 units per day, the takt time decreases to a rate of one unit every 2 minutes. Likewise, as demand decreases, the takt time will increase (Henderson and Larco 1999).

The purpose of changing the demand to takt is simply to convert the demand into a rate that everyone in the production facility may identify. For

	Material planning approach	
Basis for planning and control	**Time-phased**	**Rate-based**
Control point	Shop/purchase orders	Planning bills
Control unit	Batches	Kanbans
Product level	Material explosion of time-phased net requirements for product components	Material explosion of rate-based requirements for product components
Material planning features		
Fixed schedules	No	Yes
Use of WIP to aid planning	High	Low
Updating	Daily/weekly	Weekly/monthly
Inventory netting	Performed	None
Lead time offsetting	Performed	None
Lot sizing	Performed	None
Safety stock/safety lead time	Considered	Not considered
Container size	Not considered	Considered
Bill of material	Many levels	Single level

Figure 2.3. Features of Detailed Material Planning Approaches (Vollmann, Berry, Whybark 1992, 1997).

Strategic Variables			Detailed material planning approach	
			Time phased	Rate based
Market requirements	Product	Design	Custom	Standard
		Variety	Wide	Narrow
	Individual product volume per period		Low	High
	Ability to cope with changes in product mix		High potential	Limited
	Delivery	Speed	Through scheduling/ excess capacity	Through inventory
		Schedule changes	Difficult	Straightforward
Manufacturing	Process choice		Batch	Line
	Source of cost reduction	Overhead	No	Yes
		Inventory	No	Yes
		Capacity utilization	Yes	No

Figure 2.4. Material Planning Approach for Market Requirements and Manufacturing Strategy (Vollmann, Berry, Whybark 1997).

instance, shop floor workers understand the quantity that remains to be produced in a day because the information is visual and easy to understand. Managers and workers have a common language with which they may discuss the status of the system. Suppliers know how many components to provide due to the simple rate. However, management discussing the capacity and status of the production system is probably the most important aspect.

In the RBPS environment, the rated schedule must be faster than the takt time. Even though the organization has implemented lean concepts to reduce the variation, there may always exist certain defects, design issues, and other reasons for variation in the process. Therefore, the plan must always be for a rate faster than the takt time to allow for reserve capacity and to ensure that the product will be able to flow through the process by the required due date. The difference between the rate and the takt time may be minimized as preventive and predictive maintenance techniques are implemented and as changeover times are reduced.

But how is this rate used in industry? An initial assumption is made that the Master Production Schedule (MPS) is fairly level (Nicholas 1998). Stemming from this hypothesis, the monthly production schedule is changed into a rated schedule so products may be repetitively made every day or week (Behera 1992, Knight 1996, and Schonberger 1997, Silver and Smith 1981). The MRP designates the rate that operators follow until the MRP develops a new Rate-Based MPS. More recent orders may cause the rate to deviate daily to meet customer demand (Nicholas 1998). Companies will be able to maximize their yield by holding the production rate level for at least a review cycle (Silver and Smith 1981).

Ptak and Schragenheim (2000) agree with Nicholas when stating that the production schedule should be changed to daily or even per-shift rates. This rate should remain constant over a period of time. However, the production rate may be changed at any time with little effort when the demand changes. A new rate simply replaces the old rate. This is a vast improvement over adding and subtracting orders from the process to control production. Even then, expeditors would have to push the orders along to ensure that they were finished on time.

The positive aspect of producing to a rate is that production is repetitive. Suppose our rate is 50 units a day for Product A and 100 units a day for Product B for a 400 minutes work day. This means that a unit of Product A will be made every 8 minutes and Product B will be produced every 4 minutes. There are no surprises in this information. The same amount will be made every day.

2.3.2 Objective and Goal of RBPS

As stated in the literature on RBPS by Behera (1992), Woodhead (1992) and Maskell (1994), the goal is to smooth production. Rate-Based Planning will smooth the plan so that pull execution systems may produce according to the customer demand. Schonberger (1986) stated the idea best - “Make the same family of parts over and over again, hence the term 'family repetitive' production."

2.3.3 Capacity Buffer

According to James Reeve in "The Financial Advantages of the Lean Supply Chain," "Lean supply chains create growth by matching capacity to actual demand through Rate-Based Planning and Execution (RBPE)." The end consumer does not buy goods in batches. Products are purchased one or two at a time. Therefore, products should be manufactured as they are consumed. However, there is often volatility in the demand quantities over time. In RBPS, capacity will buffer against this variation rather than the traditional methodology of using inventory. Rather than trying to chase demand with production, the goal is to smooth production, understand the true demand, and use RBPS to create capacity that may be used for growth of the company (Reeve 2002).

To further understand the difference between traditional planning and scheduling versus RBPS, refer to Figure 2.5. Conventional MPS vary production as it tries to chase demand. The focus is to maintain the quantity of safety stock. On the other hand, Rate-Based MPS tries to smooth production over several periods to minimize fluctuations within the facility. The inventory buffer will fluctuate as demand oscillates around the rate of production. Then, by passing this schedule on to suppliers, the smoothed production rate of the MPS reduces the volatility typically seen by the tier 1

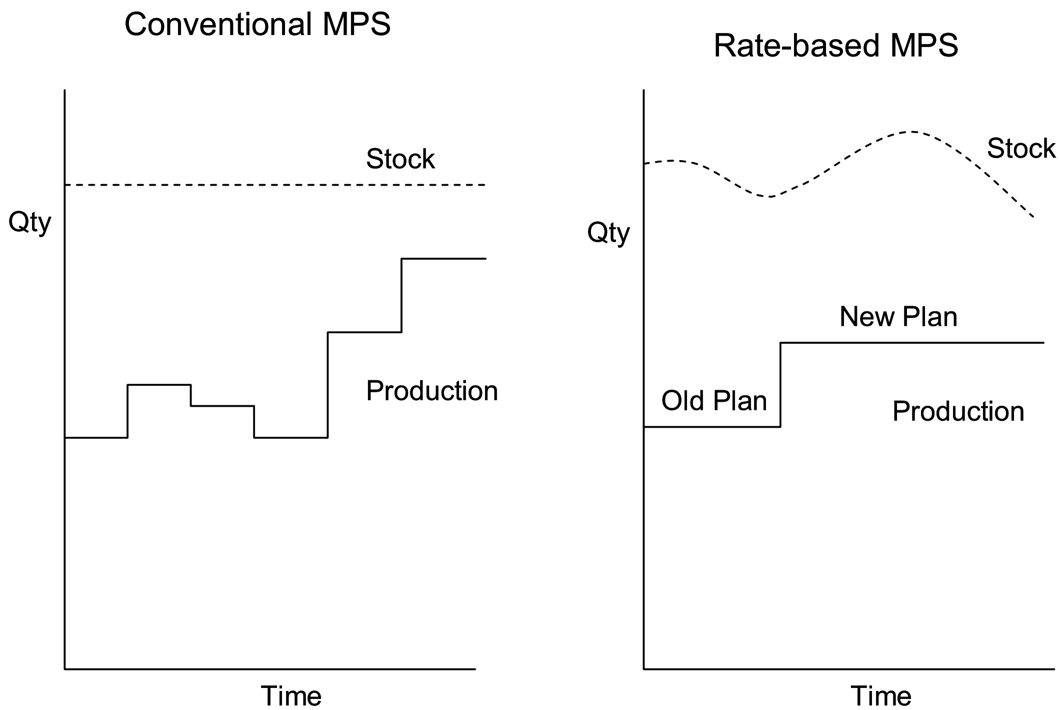

Figure 2.5. Conventional MPS vs. Rate-Based MPS (Woodhead, Feb/Mar 1992).

and 2 suppliers.

For instance, notice in Figure 2.5 that the goal of the conventional approach is to maintain a level amount of safety stock. As demand fluctuates in this environment, so does the rate of production. The facility may produce 50 units one week and then 300 the next. In this scenario, the demand volatility is buffered using inventory. However, the Rate-Based method levels the rate of production. Capacity is then used to buffer against the uncertainty in demand rather than using inventory as the buffer. As demand changes over time, the rate is adjusted to minimize the number of stock outs and improve the customer service level.

The planner must understand the effects of changing the rates and how it impacts the production system. Hopefully an increase in the rate of product A will cancel out the decrease in rate of product B. But the planner must pay attention to times of peak demand and ensure that the capacity plan does not exceed the capability of the production system (Woodhead 1992).

2.3.4 Benefits of RBPS

Limited amounts of research have been performed regarding RBPS. Even fewer people have written about implementation of the Rate-Based concepts. However, some conclusions may be made regarding the benefits of implementing RBPS.

Peter Knight (1996) believes the primary benefit of RBPS is it reduces the administrative overhead by performing the basic job control tasks "(i.e.

costing, backflushing, labour costs)", by eliminating complexity caused by job numbers and other paperwork (Knight 1996). Schonberger (1997) supports this belief by stating that RBPS causes a reduction in administrative overhead, decline of work in process, elimination of work orders and other production control documents, and the eradication of overhead linking with suppliers. By reducing the overhead costs, a company is eliminating the "dominant component of their cost structure" (Schonberger 1997). Knight supports this theory even further by explaining the focus of RBPS is "to achieve optimum productivity and efficiency, using a paper-less, rate based, customer-driven process" (Knight 1996). The common thread is that the Rate-Based methodology will drastically reduce the number of transactions required, and therefore, cost (Reed 2002).

2.3.5 Steps to Implement Kanban

A philosophy exists that RBPS is simply a stepping stone to transition from MRP to kanban. Kanban is a signal to pull inventory or to start production for a particular product. Dan Reed (Feb 2002) states that "in order to evolve to Kanban, a plan must be developed to migrate from a work order environment to a rate flow environment." Therefore, the MRP system must change from a work order system to a Rate-Based system. Reed states that the main purpose of the transition is to ensure an accurate inventory tracking system. In this rated environment, the required components per product are subtracted from the on-hand inventory count by utilizing the backflushing technique.

Kirt Behera believes that lean concepts may not be implemented without a repetitive environment. When a company changes to a Rate-Based philosophy, the production process inherently becomes more repetitive. Therefore, Behera (1992) agrees that RBPS is not only a stepping stone, but is a requirement in order to implement pull execution systems.

2.3.6 Flex Fences and Flex Limits

Even though the concept of Rate-Based declares that production will manufacture products at a given rate, practice shows that production will still vary as demand fluctuates. A method to limit the flexibility in the production environment while maintaining stability is by using flex fences to place bounds on the production level. Companies may still increase or decrease their production and/or requirements, but only within the allowed limits.

Costanza (1996) uses a technique with maximum and minimum limits in The Quantum Leap… In Speed-To-Market. He utilizes demand time fences and flex fences to allow the marketing department to change the demand information only a given amount (flex limit) for a certain period of time (flex fence). Once the demand time fence is reached, the forecast is frozen. However, during the flex fence periods, marketing may vary the demand information up to the specified limits. For instance, the company may determine that marketing and/or sales may change the demand information ±5% for the next two weeks, ±15% for the following two weeks, and ±30% for the last two weeks of the 6 week planning horizon (Costanza 1996).

The limits inform marketing how much they may sell over a time horizon further in the future as shown in Figure 2.6. These time horizons may change in length depending on the company and the negotiated agreements between production and marketing. The purpose of the flex fences is to minimize the amount of variation in demand for production to ensure that the planning process is simplified and that the facility is capable of meeting the demand targets. Therefore, even though Costanza's method is not named RBPS, this technique forces a constant repetitiveness in the manufacturing system, which is the focus of RBPS (Costanza 1996).

Costanza discusses how to determine flexible demand more explicitly in his patent that was accepted in 1995. The patent regarding demand and flex fences flowcharts the decision criteria for a computer system to support production. The purpose of the patent is to explain how to establish the demand for the production system and also how to project this demand daily. Costanza's schedule is frozen up to the demand fence as displayed in Figure 2.6. However, the demand may vary within the flex limits up to each flex fence. The flex limits are defined by the user, and the flex periods may be of varying lengths. If demand is greater than the upper flex limit, the software will try to spread the order over earlier dates up to the demand fence. However, if demand is less than the lower flex limit, the company will go ahead and manufacture the quantity of products as defined by the lower limit.

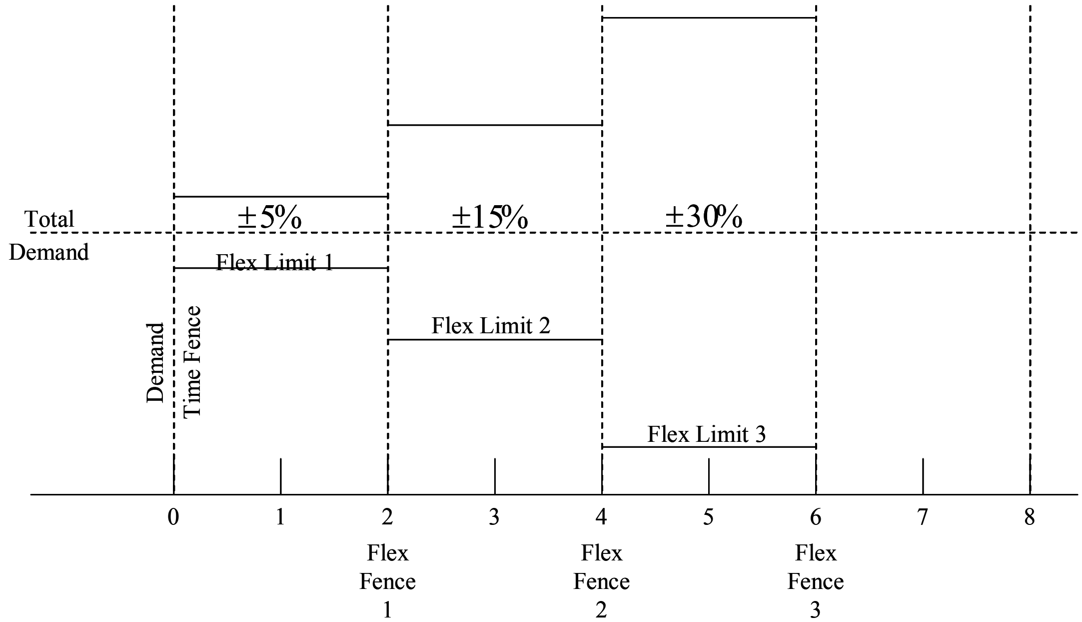

Figure 2.6. Demand and Planning Flex Fences (Costanza 1996, 93).

This occurrence will increase the inventory, which will hopefully be consumed in the future. The following discussion will explain these ideas in more detail. The planner and/or scheduler must first understand how to incorporate sales with the flex fences methodology. Marketing takes orders over four time periods (or time fences). The first interval is the demand fence, under which all orders are frozen. These orders consist of customer orders or orders from marketing, which will be kept in inventory. None of the numbers may be changed during this time. The user defines the length of the demand fence. However, this frozen time period is normally longer than the manufacturing lead time or the time required to obtain raw materials, whichever is longer.

After the demand fence, the larger of the customer orders or the marketing forecast is chosen as the total demand for each day, as shown in the first few blocks of Figure 2.7. Next, the flex limits are determined from Equation 2.1, and the system determines if the demand is within the flex limits

$$D_{r\iint L} = D_r \times (1 + X/100)^N$$

$D_{r\iint L}$ is the Flex Fence Limit Value

D_r is the rate of demand

X is the flex percentage

N is the flex period

(Equation 2.1)

(Figure 2.8). If so, the order quantity is acceptable, and the quantities are sent to purchasing to guarantee that the needed materials are available. However, if the demand is outside the limits, the information is smoothed, as

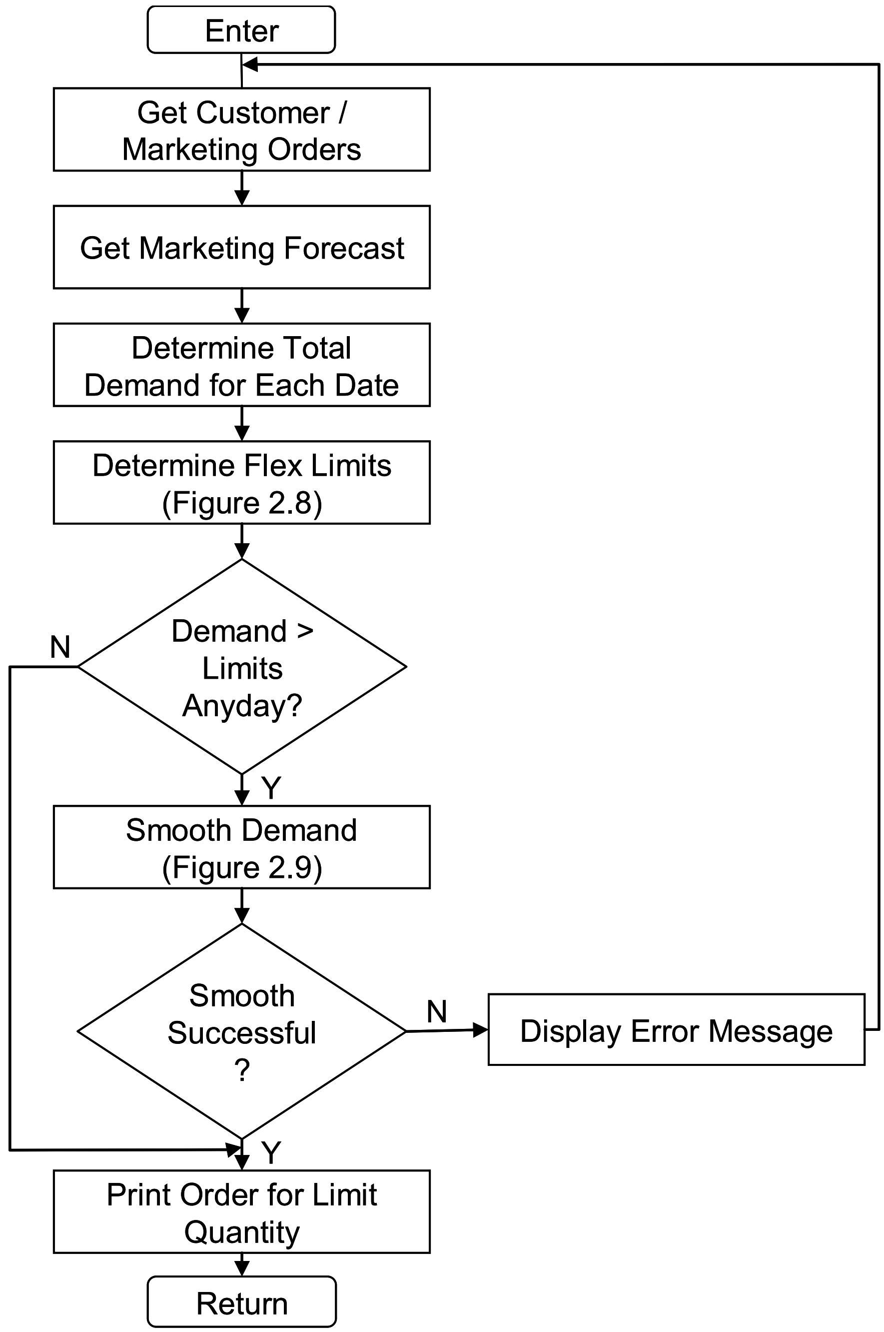

Figure 2.7. Top Level Flowchart for Determining Flexible Demand (Costanza 1995).

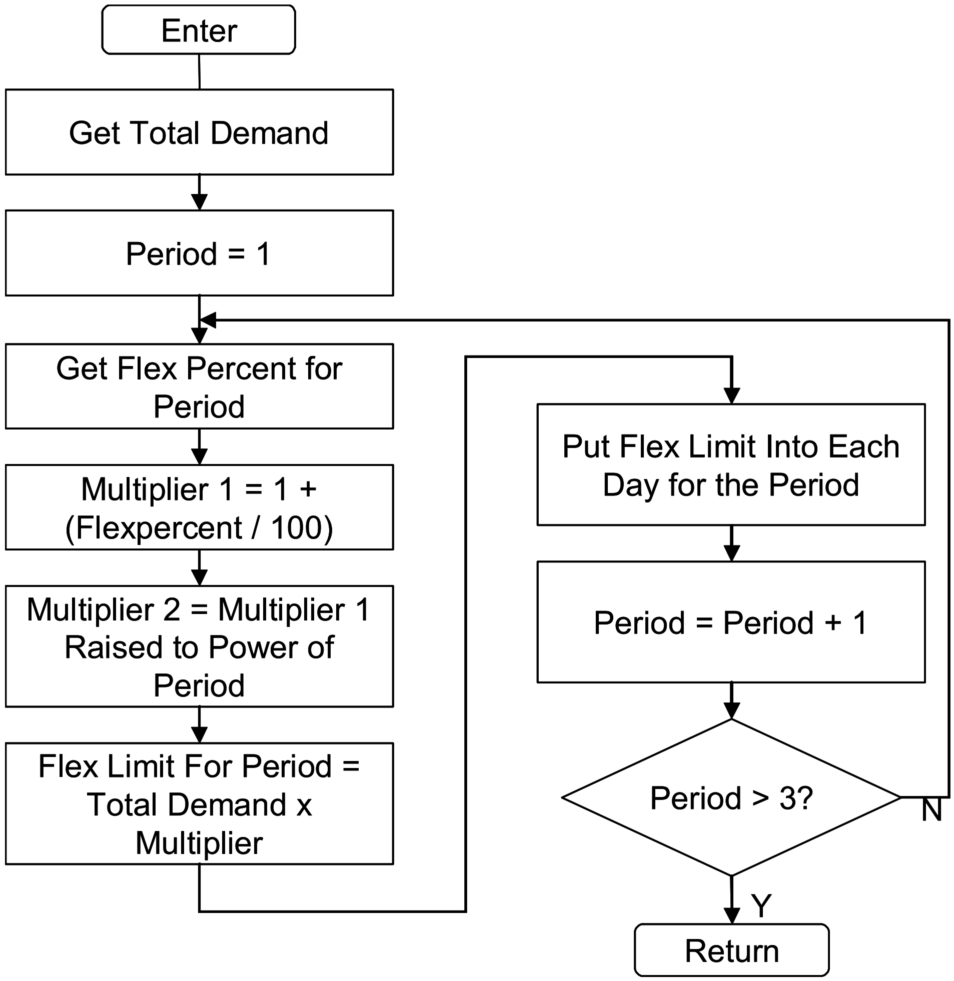

Figure 2.8. Flowchart to Determine the Flex Limits (Costanza 1995).

later discussed in Figure 2.9. The demand is accumulated, and the system determines the size of the flex limits. Then, the computer system begins with the first flex period to determine the flex limit. The next few blocks in Figure 2.8 define the multiplier for the flex fence and the quantity that it represents. This procedure is repeated until all limits for the three flex periods are defined.

If the flex limits were breached, then the methodology from Figure 2.9 is put into play to smooth the demand. If demand is greater than the upper flex limit, the system smoothes the demand by moving some of the demand to earlier periods before the due date. Likewise, if the demand is below the lower flex limit, the schedule is equal to the lower flex limit. Similar to the instance with the upper flex limit, production will be sustained at this lower limit in previous periods until the minimal amount desired is achieved. However, the demand information may not be adjusted inside the demand fence.

When the demand needs smoothing, the methodology from Figure 2.10 is retrieved. First, the smooth amount is identified by subtracting the total demand for the day from the upper flex limit. The remaining amount is the demand that exceeded the limit, called the smooth amount. Then, the system tries to fill in the remaining capacity for each previous day with the smoothing amount. If the previous day will accept the total smooth amount without exceeding the flex limit, the process is finished. On the other hand, if a fraction is left on the previous day, then that amount is added to the day's demand, and the remaining quantity is the new smoothing amount. This

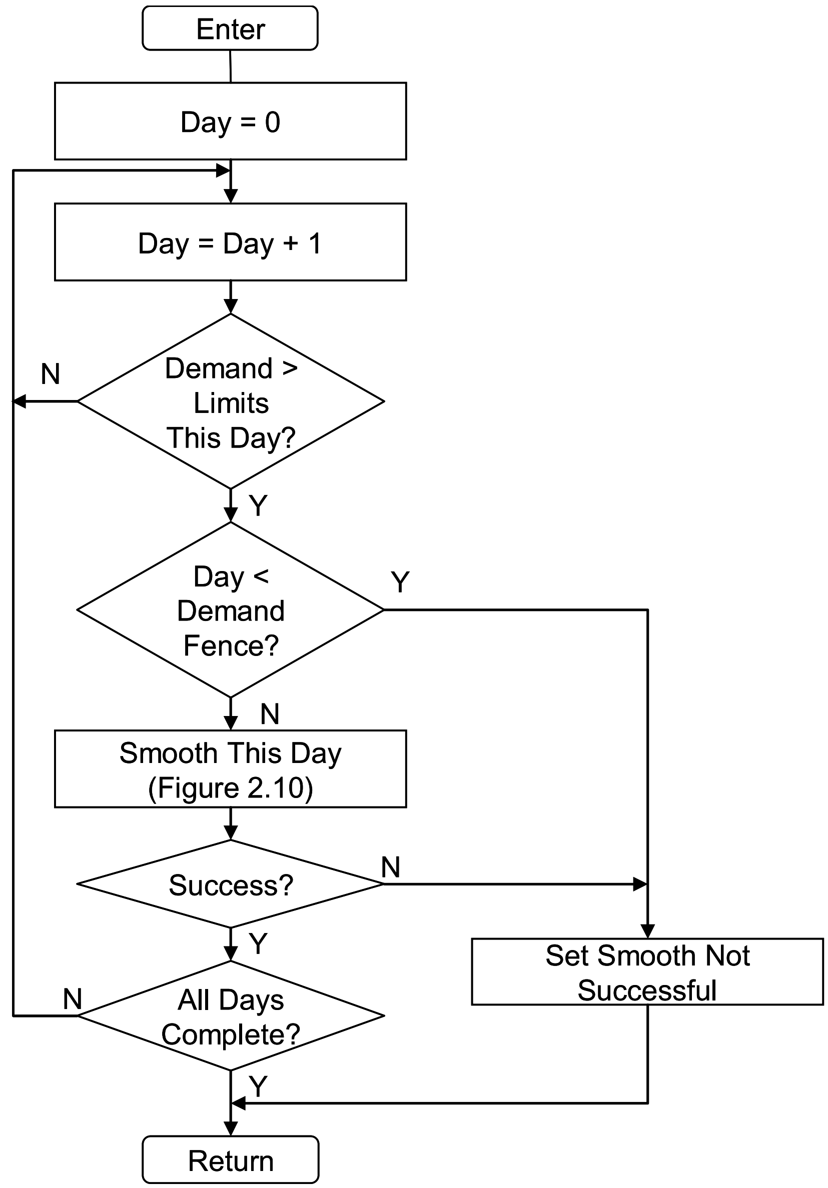

Figure 2.9. Flowchart of the Smoothing Method (Costanza 1995).

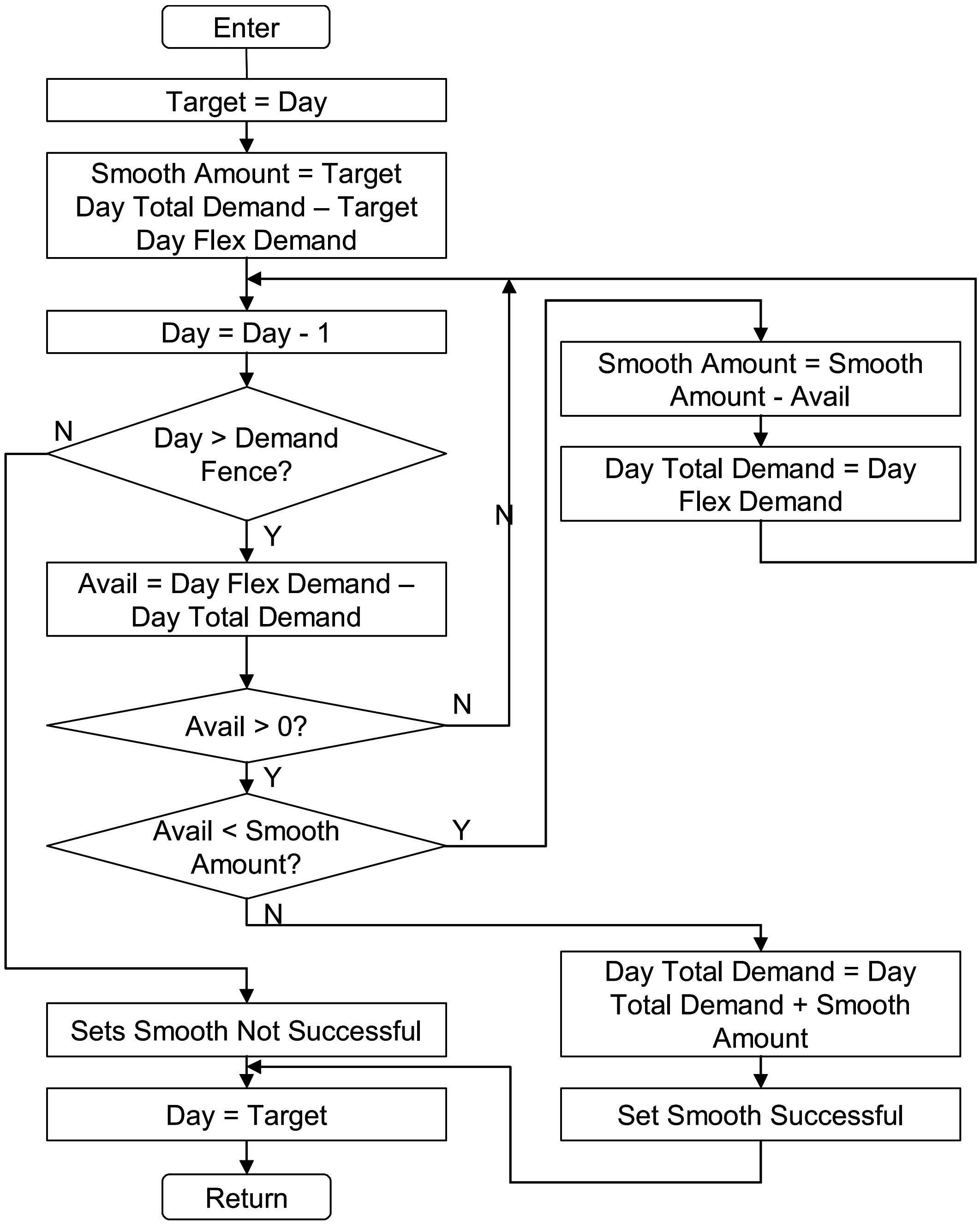

Figure 2.10. Flowchart of the Smoothing Method for a Single Day (Costanza 1995).

process is repeated until all demand is within the limits, or until the demand fence is reached without using the entire smoothing amount. If more capacity is needed when the demand fence is reached, a signal is sent to the planner that the schedule may not be achieved.

For example, suppose the average demand is 100 units, and the flex limits are calculated to be 95 and 105 for flex fence 1, 90 and 110 for flex fence 2, and 85 and 115 for flex fence 3. Management has decided to have three time periods per flex fence. The project demand data is also known for the next nine, periods as shown in Table 2.1. As depicted by Figure 2.11, the demand in period 6 does not fit within the flex limits.

The demand point beyond the limits must be smoothed over the previous time periods. The methodology in Figure 2.9 acknowledges that the demand is outside the limits, and therefore, the technique used in Figure 2.10 is initiated. The demand data is brought down to 110 units for period 6 and 11 units must be smoothed over the previous periods as depicted in Table 2.2 and Figure 2.12. In period 5, the difference between the flex limit (110) and the demand of 108 is 2. Therefore, two units are added to period five, and the remaining nine will be smoothed over the previous periods. Likewise, five units may be added to period four before the limit is reached, which leaves an excess of four units. Now the flex limit for period three has shrunk to 105, but there is room to add three units to meet the flex limit. The one unit left over may be added to period two. The result is a schedule that is maintained within the limits designated by the organization.

Table 2.1. Example 1 Demand Data with Flex Limits.

Period	0	1	2	3	4	5	6	7	8	9
Upper Flex Limit		105	105	105	110	110	110	115	115	115
Lower Flex Limit		95	95	95	90	90	90	85	85	85
Demand		103	98	102	105	108	121	112	111	109

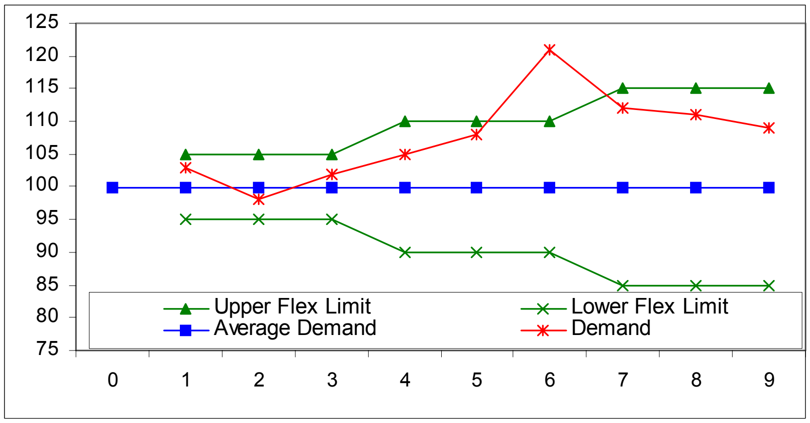

Figure 2.11. Example 1 of Demand Outside the Flex Limits.

Table 2.2. Example 1 of Smoothing the Demand Inside the Flex Limits.

Period	0	1	2	3	4	5	6	7	8	9
Upper Flex Limit		105	105	105	110	110	110	115	115	115
Lower Flex Limit		95	95	95	90	90	90	85	85	85
Average Demand	100	100	100	100	100	100	100	100	100	100
Demand		103	99	105	110	110	110	112	111	109
Excess				1	4	9	11			

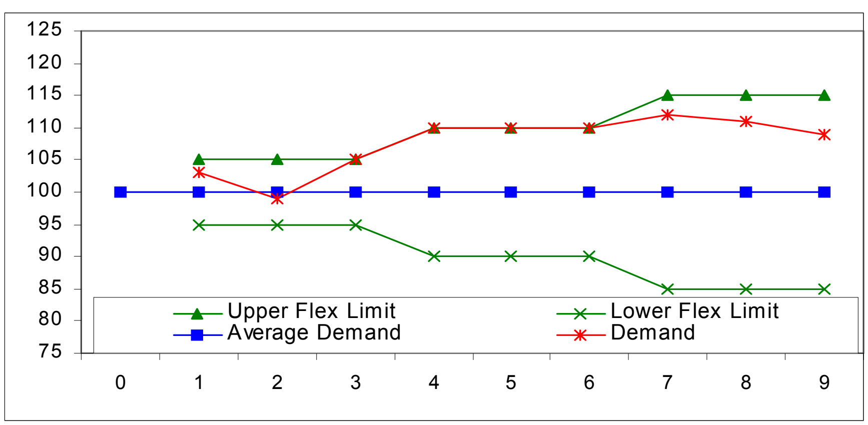

Figure 2.12. Example 1 of Smoothing the Demand Inside the Flex Limits.

If there is not room for the excess demand in the previous periods, then the schedule will result in an error. For instance, if the demand in period six was for 132 units as shown in Table 2.3 and Figure 2.13, the demand would need to be smoothed again. However, as shown in Table 2.4 and Figure 2.14, there are still three units of excess when the frozen demand fence is reached. Therefore, an alert is given to the scheduler who then needs to make some adjustments to the schedule or tell marketing that the sold units may not be produced on time.

The main idea of Costanza's methodology is to keep the demand within certain constraints. These boundaries are formed by the scheduler to minimize the amount of variation in the demand. This methodology of Costanza most closely parallels the research in this dissertation.

One unknown in the procedure is how to determine the length of the flex fences. The company must determine the length of each planning flex fence relative to their strategic objectives. If the company would like to be more flexible, the planning fence may be shorter. On the other hand, if the company wants to reduce variations in the plan, the planning flex fence may be lengthened to deter these fluctuations.

How do we determine the flex limits for the production system? James Reeve (2002) suggests that two factors influence the limits. First, the amount of flexibility allowed is a function of the planning horizon. Usually, companies have more flexibility as they look further into the future. However, as the time approaches, the limits should narrow, which will define the scope of

Table 2.3. Example 2 Demand Data with Flex Limits.

Period	0	1	2	3	4	5	6	7	8	9
Upper Flex Limit		105	105	105	110	110	110	115	115	115
Lower Flex Limit		95	95	95	90	90	90	85	85	85
Average Demand	100	100	100	100	100	100	100	100	100	100
Demand		103	98	102	105	108	132	112	111	109

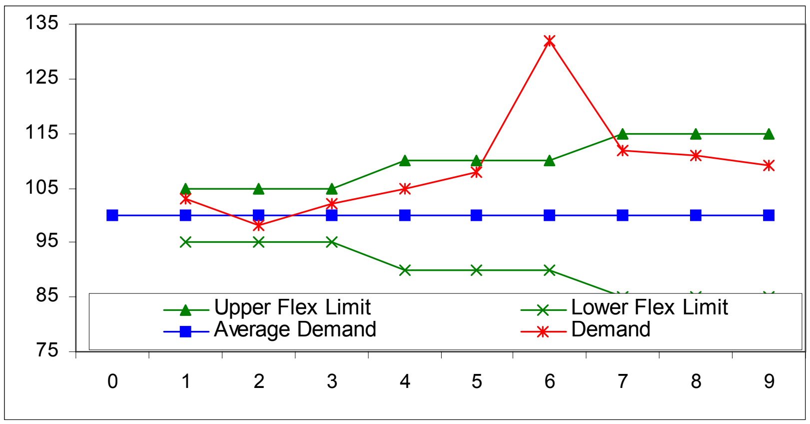

Figure 2.13. Example 2 of Demand Outside the Flex Limits.

Table 2.4. Example 2 of Smoothing the Demand Inside the Flex Limits

Period	0	1	2	3	4	5	6	7	8	9
Upper Flex Limit		105	105	105	110	110	110	115	115	115
Lower Flex Limit		95	95	95	90	90	90	85	85	85
Average Demand	100	100	100	100	100	100	100	100	100	100
Demand	103	105	105	105	110	110	110	112	111	109
Excess		3	5	12	15	20	22			

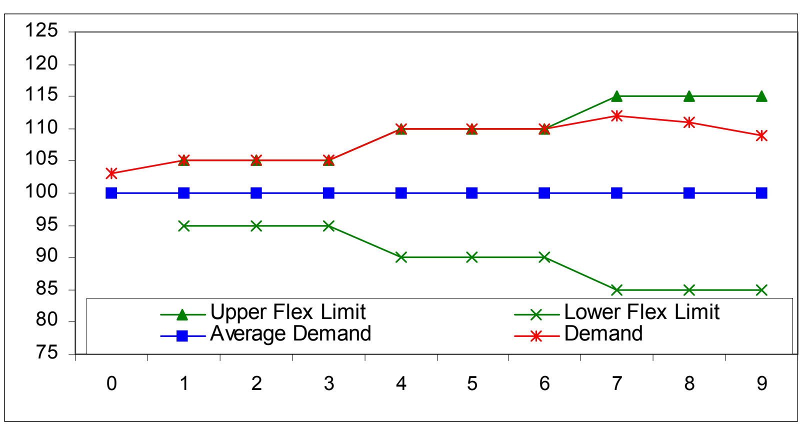

Figure 2.14. Example 2 of Smoothing the Demand Inside the Flex Limits.

production by reducing the demand variation. Also, fluctuations in demand will help determine the bounds set on the capacity. Companies may use historical information to predict demand fluctuations, and hence, place the flex limits around the variation (Reeve 2002).

NDS Systems agrees with the concept of setting minimum and maximum limits for the production quantity to maintain the Rate-Based Schedule. The order quantity should always fit within these limits. If demand is greater than the maximum limit, hopefully the excess demand may be rolled back to the previous time period. If demand is less than the minimum agreed production rate, inventory will be accumulated and will hopefully be consumed in the next time period. However, NDS states that if the limits are not definable, then the manufacturer should produce in Lot-for-Lot sizes. Lot-for-Lot means the production lot size equals the amount of the demand quantity (NDS 2002).

2.3.7 Safety Stock, Customer Service Level, and Flexibility

In RBPS, the production plan and schedule will be kept fairly constant. But in the meantime, demand will fluctuate and may cause the Customer Service Level (CSL) to deteriorate. For this reason, safety stock will be used to ensure that good CSLs are maintained. When the safety stock runs low or when marketing anticipates changes in the market, changes are allowed in the RBPS to meet these needs. This section will discuss the impact of safety stock on CSL and how to improve flexibility and reduce inventory by the strategic placement of the safety stock.

Woodhead declares that the benefits of balanced production and finished goods inventory more than offset the loss of customer service levels (Woodhead 1992). While this is an intriguing look at the reasons for smoothing production, most researchers and practitioners would agree that customer service levels should not be affected by this new initiative. Instead, safety stocks should be allocated for specific products or modules to ensure good customer service levels. However, with this strategy in place, a company may realize that a customer is costing so much money that the manufacturer is not profiting from the relationship. This futile relationship might force the manufacturer to eliminate their affiliation with this customer. Instead, the manufacturer may focus on other customers that will boost the profitability of the company.

Woodhead also claims that capital should be moved from the high volume products to the lower volume products. The reason for this is to provide more safety stocks for the low volume items to ensure good customer service levels (Woodhead 1992). However, the manufacturer may want to pre-build the high volume products because these products are almost certain to sell in the market. Therefore, the company may reserve capacity to produce the lower demanded items when they are ordered, similar to a make-to-order environment. This is especially true when a company is capacity constrained, such as in a seasonal or highly variable demand environment. However, if the low volume products have high profit margins, there probably is sufficient reasoning to hold inventory of these items to buffer against demand variation. Even with high profit margins, a company still might not want to hold inventory when the buffer stock requires a large capital investment, such as the expenditure required for an extra airplane.

Inventory may be reduced while increasing flexibility by the strategic placement of the inventory. Sanford Friedman (2002) provided an insightful assessment of where inventory should be placed depending on the product delivery strategy, as shown in Figure 2.15. The strategic inventory should be placed at the designated time fence for each strategy. For instance, if a company assembles each product to-order, they should keep inventory before final assembly and then build the product according to specifications when ordered. This allows the company to reduce their inventory while increasing flexibility by delaying the point of product differentiation. The delay of product differentiation linked with strategic inventory allows the company to minimize inventory while still achieving promised customer lead times. For the make-to-stock strategy, inventory should be held in finished goods. When the customer places an order, the purchased amount is pulled from finished goods. The scheduler then arranges for the purchased amount to be replenished.

A company must maintain the safety stock levels as the demand fluctuates and as the rate of production increases or decreases. With the safety stock in mind, the company may then analyze the capacity plan with the change in rate per product group, product line, or assembly area. The

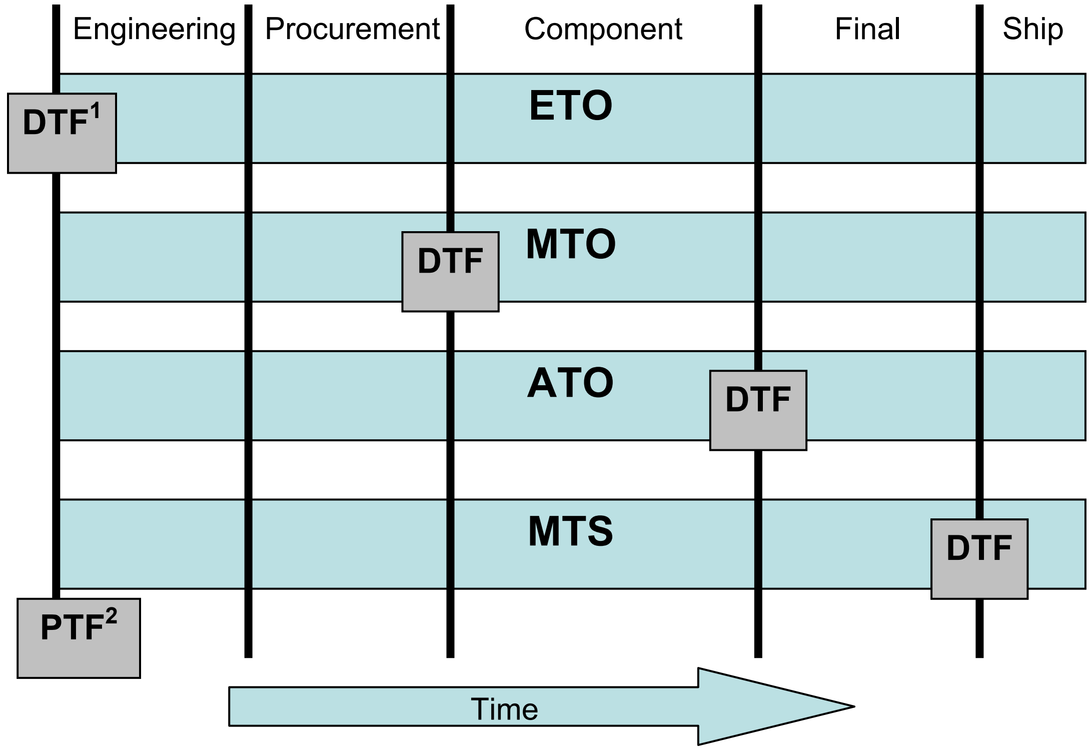

Figure 2.15. Time Fences in Relation to Product Delivery Strategy (Friedman 2002).

[1] DTF is a Demand Time Fence where strategic inventory is usually held for a particular delivery strategy.
[2] PTF is a Planning Time Fence where many decisions like flexibility, capacity, inventory, and delivery is determined.

change in rate may either increase or decrease inventory. The decisions are based on flexibility, demand volatility, supplied component shortages or surplus, and potential market changes.

2.3.8 Impact of Demand

In order to develop a RBPS, the company must first understand its demand information. Conclusions should be based on whether the demand data is dependent or independent. Historical information is also used to make assumptions regarding demand. Also, the company must understand how the demand information is generated and whether the method is an appropriate technique.

Independent demand is information obtained directly from the end-consumer. The company may develop many assumptions regarding trends in the information, but also must be cognizant whether certain marketing strategies caused trends in the information. For instance, many retailers such as Home Depot and Sears receive independent demand information because the end-customers purchase products directly from them. Dependent demand is obtained from a customer who is not the end-consumer. The demand information may be skewed due to purchasing decisions from the customer. These companies are often considered tier-1, tier-2, etc. suppliers. For instance, Craftsman tools are sold through Sears. Therefore, Craftsman receives dependent demand from Sears. The dependent demand may be more volatile than the independent demand for Sears since Sears purchases in quantities deemed from economic studies rather than true demand (Mentzer and Bienstock 1998).

When Maskell discussed the implementation of RBPS, he stated that the demand information must be in fairly consistent quantities. During the analysis period, whether it is week-to-week, month-to-month, or year-to-year, the quantities are to remain rather stable and constant. Even though demand may be influenced by seasonal and market factors, the demand will not fluctuate very much over the analysis period (Maskell 1994). This assumption explains the RBPS's dependency on consistent demand because to maintain a repetitive production schedule, the demand must be predictable.

The manufacturer must also understand the demand, its origins, and how it translates into a production schedule. Two questions should be asked: Does the production information result from historical averages, sales forecasts, or actual customer orders? Are these orders forward orders (orders received before actual demand) or backlog? Once there is an understanding of the demand, the manufacturer may prioritize the information. Priority should be given first to the actual customer orders, then forecasts, which are then followed by projected averages (Woodhead 1992).

Once the company understands where the demand information originates, they should analyze the characteristics of demand. Three patterns of demand will be discussed in the following sections: repetitive, seasonal, and variable demand.

2.3.8.1 Repetitive Demand

The main idea of RBPS is to produce in a repetitive manner so a company may make every product every day, week, month, etc. as deemed necessary. Of course, this environment is more easily implemented in a repetitive demand environment. The RBPS may be limited in a low volume or "lumpy demand" environment (Woodhead 1992). Demand quantities may deviate a small amount from the average or trend, but the quantities remain fairly stable.

The RBPS will take the repetitive demand and level the schedule across the supply chain as shown in Figure 2.16. The goal of this system is to produce a similar amount of product as required by the customer over time, as shown in Figure 2.17. This plan is permeated through the supply chain with plenty of time to plan for products with longer lead times. Then the lean execution system will pull from the quantities developed in the Rate-Based Plan to provide good customer service levels.

OPW Fueling Components actually implemented these ideas with the help of Dr. Richard Schonberger with very little effort. Schonberger agreed that any company that has repetitive demand may implement RBPS. The main idea is to eliminate the lumpy and irregular orders and create a smooth production schedule. In this case study, OPW Fueling Components chose to produce two erratic products to a rate, but sold some units every day. One product is to be made every day, and the other is to be produced once a week due to large setup times (Schonberger 1997).

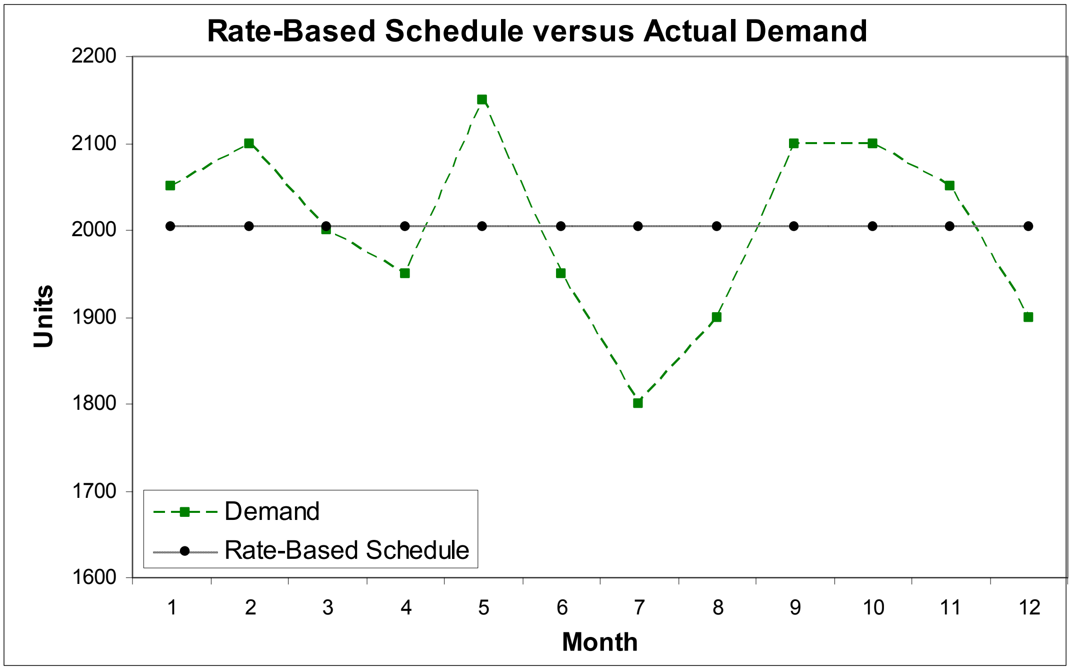

Figure 2.16. Rate-based plan for demand without much variability (Kirby and Toney September 2002 and October 2002).

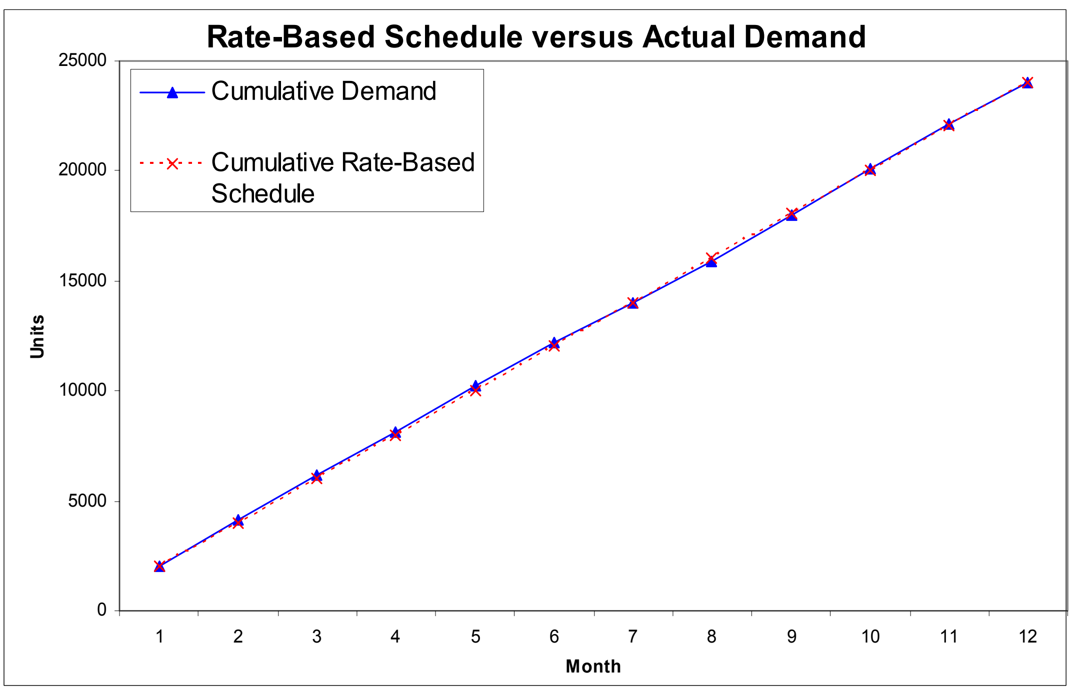

Figure 2.17. Linearity of demand with the rate-based plan over time (Kirby and Toney September 2002 and October 2002).

2.3.8.2 Seasonal Environment

Demand is not always level. Products such as air conditioners (Sutton 1995) and toys (Mullins 2001) have seasonality that does not allow for repetitive supply to the customer. Usually, companies prebuild products trying to anticipate demand. Therefore, seasonal environments require accurate forecasts so the manufacturer is not stuck with large amounts of excess inventory.

In the case of seasonality, the manufacturer may choose one of several options. First, production may chase the demand. As the demand increases and decreases, a company varies the production schedule by the same amount. In most industries, enabling production to vary this much is often a costly decision. A less costly option is to level production by determining a balanced Rate-Based Plan to meet the peak demand. However, some people do not care for this option because it forces the company to hold large amounts of inventory. Another option is smoothing production at a level below the peak demand volume (Brandolese et. al. 2001), which will be called level-chase. Once the peak period arrives, the company will use the prebuilt inventory to fulfill orders and then use capacity to chase the remaining demand quantities. Another option is the prebuild and chase (prebuild-chase) strategy. The difference between prebuild-chase and level-chase is that the former ramps up to build inventory a few time periods before the peak demand. This is an intuitive method and is seen the most in industry.

Chasing demand would be the preferred strategy in a seasonal environment if capacity is not too costly. However, maintaining enough capacity to achieve the peak demand period often requires a large investment in machines, space, temporary operators, and training. Most companies cannot afford to invest this amount of capital in facilities to operate fully for only one or two months. Therefore, this option is not used too often even though it is probably preferred. If a company could utilize this strategy, they could operate in a make-to-order environment even during peak periods.

Leveling the plan during the year is a way to maintain production and smooth the order requirements on the supply chain. The Rate-Based Plan may be utilized for this strategy in the seasonal environment. However, the RBPS also becomes a Rate-Based Schedule because the plan will manipulate what products are built before the peak demand period. Some companies do not prefer this option because their inventory may be costly. However, some companies change the corporate mindset by producing the goods during the entire year. The level schedule helps facilitate implementation of lean execution concepts to become more flexible.

The RBPS strategy requires good forecasts to plan for the proposed seasonal demand. One option here is to pre-build components early and then only add the differentiating characteristic when ordered. For instance, candy may be pre-made and stocked. But when the peak demand period comes before Halloween, the manufacturer may fill the appropriate sized packages with the necessary graphics that differentiate between the customers. Figure 2.18 shows the mentality of building early before the peak, and Figure 2.19 displays the ability to meet the peak demand.

Future demand may not always be accurately predicted. Therefore, the production level may need to shift sometime before the sales peak, as shown in Figures 2.20 and 2.21. If the projected sales are believed to be higher than predicted, the level will increase in slope on Figure 2.21 as the rate of production is increased. On the other hand, if sales will be less than predicted, the production rate will be reduced. It is important to minimize the number of changes to the rate to reduce the bullwhip effect on the downstream suppliers.

However, sometimes the planning cycle does not match the seasonal sales cycle. In this case, the company must manufacture at a level to meet the earlier peak. Then once the peak has passed, production may be reduced to lessen the risk of overproducing for the next sales peak, as shown in Figures 2.22 and 2.23. Some companies are not able to estimate potential sales accurately for the next sales peak. Therefore, they will reduce the rate of production after the peak period, which will decrease their risk. When they are able to predict future sales accurately, production will be ramped up to meet the projected demand.

The level-chase strategy brings the previous two ideas together to benefit from the positive aspects of both. The manufacturer develops a level production rate for the year. However, this rate is less than the necessary amount to meet the peak demand. As shown in Figure 2.24, the Rate-Based

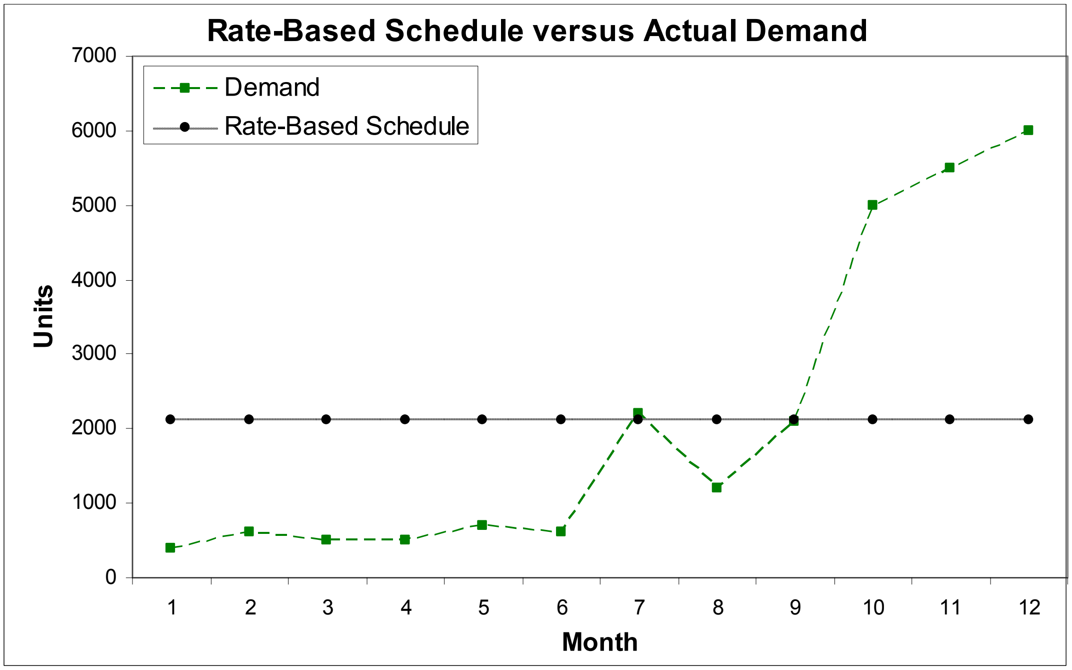

Figure 2.18. Rate-Based Plan in a Seasonal Environment (Kirby and Toney 2002).

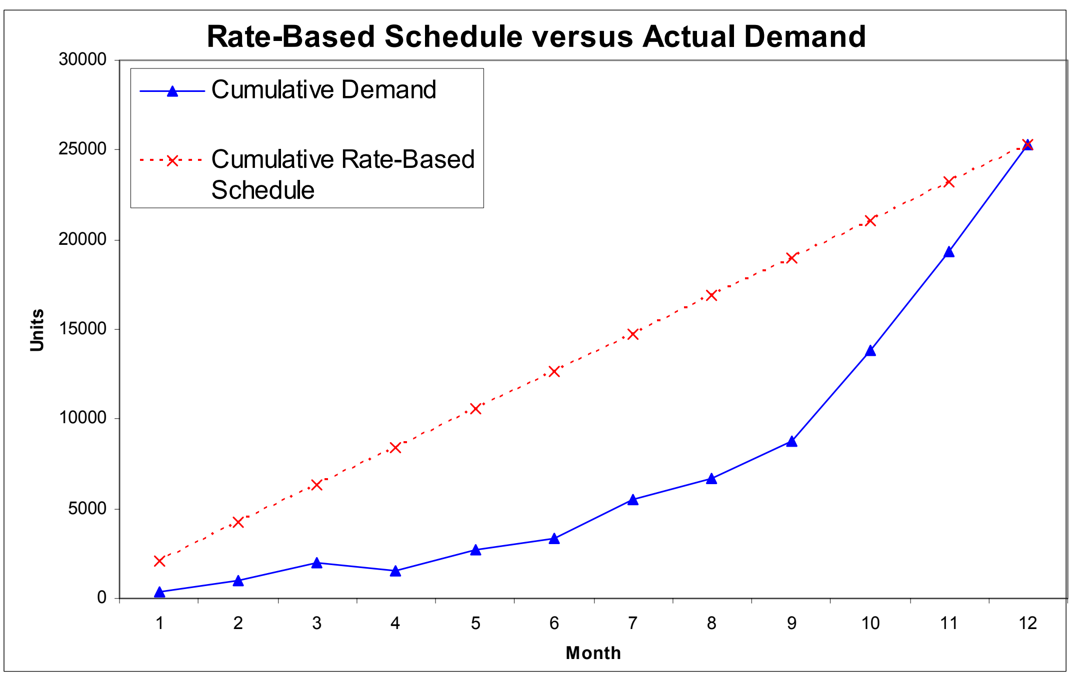

Figure 2.19. Cumulative Data Displays the Ability to Meet the Peak Demand (Kirby and Toney 2002).

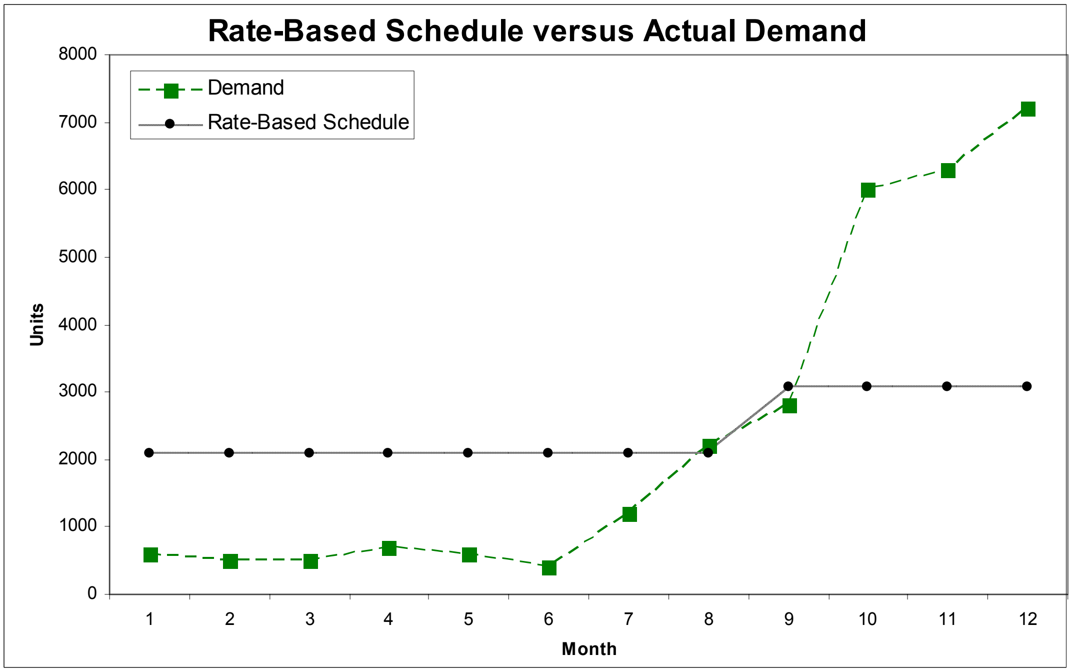

Figure 2.20. Adjustment in the Level of the Rate-Based Schedule (Kirby and Toney, 2002).

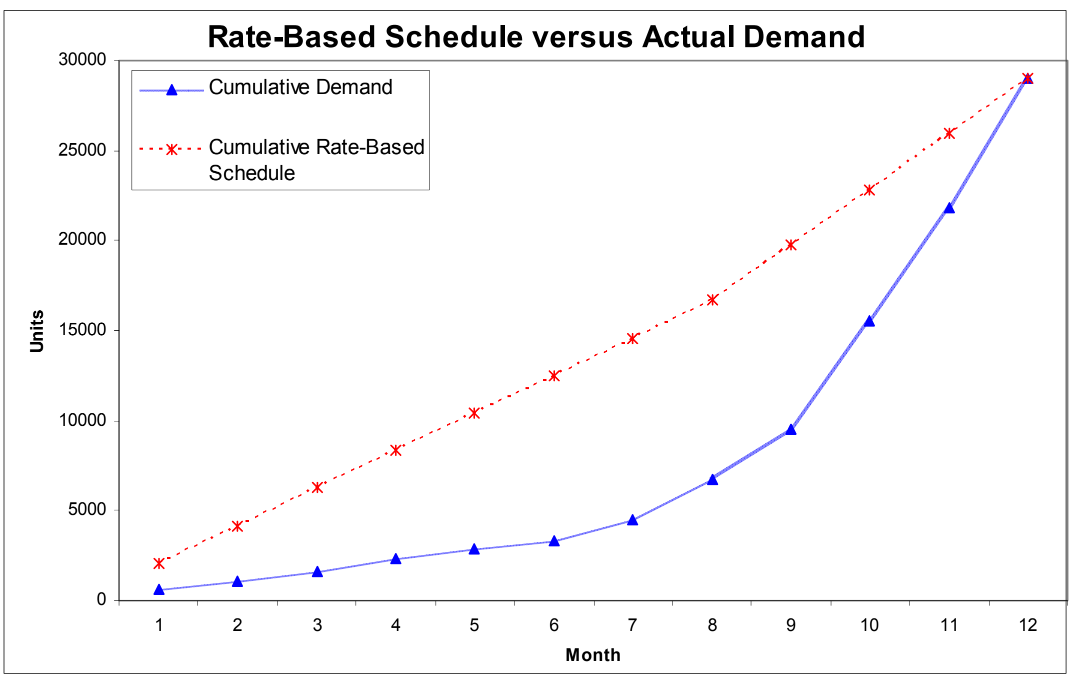

Figure 2.21. Change in Level to Achieve Demand (Kirby and Toney 2002).

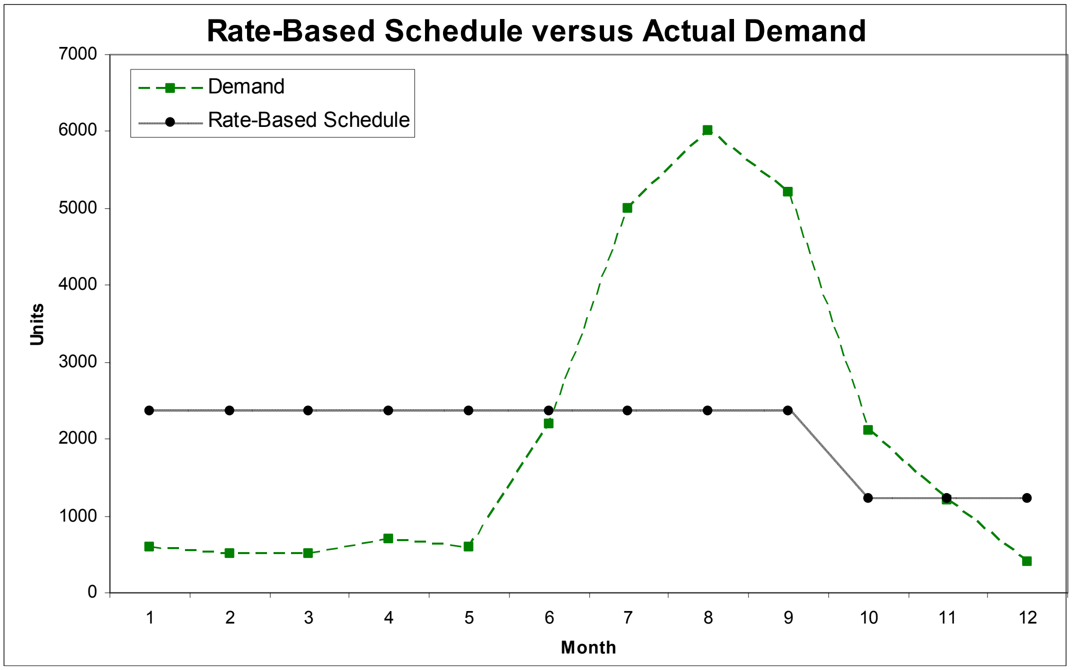

Figure 2.22. Adjusting the Level of the Schedule to Delay Production Decisions (Kirby and Toney 2002).

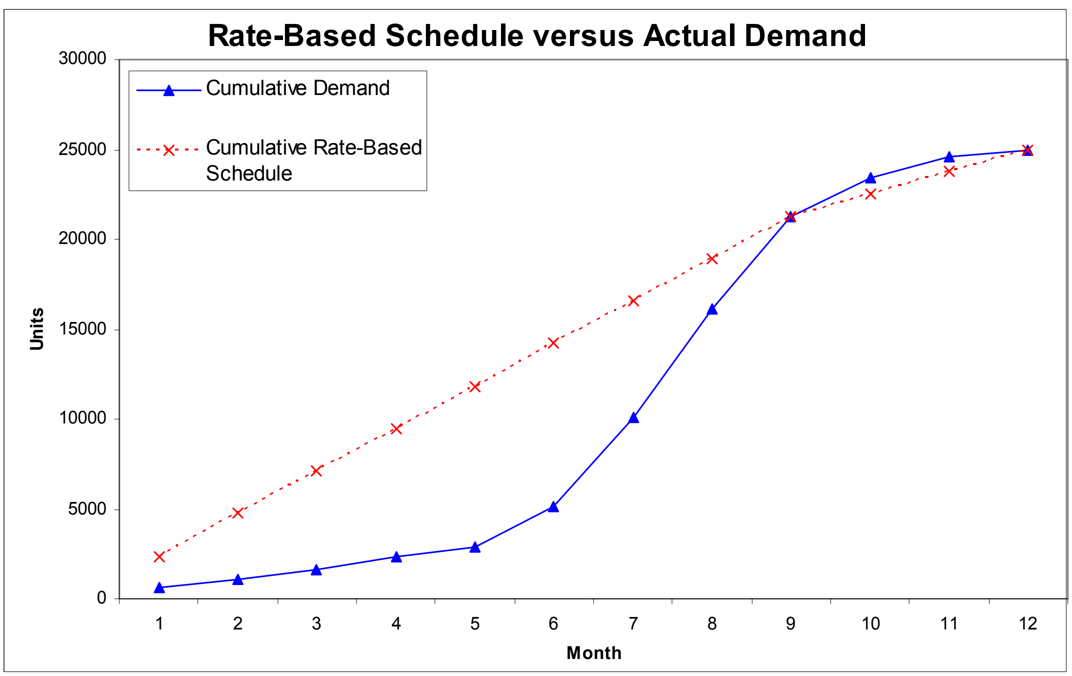

Figure 2.23. Ability to Meet Demand By Adjusting the Level of Production (Kirby and Toney 2002).

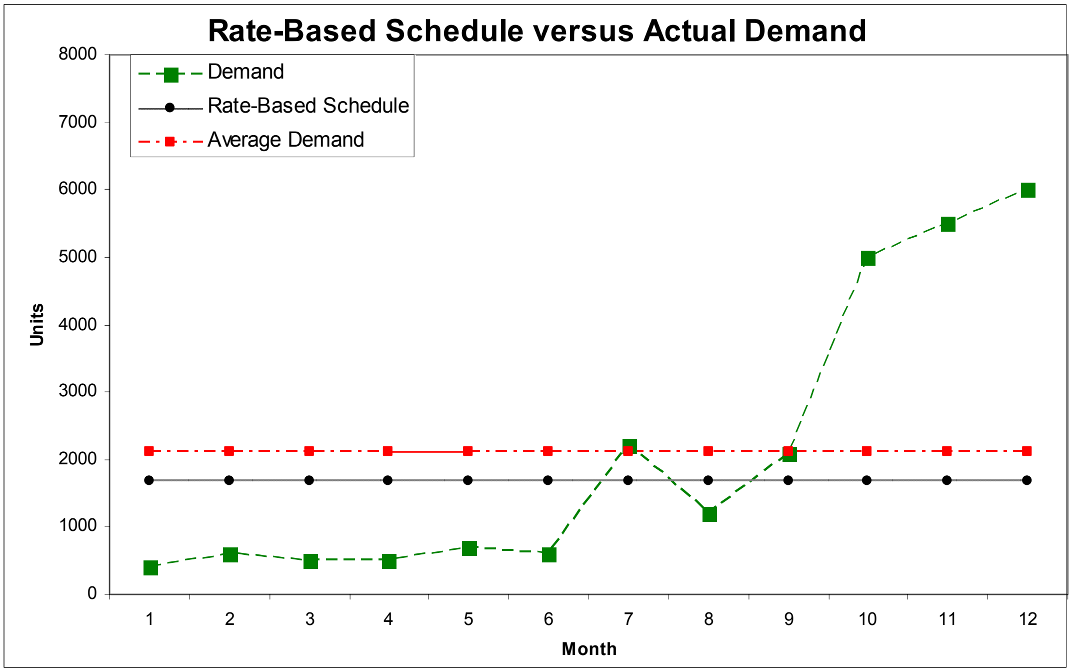

Figure 2.24. Lower Rate of Production for Level-Chase Strategy.

Schedule is below the average demand where the schedule would normally be. Instead, the organization strives for a rate that will produce enough inventory so they may utilize the remaining capacity to produce the remainder of the orders during the peak period (Brandolese et. al. 2001). Figure 2.25 shows that the final demand is much more than the amount scheduled for the Rate-Based Schedule. The difference will be produced with excess capacity during the peak period. The supply chain benefits from a predictable schedule through the year. Also, the manufacturer benefits by not holding as much inventory in stock and instead utilizing capacity to buffer against uncertainty in the seasonal demand quantities.

The final strategy is the prebuild-chase. In this case, the manufacturer ramps up production a couple of time periods before peak demand. Operators must be hired and trained, and materials must be accumulated to ensure that production is possible. As the peak period arrives, manufacturing may ramp up or down depending on sales. This strategy is called prebuild-chase because products are prebuilt just before the peak demand period to develop some prebuilt inventory, and then demand is chased during the peak period. Often, not much planning is involved with this scenario, which is frequently more costly as a result of training new employees, dealing with quality issues, and holding massive amounts of inventory due to poor planning.

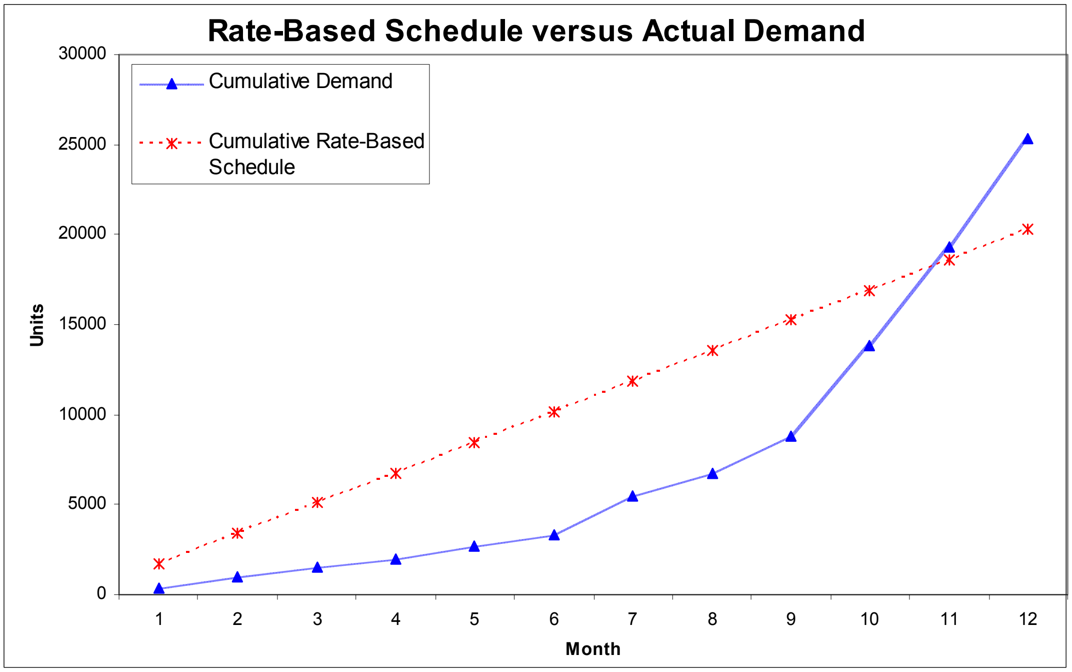

Figure 2.25. Rate-Based Schedule Does Not Meet Demand, Capacity Does.

2.3.8.3 Variable Demand Environment

Sometimes demand is very volatile. Many companies try to chase the demand with little success. Others try to hold large amounts of inventory to buffer against the variation, but often find that they are holding large amounts of the wrong kind of inventory. RBPS may be used once again to try to smooth out the demand requirements on the supply chain.

A level rate of production is maintained to try to balance the supply chain. Excess capacity is utilized to meet the fluctuations in demand. However, the level of production will change based on the amount of capacity needed to achieve the fluctuations in demand. For instance, Figure 2.26 shows that a rate-based plan may be developed to produce what is known to be ordered. In the figure, 15,000 units will be ordered most every period. As a result, a Rate-Based Plan is set at this level so a large amount of inventory is not built. This assumes that the remaining fluctuations will be fulfilled by utilizing the remaining capacity in the production system.

However, there usually is not enough capacity to fulfill all of the variation in demand. Therefore, the Rate-Based Plan is increased to a level determined by the company. The factors involved in the study are capacity of operators and machines, and the amount of materials that may be supplied in each period. As shown in Figure 2.27, the rate was increased to around 17,000 units per period. This rate will allow for some inventory to accumulate over time. However, the inventory will help buffer against the variation. The remaining quantities of orders are built when ordered. This example is

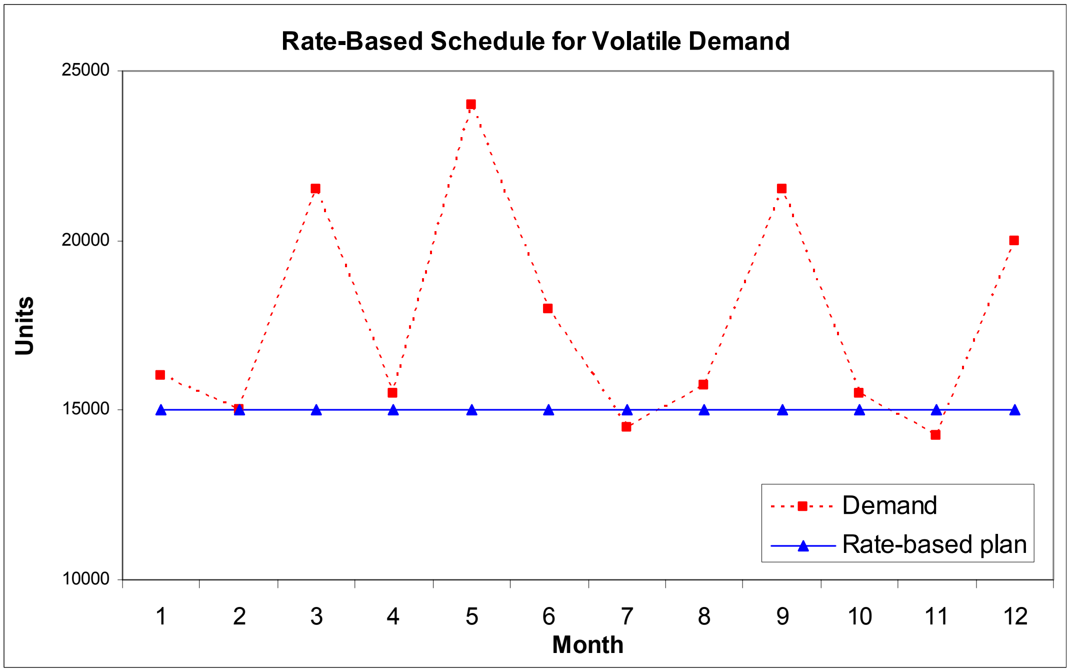

Figure 2.26. Rate-Based Plan for Volatile Demand (Kirby and Toney 2002).

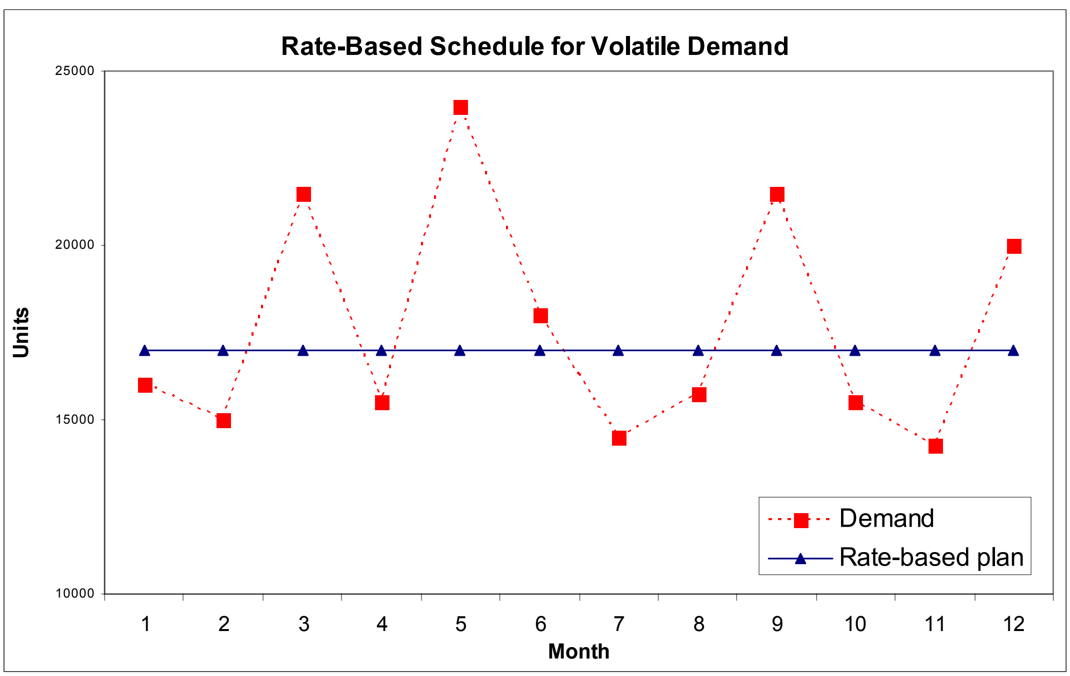

Figure 2.27. Higher Rate-Based Plan to Buffer Against Variation (Kirby and Toney 2002).

assuming that there is enough capacity to produce an extra 7,000 units (24,000 – 17,000) represented in the fluctuations. Usually, this quantity will not be produced due to the excess inventory that is assembled during the periods of low demand.

The Rate-Based Plan in this environment is optimal because there is little risk in producing ahead. As shown in the examples, even if the plan is greater than the amount required, the excess inventory will soon be depleted due to the sudden increases in demand. Once again, this plan should reduce costs due to a decline in variation of the plan through the supply chain, which will reduce the inventory in the supply chain.

2.3.9 Information Flow

As the RBPS is developed, the information must be passed through the supply chain. If the RBPS is kept within the company, the improvements in efficiency and cost may be minimal. To benefit the most from these efforts, the Rate-Based information must be passed on to the company's tier-1 and tier-2 suppliers so everyone in the supply chain understands the objective of the company. Only then may the suppliers also build to a RBPS to improve customer service levels while minimizing cost. If the information is not passed upstream to suppliers, they may still utilize batching methods to meet demand and will still result in the bullwhip effect discussed in section 2.2.

2.3.10 Implementation of RBPS

The purpose of this section is to accumulate many ideas that are necessary to implement RBPS. First, a method for the implementation is provided from Behera and Knight. This will lead to a discussion of many concepts currently used in lean execution systems and how they must be utilized to implement the RBPS.

Kirt Behera (1992) was the first author to provide an implementation approach for RBPS. He asserts that the implementation should follow the following procedure:

1. "Design an approach for JIT and Master Production Scheduling (MPS) systems;
2. Create an Implementation Organization;
3. Implement JIT on two product lines;
4. Implement the JIT pilot quickly using discrete MPS techniques;
5. Implement JIT on the rest of the product lines;
6. Implement Rate-Based Scheduling System; and,
7. Ensure that the system allows for simplicity, flexibility, and visibility" (Behera 1992).

The main point of this procedure is to understand that many methods have to be put in place before a Rate-Based schedule may be implemented. The JIT concepts must first be applied to a couple of lines to train the workforce and to prove to them that JIT technique works. Once the lines have become flexible utilizing JIT, then the RBPS method may be implemented.

Knight confirms the ideology that a plan may be developed into a RBPS by converting the plan into a rate "production line, by day and by product." The MRP (Material Requirements Plan) is used to plan the process. A rate is then developed to provide to the shop-floor. Then, manufacturing executes the rated plan by using a pull execution system as shown in Figure 2.28 (Knight 1996).

One way these two methods differentiate is that Knight uses the help of MRP systems to develop the rated plan and schedule. Knight's figure provides the assumption that the RBPS must be implemented first before the lean execution system may be realized, which is supported by Maskell (2001) and Reed (2002). On the other hand, Behera does not discuss MRP at all. Also, Behera proclaims that the pull execution systems should be developed before the RBPS may be achieved.

Even though the concept of RBPS is very simple, Schonberger believes that not many companies have implemented the idea. One reason may be that the benefits are not as tangible as other improvements. Also, people might be hesitant to produce according to a rate rather than orders (Schonberger 1997).

2.3.10.1 Explode BOM

One aspect of the MRP system is still applicable to the Rate-Based Plan. MRP is good at exploding the demand requirements through the Bill-of-Material (BOM) to communicate customers' needs to their suppliers. RBPS

The Phases of Supply Chain Management

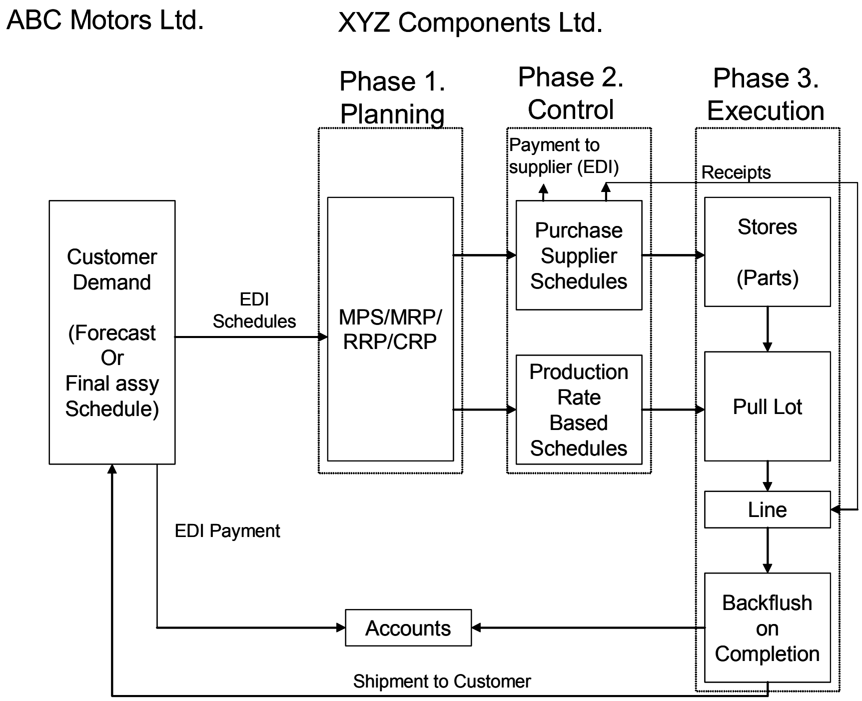

Figure 2.28. The Phases of Supply Chain Management (Knight May 1996).

may still use this concept to convey the demand requirements to the suppliers. The difference is that the RBPS will not use the lead time offsets that MRP does (Reeve 2002). A company must determine how often the RBPS will distribute the requirements. But when the rate changes, the new mix of component parts required for production must be sent to the suppliers to help the end supplier maintain their high customer service levels (Maskell 1994).

The key question is how many suppliers need this demand information. The goal is to communicate this information to as many suppliers as possible so that everyone has the same objective in the product delivery system, which will reduce the bullwhip effect described earlier. In fact, the goal of the RBPS may even be to smooth the requirements on the supplied components rather than on the Original Equipment Manufacturer (OEM) in order to ensure level planning and cost reduction at the suppliers. Smoothing the requirements on the suppliers becomes much easier if the OEM is very flexible and in tune with the customers' demand. The optimal situation is when the OEM produces according to the customers' need, not according to what the OEM thinks the customers want.

2.3.10.2 Blanket Orders

To fully utilize the benefits of RBPS, companies should develop blanket orders with their suppliers. A blanket order is a contract for a given amount of time that declares that a company will purchase a certain amount of products from the supplier for a set price. The idea is to reduce the purchasing burden on the company (Anderson 1994). Blanket orders are preferred because it reduces administration overhead, hassling with quotes, and the supplier may better anticipate production and inventory needs (*Industrial Distribution* 1989). With the blanket order, these purchases have already been approved and the quantity needed from the supplier is deemed by the RBPS, pull execution system, or the Finite Capacity Scheduling (FCS) system used to execute to demand.

Brian Maskell uses blanket orders to eliminate work orders. Maskell proclaims that work orders should be eliminated and then replaced by a RBPS system or no scheduling at all. In the RBPS environment, cells are scheduled by demand rates rather than work orders. The assumption is that the production rate is synchronized with the demand rate. The repetitive rate will help the manufacturer smooth production of each product. Then over time, the scheduling process will be eliminated as the manufacturer becomes more flexible. Instead, the customer orders pull the product through the process to ensure what is made is what the customer wants today. Maskell further explains that the demand and RBPS may be run against the MRP instead of tracking production orders (Maskell 2001).

However, Behera still believes that the workorders are needed in a RBPS system. The workorders are still initiated by MRP, which also instigates material orders from suppliers while utilizing a blanket order. Then, MRP may replicate the rate-based system by initiating “weekly net rate production schedules," which pull from each sub-assembly workcell (Behera 1992).

2.3.10.3 Lean and Finite Capacity Scheduling

Lean and Finite Capacity Scheduling (FCS) are the two most efficient methods for executing schedules today. Lean uses the help of fast changeovers to reduce batch sizes and therefore lead times of production. This allows increased flexibility that may fulfill the customer's needs by pulling products through the system. FCS, on the other hand, uses batching techniques but always has real-time information to stay up-to-date. If a machine fails, the FCS system realizes the fault and reschedules the facility to ensure that the orders remain on time (Plenert and Kirchmier 2000).

Researchers agree that JIT and lean execution systems[3] must be implemented in a repetitive environment. Therefore, the RBPS environment will provide a better atmosphere for lean execution systems. The predictability and stability of the demand offers great advantages in promoting better efficiency of the production system (Monden 1998, Behera 1992).

Also, lean is very flexible as it holds inventory in strategic locations. When the inventory is needed, it pulls the inventory to build according to demand. This adds flexibility by not specifying certain components for a given order.

The lean concepts of kanbans and mixed model sequencing also drive

[3] JIT and lean execution systems will be referred in general as lean execution systems.

the repetition of the production system. Behera (1992) states that the success of the kanbans in a lean system is dependent on repetitiveness of the production. Luckily, mixed model sequences often promote the uniformity and repetition of production schedules in lean systems. Mixed model schedules attempt to level the demand requirements on the component parts and therefore, the suppliers (Monden 1998).

FCS does produce according to orders, and alienates the concept of producing to a rate as discussed in Schonberger (1997). However, FCS schedules according to the status of the system, not according to assumed lead times. Therefore, the FCS system may allocate these orders to the timetable to maintain the rated plan and schedule.

2.3.10.4 Management Commitment

RBPS is a strategic initiative that will require many changes in the organization. Management must commit the organization to implement the ideals of RBPS or the initiative will fail. Tactical changes with production strategy and incentive systems may only be performed at high levels of management. Also, “what if” scenarios may be analyzed very easily from this high-level view of the system to ensure the feasibility of the project (Ptak and Schragenheim 2000).

Schonberger attributed much of this success of his implementation at OPW Fueling Components to the cross-functional managers that helped develop the RBPS. Management’s commitment to the success of the project was necessary to push the project to completion. However, in hindsight, Schonberger wished that he had included the front-line workers in the analysis so they would have understood what the company was trying to accomplish (Schonberger 1997).

On a more positive note, Woodhead declares that the production system is much easier to manage when production does not vary. The rated goal of production is easy to understand and employees quickly recognize when problems will not sustain the rate. Also, the rate may be easily changed as demand shifts over time. Rather than following orders to predict when the units will be shipped, the rate allows everyone in the organization to take the appropriate actions to ensure good customer service levels (Woodhead 1992).

2.3.10.5 Small Batches

Companies should produce in smaller batches to increase flexibility while decreasing lead time. Production is often erratic when companies manufacture products in large quantities that do not replicate demand. As the batch sizes are reduced, production may emulate demand better and the production requirements on the facility become fairly stable (Maskell 1994, 83-91). Manufacturing in small batches leads to the same products being made every day or every other day, which is closer to a rate and the ideals of RBPS.

RBPS is utilized to smooth the flow of production and to orchestrate production with actual demand. If a company has demand of 100, 200, and 50 units a month for products A, B, and C respectively, then the company needs to always produce in this ratio. The goal of RBPS is to reduce the batch size as much as possible by making the production process more flexible through setup time reduction, point-of-use materials storage, visual controls, increased asset reliability, and other lean tools. At first, a company may reduce the ratio to 50:100:25 and repeat this production schedule twice per month. The main idea is to change from a monthly schedule to a weekly, or half-week, and then to a daily schedule (Garg 2002). The ultimate achievement would be to reduce the ratio to 2:4:1 and repeat this sequence fifty times a month or more than two times per day (assuming a 25 day month) (Maskell 1994).

Producing in smaller batches will also minimize inventory. Stemming from the previous example, originally, a company would have to hold enough inventory to buffer for over a month. As the batch size is reduced and products are produced more often, inventory may also be reduced. If a company achieves the ability to produce in the ratio 2:4:1 two times a day as shown in the example, they would only have to hold roughly enough buffer for that day. This is a major factor that will allow companies to implement lean execution systems that feed off of RBPS.

2.3.10.6 Daily Deliveries

As batch sizes are reduced and production increases flexibility, companies should begin using daily deliveries. Manufacturing traditionally filled a truck with a large batch of a particular item to achieve economical transportation rates. Now with the small batch sizes, a company may fill a truck with many items that are being shipped to a particular customer.

With the daily demand deliveries, companies are able to satisfy demand within a quicker timeframe. For instance, Toyota develops a schedule and expects their suppliers to meet the schedule in a short lead time (Minahan 1998). Gerald Braga, corporate manager of procurement and supply chain management of Toyota Motor Sales USA Inc., stated, "As the demand occurs, the information will transmit on a daily basis to our suppliers, and they will respond to that demand with daily deliveries to our distribution points in North America" (Teresko 2001). Without these daily deliveries, Toyota's supply chain would never be able to improve their flexibility while minimizing the inventory in the supply chain.

2.3.10.7 Forecast

The RBPS environment requires good forecasts. A company must understand what will be consumed, and when it will be consumed. Many people say that forecasts are always wrong (Wiersema 1997, *Purchasing* 2002). This is often because the customer analyzes the demand data and adjusts the forecast with inaccurate information. Then, a schedule is made based on the inaccurate information and the component requirements are sent to the suppliers. These suppliers then try to develop a forecast off of a skewed schedule, which causes more errors in the forecast. The more companies in the supply chain that change the forecast and schedule, the higher the probability that the resulting forecasts will be wrong.

Forecasts are used for planning and are essential to RBPS. Several functional units of the organization should work together to ensure that the forecast is accurate and may be achieved by production. The forecasts will predict increases or decreases in the demand so a company may make appropriate adjustments to the rate (Reeve 2002).

Then, the forecasted demand will allow creation of the plan for the end items at the Original Equipment Manufacturer (OEM) and then explode the demand information for the required materials through the Bill of Materials (BOM). The goal is to create a level production plan for the suppliers because the end item schedule is level. From this plan, the lean execution system will pull what is required. Therefore, the production schedule is based on real demand, not what the sales department thinks the customer needs. Also, the RBPS has helped the suppliers forecast what the OEM will need.

Jerry Wei and Gary Kern (1999) evaluated the impact of forecasting on scheduling in the production process. The reason for this study is to understand the impact of long-term forecasts on strategic decisions like budgeting, facility investment, capacity, and workforce planning. The authors agree that forecasts are usually incorrect, but may be very helpful in the strategic planning of a company. The basis of the study is that JIT environments rely on a level master production schedule that developed a Rate-Based MPS. Therefore, the paper was to determine if better forecasting models improve the performance of JIT systems when Rate-Based MPS are used.

2.3.10.8 Integrate with Supply-Base

As the suppliers become more flexible and are able to provide their customers with better service levels, the customers start to trust the manufacturer more. Hence, a new relationship and partnership between the two companies is developed. The customer will then trust the supplier better and may then share the projected demand information. Once the trust has been established and information is shared, suppliers receive actual demand patterns from the end consumer, which therefore allows them to create better forecasts.

The benefit of the RBPS is to ensure that even the slightest of changes will not flow through the supply chain and cause the bullwhip effect as discussed in Section 2.2. Instead, the RBPS will ensure that the schedule is maintained through its own production system and also the suppliers' systems. With this visual plan permeating the supply chain, suppliers may tell the OEM whether or not they will be able to meet the schedule. The newly enabled communication between the OEM and the supplier is probably the greatest benefit of RBPS.

The RBPS also helps with the long range forecast and plans for the supply chain. Since communication has increased through this process, the suppliers are always aware of special causes regarding changes in the demand information. These causes may be sales, new marketing schemes, holidays, etc. Regardless, everyone must be on board and understand why there are fluctuations in demand.

Simplification of production may be passed along through the supply base. Once the rate is declared, it is sent to the suppliers by exploding the rate through the BOM. For instance, an automotive manufacturer is going to make 1,000 units per day. Since there are five tires on each car (four tires plus the full-size spare), the consumption rate of tires is 5,000 units per day. The supply chain may then build to the rates determined for their component rather than building to a production schedule with lead time offsets (Reeve 2002).

Also, the forecast may help the logistical portion of the supply chain. The rate is used by supply chain managers to reduce the distribution costs. As the rate is cyclically sent to the distribution centers or warehouses for restocking, a repetitive pattern develops. Hence, transportation planning becomes much more predictable with these rhythmic shipments.

JLG Industries in McConnellsburg, Pennsylvania adopted the RBPS policy. From the Best Manufacturing Practices (2001) article, JLG focuses more along the area of purchasing rather than production. JLG communicates with their suppliers utilizing a moving forecast. The suppliers then ship components to JLG in small quantities. To ensure that costs are minimized, JLG has contracted a truck service to make milk-runs to their suppliers, which allows JLG to maintain control of its repetitive supply. Therefore, JLG was forced to minimize and certify the number of suppliers that are used. This has created a partnering relationship between JLG and its suppliers. An MRP system still generates quantities for the suppliers based on usage rates and replenishment times. A 52-week rolling schedule is developed and sent to the suppliers every other week. However, material releases are faxed to suppliers every week that designate the quantities that will be picked up on the milk-runs.

2.3.11 Production Strategies

RBPS may be used differently depending on the type of production strategy that is used to meet customer demand. The first scenario discussed allows a company to build their finished goods inventory before the products are ordered. The customer may then pull from the finished goods when needed, which will be referred to as Build-To-Stock (BTS). Another method is called Build-To-Order (BTO). Companies may hold inventory of component parts in their facility. When a customer submits an order, the production system assembles the product according to the customers' expectations. The following sections will elaborate on how to implement RBPS in BTS and BTO environments.

2.3.11.1 BTS

Schonberger (1997) and Woodhead (1992) visualize RBPS as a make-to-stock[4] strategy. Manufacturing will produce to a given rate that will fill a buffer stock of finished goods inventory, as shown in Figure 2.15. Then the customer may pull from this inventory as needed. Therefore, if sudden spikes in demand occur, production will not react to fluctuations in demand to fill the orders because the inventory will buffer against this demand variation (Schonberger 1997).

However, if there are many end-item SKUs, then the company may produce as a build-to-stock environment to a certain point in the process. This point is determined by the lead times promised to the customer and the point of product differentiation in the process. As discussed by Srinkanth and Umble (1997), companies may reduce the amount of inventory in the production system by maintaining a level of WIP as early in the process as possible as shown in Figure 2.29. This point of strategic WIP may be determined by customer service lead times. If the quoted lead time for the customer is 1 week, the WIP must be held before operation 4. However, if the lead time is 2 weeks, we may hold inventory before operation 3, which may allow a decrease in WIP by 50% and changes the production philosophy to be similar to BTO.

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[4] Build-To-Stock is also known as Make-To-Stock (MTS).

2.3.11.2 BTO

As the point of product differentiation is pushed back toward the beginning of the process as explained in Figure 2.29, the RBPS will arrange for the number of component parts made in the facility and waiting in WIP. Also, an RBPS will be developed for the component parts or subassemblies that may be added to the product to distinguish between end-item SKUs. Because the RBPS is developed for the components, the requirements are smoothed on the value stream. Then, the components are assembled by using a customer order to identify each added feature.

However, if the company builds-to-order and the promised lead time is shorter than the manufacturing lead time, the RBPS may be established further upstream in the subassembly area or at the component level. Then actual customer orders will pull the appropriate subassemblies or components based on the customers' requirements. When the manufacturing lead times are shorter than the promised lead times, the manufacturer may simply order materials from the supplier as needed.

2.3.12 Benefits

The RBPS results in many benefits listed by authors. Some of these include reduction of inventory, minimizing overhead, and better control of the facility and supply chain. This section will discuss these benefits in more detail.

By implementing RBPS, JLG has reduced its inventory by more than $12 million while production has increased five-fold. Therefore, there is less

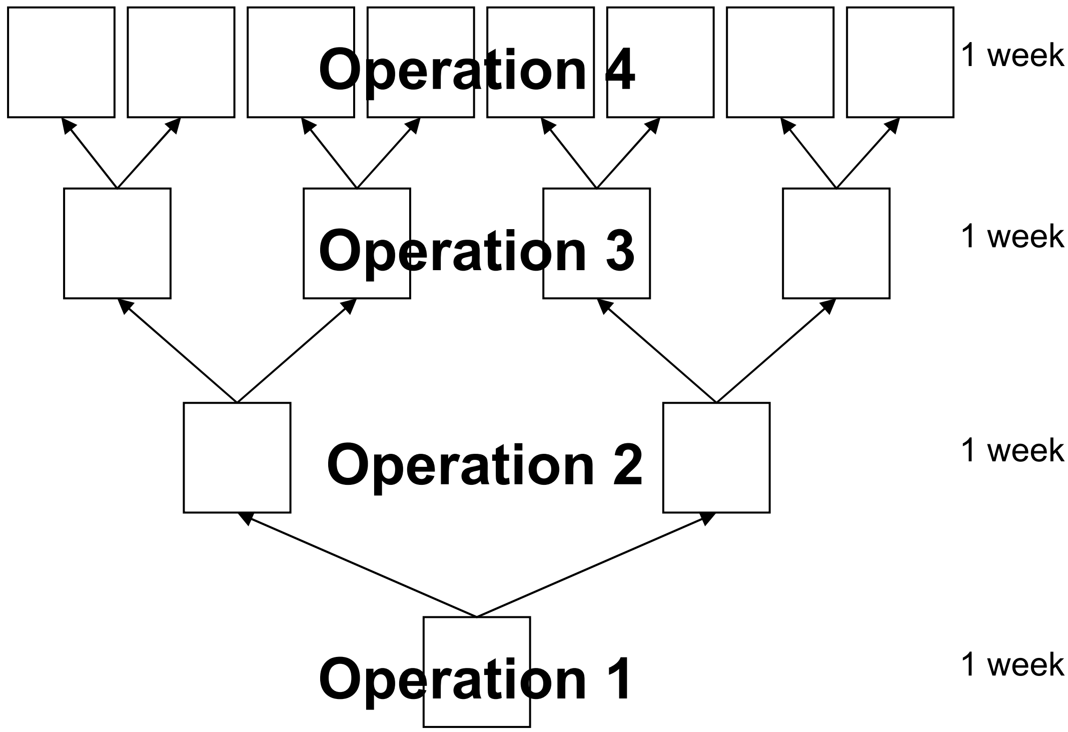

Figure 2.29. Delaying the Point of Product Differentiating.

handling of inventory, less damage, shorter lead times, and more flexibility. Annual purchase orders with the help of faxed order releases have also minimized the clerical overhead. In the meantime, suppliers have reduced their inventory and overhead costs. They have also benefited from more accurate planning due to fewer schedule changes. Overall, the business of supply to JLG has become much easier, which has helped relations between JLG and its suppliers (Best Manufacturing Practices 2001).

Schonberger was pleasantly surprised by the results of his RBPS implementation at OPW Fueling Components. Unexpectedly, the amount of finished goods inventory did not increase, which some people feared might happen. There was also an improvement in on-time performance. Most importantly, the customer service level had risen 40%. Schonberger supports this effort by stating the benefits are incurred by eliminating the inventory through the supply chain due to the smooth production schedule. (Schonberger 1997)

Woodhead proclaims that several benefits may result from stable plans and balanced inventory levels. The capacity planning process becomes one-dimensional since a company may now discuss production in terms of load per standard time period. The simplification allows easy management of the system since supervisors may easily determine if the rate is within capacity (Ptak and Schragenheim 2000).

Also, Woodhead declares that the benefits of balanced production and finished goods inventory more than offsets the loss of customer service levels

(Woodhead 1992). This may be true theoretically, but practitioners would probably state that customer service levels should not be diminished by RBPS. When stating these benefits, Woodhead is only looking within the walls of the production facility without understanding the effect on the customers and suppliers. This assumption should be supported by understanding the effect on the costs in the supply base before coming to these conclusions. However, the decision may be made to cease doing business with a customer if costs increase dramatically due to a large amount of volatility in the customer's demand patterns.

2.4 Lead Time

The concept of Rate-Based Planning and Scheduling will work well in the marketplace. However, the impact of lead times must be understood. Often when utilizing RBPS while lead times occur, the schedule is frozen to account for variables such as transport time on a ship or by rail. With the decrease in flexibility, inventory must be held to buffer against the demand variation. This section will review the current literature regarding lead times to provide a basis for implementing RBPS in this environment.

2.4.1 Strategic Use of Inventory with Lead Times

Research has been performed to understand the impact of increasing lead times on inventory to buffer against demand variation. This is a real scenario as companies are moving production overseas to reduce labor costs

(Grossman and Jones 2002). As a result, more inventory is held in the supply chain to ensure desired customer service levels, which decreases the flexibility and competitive capability of the company (Pan and Yang 2002, Harding 1995). The problem is that companies try to increase their gross margin by awarding the cheapest source with the contract. Buffering supply chains with long lead times may result in extremes of 33 percent of products being marked-down or stores stocking out, while only a third of consumers are able to find what they actually want on the shelves (Fisher et. al. 2000, Mattila et. al. 2002). To justify using the cheaper supplier, a company must make sure that the additional logistics and inventory costs, with increases in stock outs and markdowns, will still cost less than an expensive supplier with a good performance record (Mattila et. al. 2002). This section will review studies analyzing the strategic use of inventory to buffer against lead time.

In an article by Stalk (1998), he describes the order process that causes lead times. The goal is to achieve a lead time of zero. In a provocative statement, Stalk asserts that if zero lead time is achieved, a company only has to forecast for the next day. Traditionally, companies were content with producing to a forecast. Now, companies are trying to reduce the lead time so they don’t have to rely on forecasts and may produce only what is ordered. To reduce the lead time, manufacturing usually corrects their lead time issues, and then sales and distribution align their processes accordingly. Reducing lead times and increasing flexibility has to be a company’s overarching strategy.

Lead time between stages in the value stream is of great concern. The longer the lead times, the less flexible a supplier can be to meet the needs of the customer. The customer may want quicker lead times than the supplier may provide. The only way to support these demands is to protect against the lead time through the use of buffer inventory (Muckstadt et. al. 2001, Kekre and Udayabhanu 1988). This strategy to achieve these commanded short times is very common in today's marketplace. Brandolese et. al. (2001) studied a three stage system with two warehouses to better grasp the amount of inventory needed in this situation. However, this is only possible in a Build-to-Stock (BTS) environment.

When products are built using the Make-to-Order (MTO) strategy, it is harder to anticipate future demand and hold inventory for that demand. The inventory could be expensive and risky since the customer may not choose to order a particular configuration again. Use of reliable forecasting techniques is mandatory to develop accurate production schedules (Enns 2002). Realistically, companies may not be able to develop anticipatory production schedules. Therefore, they must wait for the order to be received before production on that item is initiated.

Oke (2003) explains that in an MTO environment, demand may be adjusted by varying the lead times. If demand is high, longer lead times are quoted. Conversely, shorter lead times are quoted when demand is low. This strategy would allow a company to match its set capacity with the current demand levels. However, even Oke admits that this strategy is not conducive for today's customer friendly environment.

In the environment of building only to received orders, the promised lead time must always be greater than the assembly flow time (Brandolese and Cigolini 1999). The due date quoted to the customer will have a significant impact on whether the customer submits an order to the supplier (Duenyas and Hopp 1995). Weng (1996) devised a methodology that exploits lead time and order-acceptance rates to improve the utilization of manufacturing while also increasing profits. A technique that is used more often employs the theory of postponement. Inventories are held earlier in the process which reduces their value and the cost of carrying these parts. More importantly, the manufacturing lead time is reduced since some of the assembly has been performed. Then, when an order is placed, the final configuration is determined and produced. This ensures lower inventory levels while providing shorter quoted lead times (Rabinovich et. al. 2003, Srinkanth and Umble 1997, Enns 2002).

Hopp and Roof Sturgis (2000) developed a tool to quote the shortest possible lead times as a function of inventory. This technique is also dependent on flow time, as flow time is directly proportional to inventory. The technique uses a control chart method to adjust the parameters over time.

Harvey and Snyder (1990) also analyzed a situation with lead times. They studied the impact of factors like short-term growth, seasonality, and the consequences of business cycles. The results showed that the traditional lead time variance formula underestimates the variation in the process. This underestimation occurs when the demand is nonstationary and simple exponential smoothing is used (Snyder et. al. 1999). Only after taking into account the demand model and the lead time distribution can we understand the significance of the underestimation (Harvey and Snyder 1990). Chatfield and Koehler (1991) also discussed the inadequacies of previous research. They found that others were employing the forecast of the total demand over the next h periods. However, these researchers should have used the single-period forecast for h-steps in the future. A later study worked to rectify the underestimation of the uncertainty of the total lead time demand. Traditionally, the standard deviation of lead time demand was computed by multiplying the standard deviation of the one-period-ahead forecast error times the square root of the number of lead time periods $\left(\sigma\sqrt{L}\right)$. This technique is only accurate when the demand is stationary, meaning that the average demand will not change over time. The result was a formula that incorporated the magnitude of the smoothing constant in simple exponential smoothing and the length of the lead time (Snyder et. al. 1999).

The goal in today's economy should be to minimize the lead times. By reducing lead times, the bullwhip effect and finished goods inventory may be reduced significantly (Ryu and Lee 2003). Through the use of JIT and lean techniques, companies may reduce the lead times to attain a competitive advantage (Rabinovich et. al. 2003). Also, customers may reduce the lead time to receive product by paying extra for the product (Pan and Yang 2002). According to Wu (2001), reducing lead time is the core factor to improve productivity. The benefit of less inventory and quicker products to the consumer more than pays for the extra expense incurred (Goldratt 1997). A question may be posed as to where is the greatest benefit for reducing lead times. According to Graves (1999), a greater impact may result from reducing the lead time of the downstream systems first. Reducing the lead time upstream does not minimize the bullwhip effect at all since the varying demand is still received from the customer. In order to reduce the impact of the bullwhip effect from downstream, the customer may reduce lead times or change their ordering policy to smooth its response to changes in the forecast.

2.4.2 Lead Time Behavior

As stated previously, companies are trying to reduce costs and burden by moving production overseas. However, there are three key issues with this mentality. First, companies may not be able to benefit beyond the initial savings gained from moving. Second, there is no guarantee that the savings will be the same in the future. And lastly, companies often overlook the additional costs incurred with this strategy such as procurement, verification, and inventory costs (Grossman and Jones 2002).

As described by Ouyang and Wu (1997), lead time consists of the subsequent components: order preparation, order transit, supplier lead time, delivery time, and setup time. Variations in these components may vary the lead time. However, lead time is controllable. By utilizing a crashing cost[5], lead time may be reduced. The objective when eliminating lead time is to minimize the total expected cost by weighing the ordering cost, holding cost, and the crashing cost while maintaining a given service level.

When lead times exist, customer service level is highly dependent on the forecast. However, the forecast accuracy will decline as the lead time grows (Stalk 1998, Vendemia et. al. 1995). The magnitude of the forecast error increases exponentially as lead times increase (Harding 1995). It is increasingly hard as many industries develop their purchasing strategies seven to eight months before the peak season. The uncertainty increases the potential for risk and increases the chance of a rapid supply chain stealing market share (Mattila et. al. 2002).

As the uncertainty in demand increases, companies buffer against such variability with either safety stock or safety lead times. Safety stock will shield the company against the demand fluctuations around the mean. Safety lead time, on the other hand, guards against uncertainty in completion time. The hope is that with an increase in safety lead time, production has more time to finish the product to ensure that it is on time (Buzacott and Shanthikumar 1994, Enns 2002, Huge 1979, Kekre and Udayabhanu 1988). In summary, it is harder to forecast when lead times are longer because demand is uncertain. To buffer against a wrong forecast, safety stock is used

[5] Crashing cost is a cost to reduce the lead time for a product. With the use of the crashing cost, the lead time is controllable. Assumptions are often made that if the crashing cost is raised, the resulting lead time will decrease. Crashing costs appears to be synonymous with expediting cost. Past research has sought the equilibrium point to balance the trade offs between lead time and the crashing cost.

which reduces flexibility and safety lead times are added which will cause even more doubt in the forecast. Enns (2002) recommends diminishing the forecast error first, and then using lead times and safety stock to manage the timing and quantity uncertainty. He also states that safety stock is the best approach to buffer against uncertainty. Regardless, with long lead times, there is an increasing need for flexibility to meet the customers' requirements (Milner and Kouvelis 2002). To better understand how lead times impact other factors, the next section will discuss the trade-offs.

2.4.3 Trade-offs

In business, companies often have to give in order to receive. For instance, investment in a facility may be required to improve the flexibility of the production process. Likewise, there are many trade-offs while working with lead time, as will be discussed in this section.

In industry, there is a balance between quality, cost, speed, dependability, and flexibility as displayed in Figure 2.30 (Grossman and Jones 2002). With long lead time, quality is bound to deteriorate and schedulers will have a harder time matching parts for demand (Kekre and Udayabhanu 1988).

When a supply chain is geographically dispersed and lead times are defined, one way to increase customer service levels is by increasing inventory (Grossman and Jones 2002). However, inventory carrying costs will rise (Kekre and Udayabhanu 1988). As the lead times increase, more

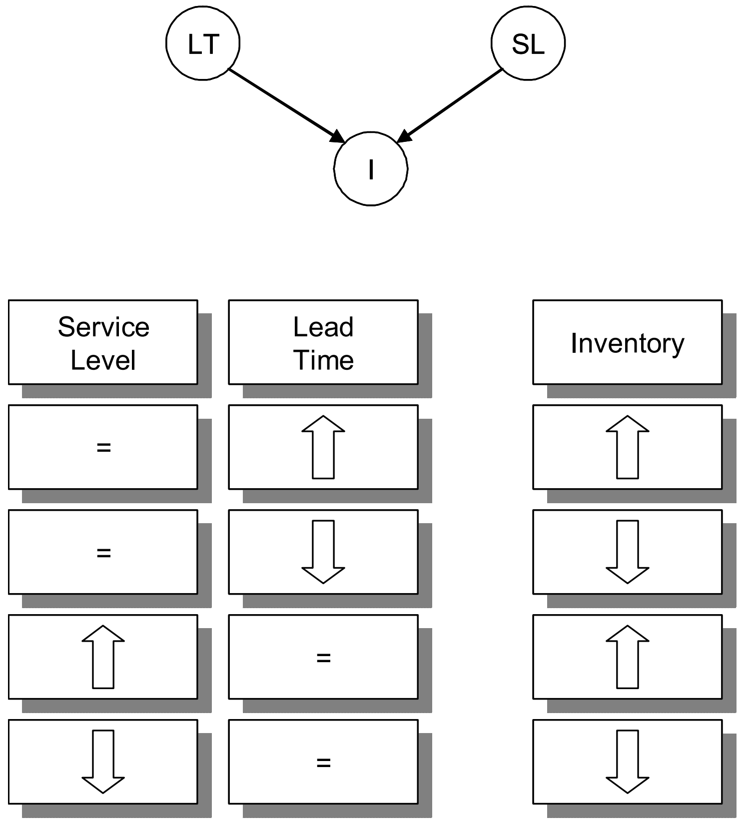

Figure 2.30. How Service Level and Lead Time Impact Inventory (Grossman and Jones 2002).

variation will arise in the marketplace, and hence the need for more inventory (Towill 1997).

There are two reasons for safety stocks to increase as a result of increased lead times. The first reason is for protection against the long lead times during variable demand. Secondly, as the lead time increases, uncertainty in the forecast also increases (Kekre and Udayabhanu 1988). Buzacott and Shanthikumar (1994) concur that large inventories are used to minimize the risk of stock outs as lead times and safety stocks increase. They also state that when lead time and safety stocks are reduced, inventory is decreased which increases the risk of shortages. However, others disagree as they believe that by reducing the lead times, stock out loss will be reduced as flexibility increases, which improves customer service level while also reducing inventory and production costs (Ouyang and Chuang 2000, Ouyang and Wu 1997, Huge 1979, Rabinovich et. al. 2003, Stalk 1998, Harding 1995). This increases the flexibility of the business and improves its competitiveness.

There is an intangible benefit to reducing lead times. With long lead times, customers order product before it is needed in order to guarantee that they will have a spot on the production schedule. Therefore, the longer the lead time, the more false orders are placed. This scenario will appear encouraging for the supplier as they may have a couple of months of backorders; seen as job security. Also, they will be able to maximize capacity utilization of the facility with the backlog (Helo 2000). And the long lead times provide time to guide planning and reallocate resources so various projects do not conflict. However, customer responsiveness declines rapidly in this environment. With an increase in forecast errors, the production schedule will not be accurate, and unscheduled jobs will have to be expedited through the process (Stalk 1998).

One problem is that marketing and production often have competing objectives. Marketing wants to provide flexibility and fast response times for their customers. The problem is that marketing's desires create volatile schedules, which inherently increases overhead and supply-base costs. Meanwhile, manufacturing wants minimal and gradual changes in the schedule to reduce inventory and overhead burden while maximizing output (Huge 1979).

Are lead times always detrimental to the organization? This answer depends on the state of the economy and the resulting objectives of the company. When demand is high, the company often emphasizes the schedule objectives. However, when demand is low and interest rates are up, companies focus on their inventory objectives (Huge 1979). Therefore, a company may not be as concerned about lead times when the demand is high as the facility is flooded with inventory to maintain schedules. However, lead time is more important when demand is low and the goal is to minimize inventory, especially when accountable for inventory in the supply chain.

These issues are very real. As Grossman and Jones (2002) discussed, Sony moved production of camcorders from Japan to China to benefit from lower wages. However, the production of camcorders that were bound for the United States, were brought back to Japan. Sony realized that the high value-add products are produced better in Japan. Also, the supply chain issues from Japan are much simpler. Luckily for Sony, they were able to use the capacity in China for items in demand locally.

2.5 Contracts

In the past, customers wanted to delay orders as much as possible. The longer they postpone ordering, the more flexibility they have and the less inventory they had to hold. This mentality pushes much of the risk and responsibility onto the supplier. Since the customer wants to delay purchases, suppliers often have to prebuild product in anticipation of demand. The supplier is compromised because they have additional risk by holding excessive inventory or capacity (Barnes-Schuster et. al. 2002).

The best case scenario for the customer is to only order from the supplier when an order is received from the end consumer. However, this may create volatile demand based on the end consumers' ordering patterns. Therefore, to minimize the risk, suppliers should limit the ordering flexibility of the customer (Barnes-Schuster et. al. 2002).

The objective is a compromise between the customer's and supplier's needs by signing a long-term contractual agreement. A resulting benefit is the supplier will reserve an agreed amount of capacity for the customer. The vendor is willing to do this to ensure security of demand over the period of the contract (Huge 1979, Xie 1998). Likewise, the customer is guaranteed product at agreed times, ensuring the receipt of product as forecasted. Another objective of long-term contractual agreements is to disperse the agreed purchase volume in small and frequent batches. These smaller deliveries will minimize the inventory carrying cost for the customer while creating a more repetitive demand for the supplier (Pan and Yang, 2002). The RBPS concepts may be integrated by using limits or bounds to restrict the demand variability.

The motivation to use contracts properly is to maximize the profit in the supply chain. The tradeoff is between flexibility and price. Often, customers will pay more to the supplier in exchange for purchasing flexibility (Tsay et. al. 1999). By sharing all of the necessary information between the two parties, the profit is maximized for both organizations; not just the customer or the supplier.

The literature defines eight common characteristics between contracts:

1. Specification of decision rights;
2. Pricing;
3. Minimum purchase commitments;
4. Quantity flexibility;
5. Buyback or return policies;
6. Allocation rules;
7. Lead time; and,
8. Quality.

Specification of decision rights assigns responsibility to one individual to control the decision variables in order to accomplish the goals set by the contract. Pricing identifies the financial agreements between two parties in the supply chain. The minimum amount to be ordered at a given time or over a longer period is declared by the minimum purchase commitments. And when the order is placed, the quantity flexibility sets bounds on the amount that may be ordered by the customer unless the customer accepts financial repercussions. Some contracts even have a buyback or return policy that states how much of the product may be returned and the amount of credit that will be received when this is done. Another characteristic that may be added is the allocation rule, which states capacity or financial options to use other resources if stock outs occur. Lead times may be defined and are also accepted as being fixed or dynamic. And finally, quality requirements may be set to ensure that quality product is passed through the supply chain (Tsay et. al. 1999, Ertogral and Wu 2001).

A key conclusion resulting from the research of Tsay et. al. (1999) is that by using either pricing or constraints, efficiency may be gained in the supply chain. A compromise must exist between how much flexibility and how much inventory are allowed in the system. If the customer is willing to pay for more flexibility, the supplier will have to invest in extra capacity. If the supplier is able to reduce the ordering fluctuations with the contract, the customer will pay less for the component, but will also have to hold more inventory to buffer against stock outs from demand variability (Burnetas and

Ritchken 2002, Cachon and Lariviere 2001).

Then again, there may not be a mediation point between the customer and supplier. If the customer demands that the supplier assume all of the risk with capacity and inventory, the supplier may need to ascertain if the partnership is worthwhile. If an agreement cannot be made, then the supplier may need to reject the orders. Similarly, the supplier may push the burden upon the customer, in which case, the customer may want to back out of the deal. Corbett et. al. (2003) found that most suppliers should reject over twenty-five percent of their customers due to an unsuccessful relationship.

If contracts have been agreed upon by the customer and supplier, the question may be posed regarding how to interface with second-tier, third-tier, and other suppliers. As stated by Kumar et. al. (1991), the overall objectives must facilitate all production decisions, meaning that the contractual settlement should be agreed upon and followed by the upstream suppliers.

On the intangible side, one of the most important factors in a contractual agreement is trust. If suppliers cannot depend on accurate information being passed up the supply chain, decisions will be made independently of other businesses. Skewed forecasts and phantom orders will easily deteriorate any confidence that has been developed. Credible information must be shared for a contractual partnership to succeed (Cachon and Lariviere 2001). For this to work, customers should purge their supply-base when creating trust with long-term contracts. It is not wise to sign contracts with multiple suppliers for one component (Wikner et. al. 1991).

The only way to build the trust is to concentrate on one supplier for each part and hold them accountable for the delivery schedule.

2.5.1 Quantity Flexibility Contracts

The research for this dissertation is most closely aligned with the Quantity Flexibility (QF) contracts. In the past, customers would overstate their forecasted orders to ensure that they could purchase product when needed. However, as the forecasted point draws nearer, the customer would decrease the order and leave the supplier with an excess of inventory. Quantity Flexibility contracts will mediate between the two sides to compromise on their objectives of price and delivery so they may both benefit (Tsay et. al. 1999, Kumar et. al. 1991, Kekre and Udayabhanu 1988). Price is determined by the manufacturing costs, overhead costs, and profit margin. Estimates of the lead time establish when the product will be delivered. But both internal and external variability should be considered when mutually deciding on price and delivery (Kekre and Udayabhanu 1988). The purpose of this section is to educate about the QF concept.

The main idea is to provide constraints to motivate both the supplier and customer to limit orders and production, which will inherently reduce costs. In QF contracts, the production level is to remain between the upper and lower limits while trying to maintain the objective safety stock level (Xie 1998, Tsay et. al. 1999, Kumar et. al. 1991). When the demand is below the lower limit like point A in Figure 2.31, the production rate will equal the lower

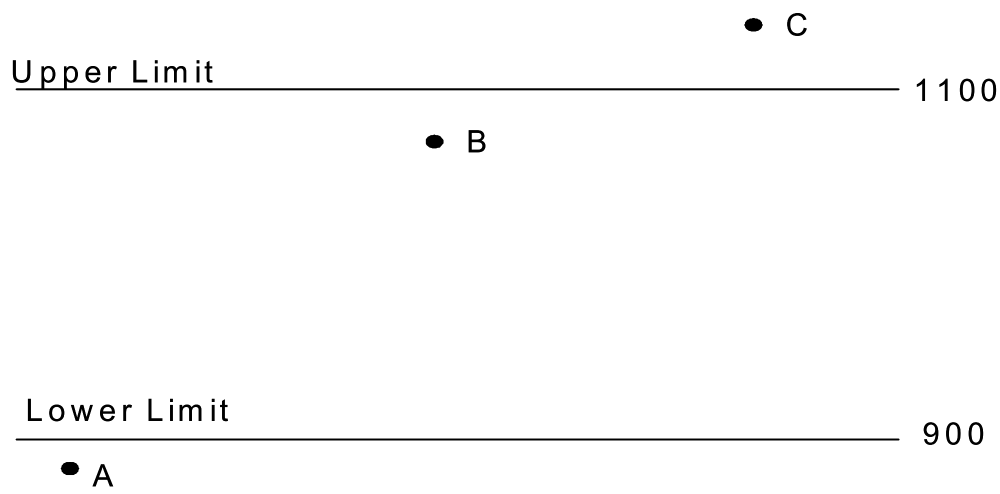

Figure 2.31. Demand Points with Upper and Lower Limits.

limit of 900 and some excess inventory will accumulate above the desired safety stock level. In the next period, point B is within the bounds, so production will be less to use some of the excess inventory. Again, the lowest level that may be produced is 900. Point C is above the upper limit in the final period shown. Therefore, the production rate will equal the upper limit of 1100 and the safety stock level will recede as inventory is used to maintain customer service levels.

The limits should take into account the capacity of the supplier. And to ensure that inventory is minimized, delivery batch sizes should be reduced to increase the frequency of orders placed by the customer (Xie 1998). With erratic orders, the volume of the order is likely to be volatile. However, the more frequent the orders, the more likely that the production rate will imitate the demand. These more frequent and less volatile orders will reduce the demand variation from the customer, and the supplier's capacity is more likely to be sufficient.

The limits will guarantee the production will remain smooth and stable. The schedule may then be passed along through the supply chain. With the limited production schedule, suppliers have an easier time meeting the plan since it is now more predictable (Xie 1998). If the customer must have a quantity outside the allowable range, he will have to pay extra to the supplier since the order deviates from the contract (Tsay et. al. 1999).

What determines the level of the upper and lower limits? According to Barnes-Schuster et. al. (2002), the customer distributes the forecast to the supplier. In successive periods, the customer may place orders for the product. However, the amount must be within a predetermined range from the original forecast for that period. The range is determined by a prearranged percentage above (α_u) and below (α_d) a given quantity as shown in Equation 2.2. The customer may order anywhere within the given range. This allows the customer to respond to fluctuations from the forecast and also protects the supplier from a large amount of variation in demand (Kumar et. al. 1991).

$$\begin{aligned} UFL &= Q(1+\alpha_u) \\ LFL &= Q(1-\alpha_d) \end{aligned} \qquad \text{(Equation 2.2)}$$

2.6 Conclusion

The motivation for this research is the bullwhip effect. It causes great inefficiencies and costs in the supply chain. One technique to reduce this phenomenon is Rate-Based Planning and Scheduling. To implement this technique, the concepts of lead time and contracts must be understood. The purpose of this chapter was to conceptually understand RBPS and contracts, and to consolidate the discussions of many authors. Through the rest of this research, the impact of lead time and flexibility will be scrutinized on a RBPS system with contractual limits. Nevertheless, the main philosophy of RBPS and this research is summarized best when Maskell stated, “It synchronizes production, allows for uniform plant loading, and provides a repetitive cycle of events that lends itself to quality and productivity” (Maskell 1994).

Chapter 3

Research Conceptualization

3.1 Introduction

Graves (1999) was quoted as saying, “Rather, to decrease the amplification of the demand process, there must be a reduction in the downstream lead-time, L, or an increase in the inertia in the demand process (smaller α), or a change in the downstream order policy that somehow smoothes the response to a forecast change.” Likewise, Silver and Smith (1981) said that, “Given the current inventory level, the planned production during the frozen period (lead time) and the forecasts of demand, how does one choose the production rate in the period (review interval) now being scheduled, so as to provide a desired level of customer service?” This chapter will present a methodology to “smooth response(s) to a forecast change” and decide “the production rate in the period now being scheduled, so as to provide a desired level of customer service.” Also, the chapter provides a detailed discussion of the research performed as the basis of this dissertation. First, a background will be presented, detailing the purpose of this research. Then a comprehensive framework explains how the RBPS system operates for this research and is followed by an example. Some assumptions are then discussed. Finally, the response variables for the experiment are provided with the expected outcome of the research.

3.2 Description

A goal of this research is to understand the impact that lead time, flex capacity, and variation in demand have on the inventory necessary to provide high service levels. This research will also compare the difference between the Retailer Smoothing and the Production Smoothing strategies, which will be discussed further in the next section. Another goal is to provide a simple algorithm that most companies may implement. In this section, a detailed model for the research will be discussed to achieve these primary goals.

3.3 Demand Strategy

As stated in the previous section, there are two strategies in this research. Some effort will now be used to examine the similarities and differences between the two strategies since they will likely impact the research significantly. The first necessity is to familiarize the reader with the information required to use these strategies. Then, the two strategies will be detailed. As shown in Figure 3.1, the production rate is frozen during the current period (period 0) and the next three periods at a level of 1000 units. Currently demand is 50 units higher than the production level. Therefore, inventory will be used to buffer against the deficiency to provide appropriate customer service levels. Estimates for the next three periods predict a continuation of the shortage since the forecasted plan is repeatedly above the frozen production levels for those periods. However, periods 4 through 7 are all well within the allowable limits (900 to 1100) and will probably be able to

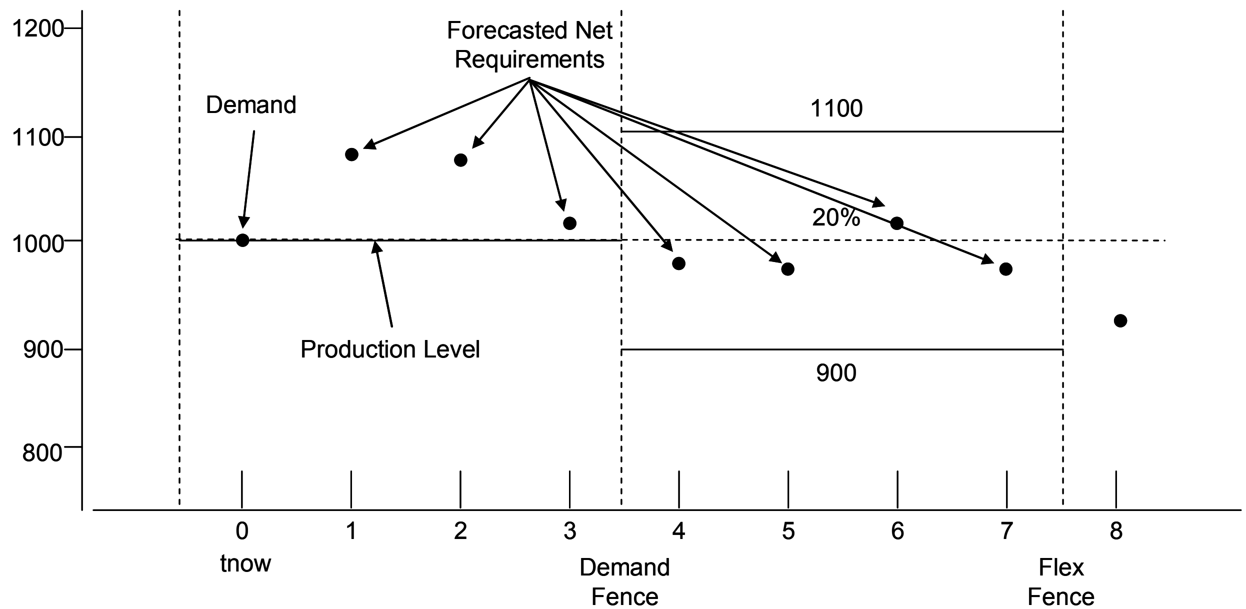

Figure 3.1. Flex Limits and Values Based on the Total Demand of 1000.

replenish the desired safety stock level. The limits are set by using a percentage of the standard deviation to buffer against the variation in demand. For this example, the standard deviation is 500 and the percentage allowance is 20%. Therefore, the bounds are 100 units (500 x .2 = 100) above and below the plan. Now that the basis for the example has been developed, the two demand strategies will be explained with the help of illustrations. The first strategy is the Retailer Smoothing Strategy (RS). In this scenario, the flex limits are determined, for the period entering the flex fence, from the predicted plan at that time. For example, during the transition from Figure 3.1 to Figure 3.2, time 0 has passed and now period 1 is the current time. The limits for periods 5 through 7 have already been determined and simply shift one period closer to the current time frame. However, as period 8 enters the flex fence, its bounds must be defined. The flex limits are set around the estimated plan for period 8 by adding and subtracting a percentage of the standard deviation to the plan at that time. This strategy allows production to shift according to their customers' demands since the bounds are determined based on the predicted plan value. If some of the costs associated with fluctuations of capacity are placed upon the customer, it will force the customer to improve their forecast, since they may only obtain the given amount of volume between the two bounds. For instance, in Figure 3.2 when period 8 becomes the current period, the plan for production must be between 825 and 1025 units. To make the situation harder, in four periods, the production level will be frozen somewhere

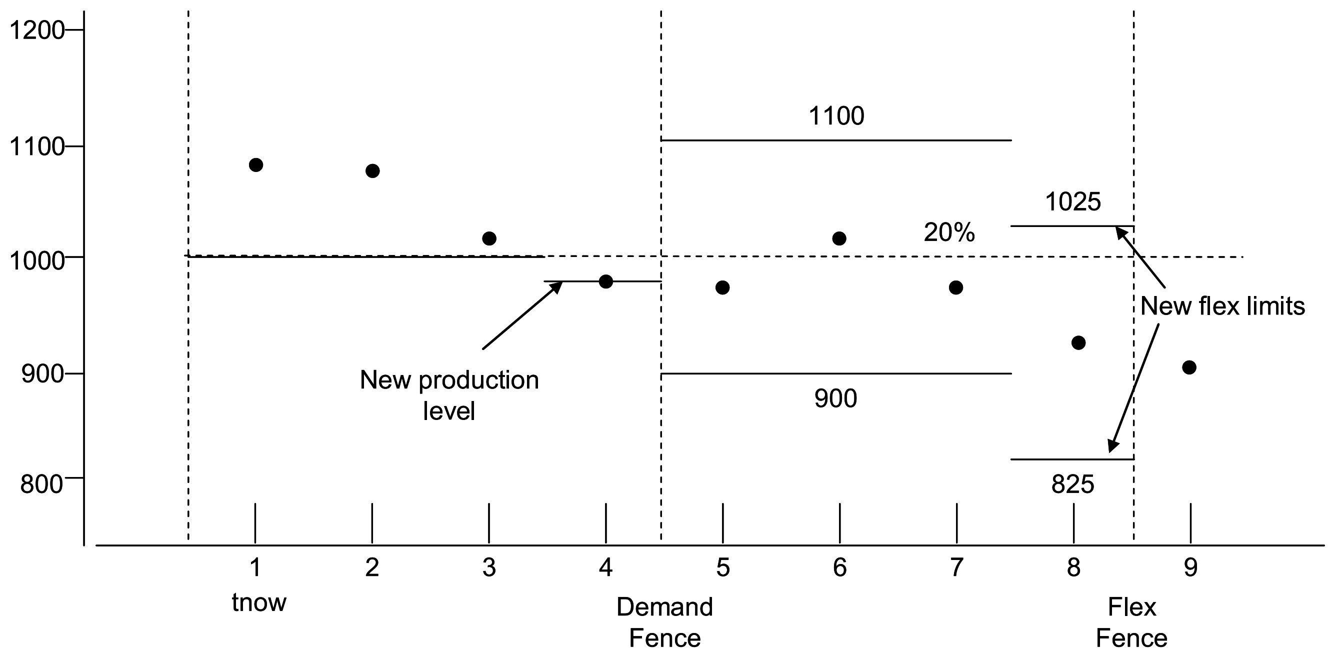

Figure 3.2. Using the Retailer Smoothing Strategy for Developing New Flex Bounds (Current Period is Period 1).

between 825 and 1025 units regardless of the estimated plan at that time. The plan could be well above 1025 or below 825, but the demand strategy states that production must be within these bounds.

There are two more important pieces of information in Figure 3.2, demand versus production, and the new frozen production level. First, since the flex limits have been discussed, notice that the new frozen production level for period 4 is 980 units. This level is equal to the predicted plan since it is within the previous flex bounds. Remember that Figure 3.1 showed production for period 4 has to be between 900 and 1100. Since the estimated plan is within these limits, the bounds simply narrow to the plan. Also note that the demand for period 1 is about 1090, or 90 greater than the frozen production level for the period. Since the actual demand is greater than production, inventory is needed to buffer against the difference.

Continuing through this example, another period advances as shown in Figure 3.3. The current period is now period 2. The demand is once again higher (1060) than the frozen production level of 1000. Therefore, inventory will again need to buffer against the shortfall. For periods 3 and 4, the frozen levels remain at 1000 and 980 units respectively. However, a new frozen level must be determined for period 5. Since the forecasted plan is again within the limits of 900 and 1100, then the frozen level will equal the plan of 1030. In addition, the new flex limits must be determined for period 9. Since the forecasted plan is 975 units, the limits will be 100 units on either side of this point as explained earlier. A planner would be a little concerned at this

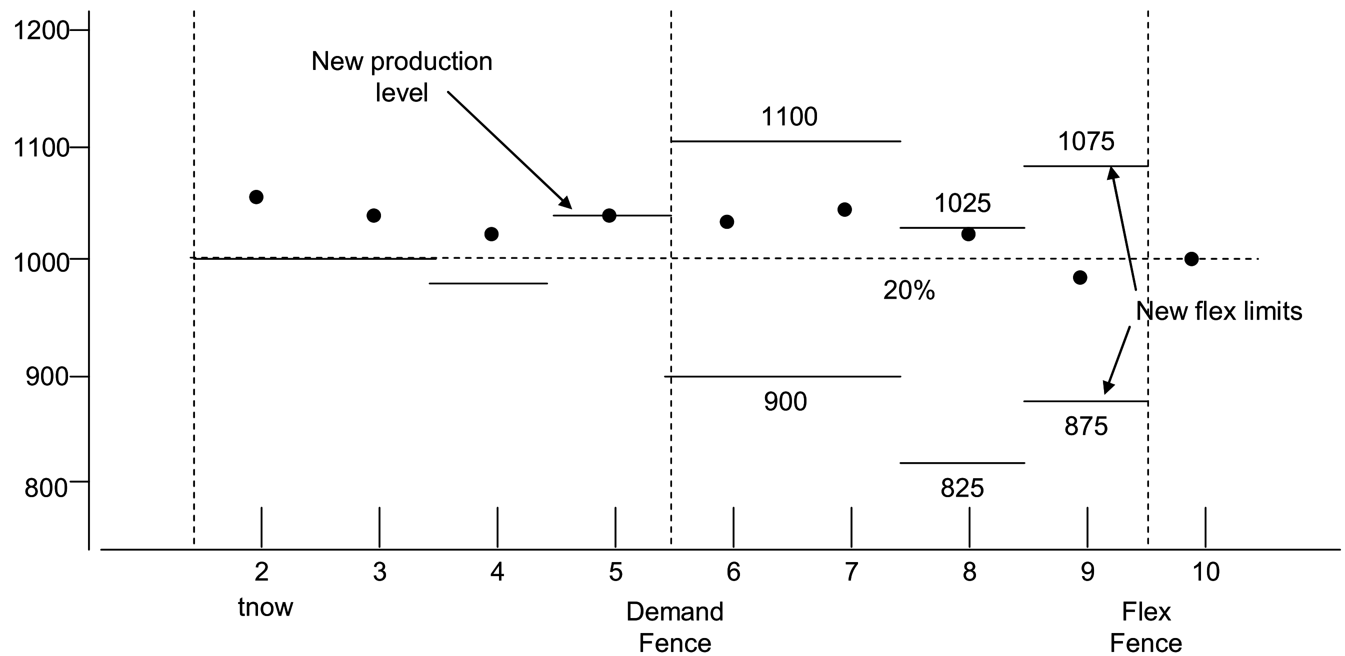

Figure 3.3. Using the Retailer Smoothing Strategy for Developing New Flex Bounds (Current Period is Period 2).

point because all of the forecasted points are above the average, hence, showing an upward trend. Luckily, Figure 3.3 demonstrates that for period 6 through 9, the forecast is within the limits. Hopefully, future forecasts will remain within the limits which will allow production to replenish the safety stock level.

The anxiety of an increasing forecast was justified as shown in Figure 3.4. Given that another period has progressed, the forecast has been updated and increased significantly. The current period is 3 and the demand is again higher than the frozen production rate, resulting in another shortfall. Periods 4 and 5 in the demand fence are predicted to have deficits also. Once more, the frozen rate for period 6 must be defined as it enters the demand fence. The problem is that the forecasted plan for period 6 is greater than the upper limit. Consequently, the frozen level will equal the upper limit and a shortfall is predicted. Luckily, new flex limits are to be created for period 10. Since the forecasted plan is rising, our limits are rising around the latest plan to enter the flex fence. This will allow production to ramp up over time, but not fluctuate quickly as a result of rapid changes.

Another ordering strategy is called the Production Smoothing Strategy (PS). Instead of basing the new flex bounds on the last forecasted plan in the fence as RS does, PS will use the current production volume as the basis for developing the bounds. Each flex bound will be a percentage away from the current production quantity during the iteration. The example used while discussing RS will also be used to discuss the PS strategy to help explain the

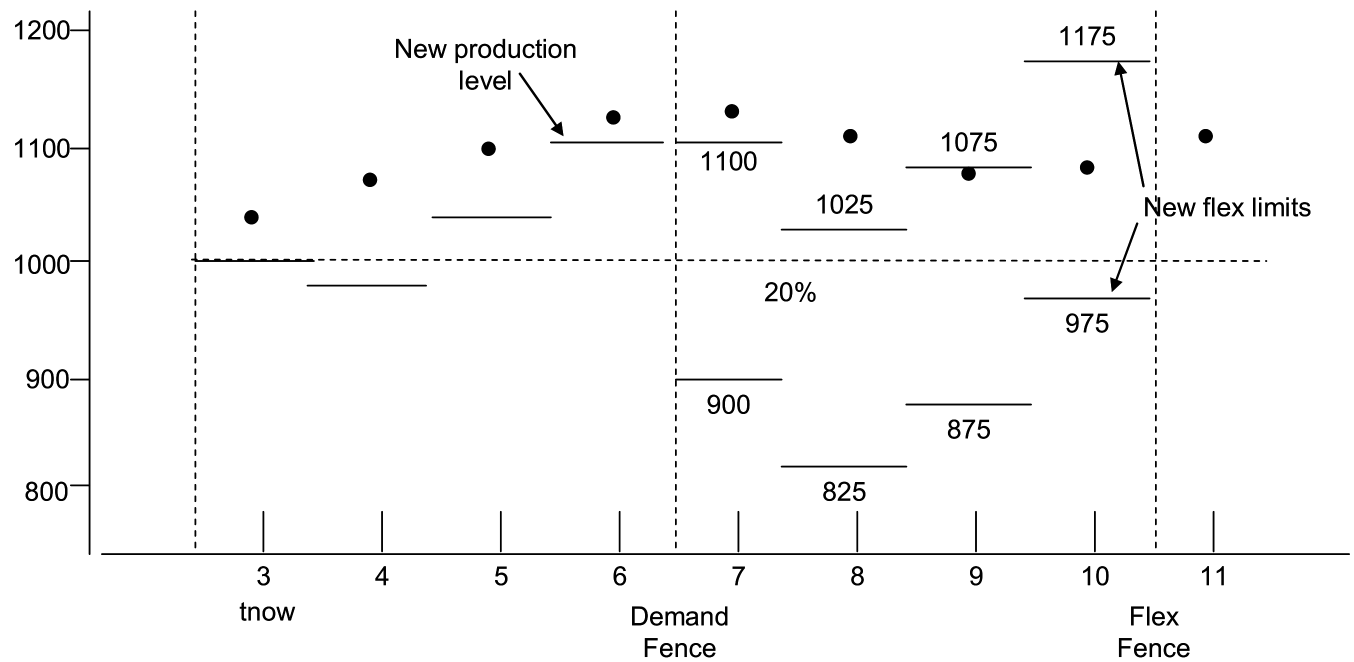

Figure 3.4. Using the Retailer Smoothing Strategy for Developing New Flex Bounds (Current Period is Period 3).

similarities and differences between the two strategies. Advancing one period from Figure 3.1, the point for period 1 represents the demand in relation to the frozen production interval (shown in Figure 3.5). The rest of the points are the forecast of the plan. Since period 8 is entering the flex fence, a new flex bound must be determined. This bound is calculated using the production level at period 1, not the actual demand. Since the 1000 units are being made in period 1, period 8's upper limit is 1100 and lower limit is 900. The only remaining change is for the frozen production rate during period 4. As in the RS strategy, the plan for period 4 is within the previous limits shown in Figure 3.1. Therefore, the frozen production level will equal the plan of 980 units. Again, the frozen production level will always equal the plan when that plan is within the flex limits. Otherwise, if the plan is greater than the upper limit, the frozen level will equal the upper limit. Similarly, if the plan is less than the lower limit, the frozen production level will be the same as the lower limit.

Moving on to the next iteration in Figure 3.6, period 2 is the current period. The demand is 1060 and is higher than the frozen production level, forcing a shortfall that will be filled with the use of inventory. The frozen levels for periods 3 and 4 remain at 1000 and 980, in that order. As period five enters the demand fence, the estimated plan is again within the limits, so the frozen level will equal the plan of 1030. The limits remain for periods 6 through 8, but need to be developed for period 9. Again, the production level at period 2 is still 1000 units. Therefore, the flex limits will remain the same

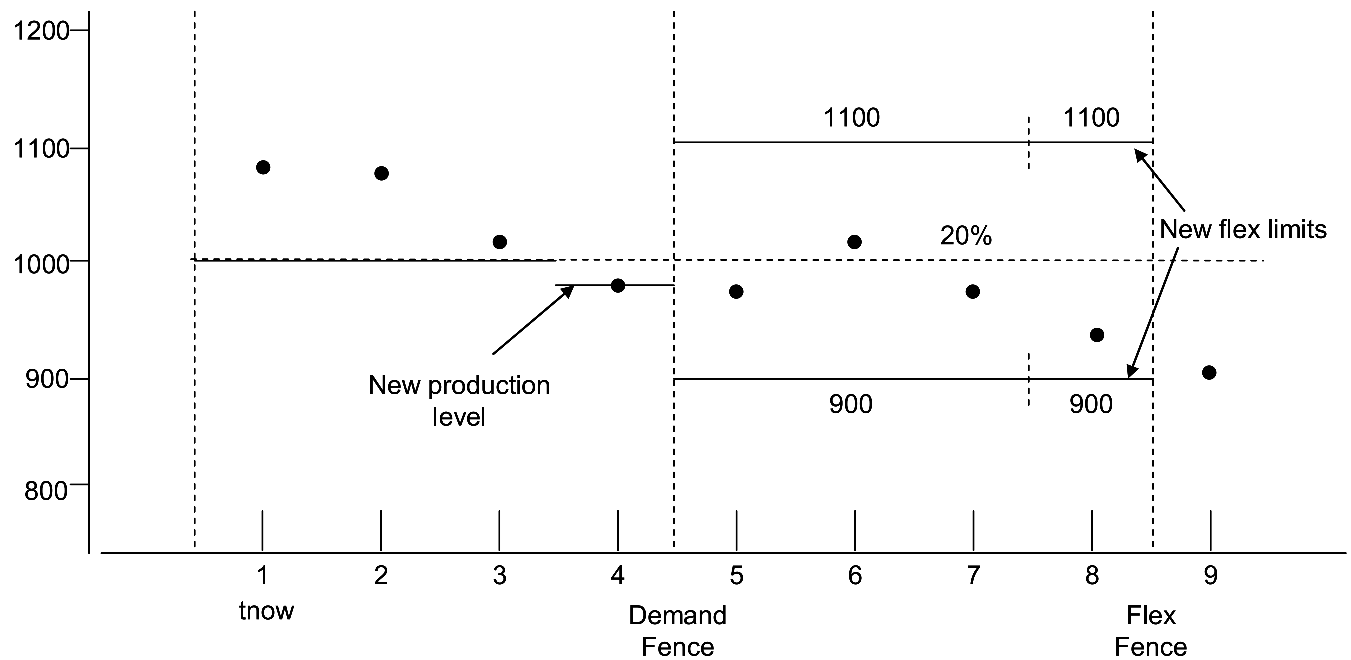

Figure 3.5. Using the Production Smoothing Strategy for Developing New Flex Bounds (Current Period is Period 1).

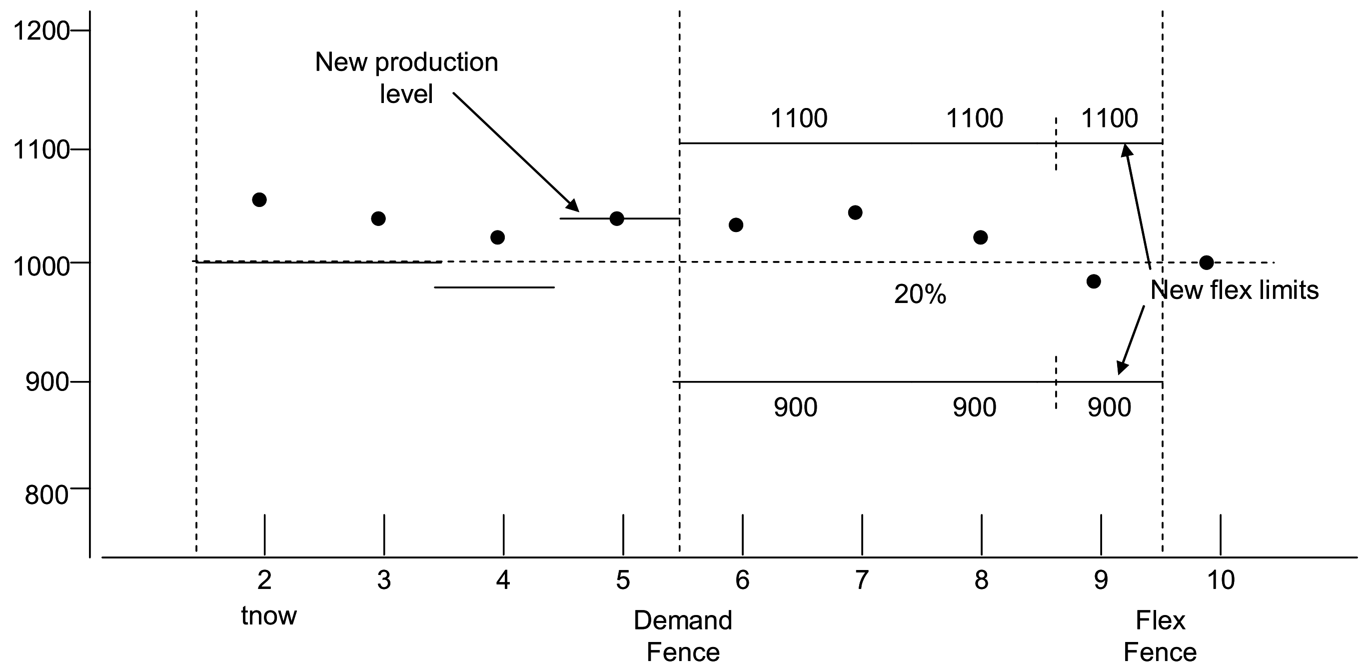

Figure 3.6. Using the Production Smoothing Strategy for Developing New Flex Bounds (Current Period is Period 2).

as the previous periods, 900 and 1100. Luckily, the predicted plan will remain between these flex bounds.

As another period passes, period 3 is the current period as shown in Figure 3.7. The demand at period 3 is again above the production level. Therefore, inventory is again used to fill the void between the two points. The predicted plan has risen steadily for every period since the last iteration. Therefore, the frozen production levels for periods 4 and 5 will not suffice for the predicted demand at those times. As period 6 enters the demand fence, the estimated plan is greater than its flex limit. Therefore, the production level will match the upper flex limit and will not be able to achieve the predicted demand. The flex limits stay the same as they move closer for periods 7 through 9. Unfortunately for most of these periods, the updated plan will most likely exceed the capability limits previously set, and will probably result in a deficit between demand and production. Since the new flex bounds are again dependent on the production level, these limits will not alter from the previous limits of 900 and 1100.

Looking into the future for this example, the flex limits will decrease slightly to 880 and 1080 during the next iteration as a result of the frozen level of 980. However, production levels will increase for periods 5 and 6, which will force the flex limits to shift upward accordingly. This example clearly displays that the PS strategy does not react quickly to variation in demand, but will shift to increasing or decreasing trends.

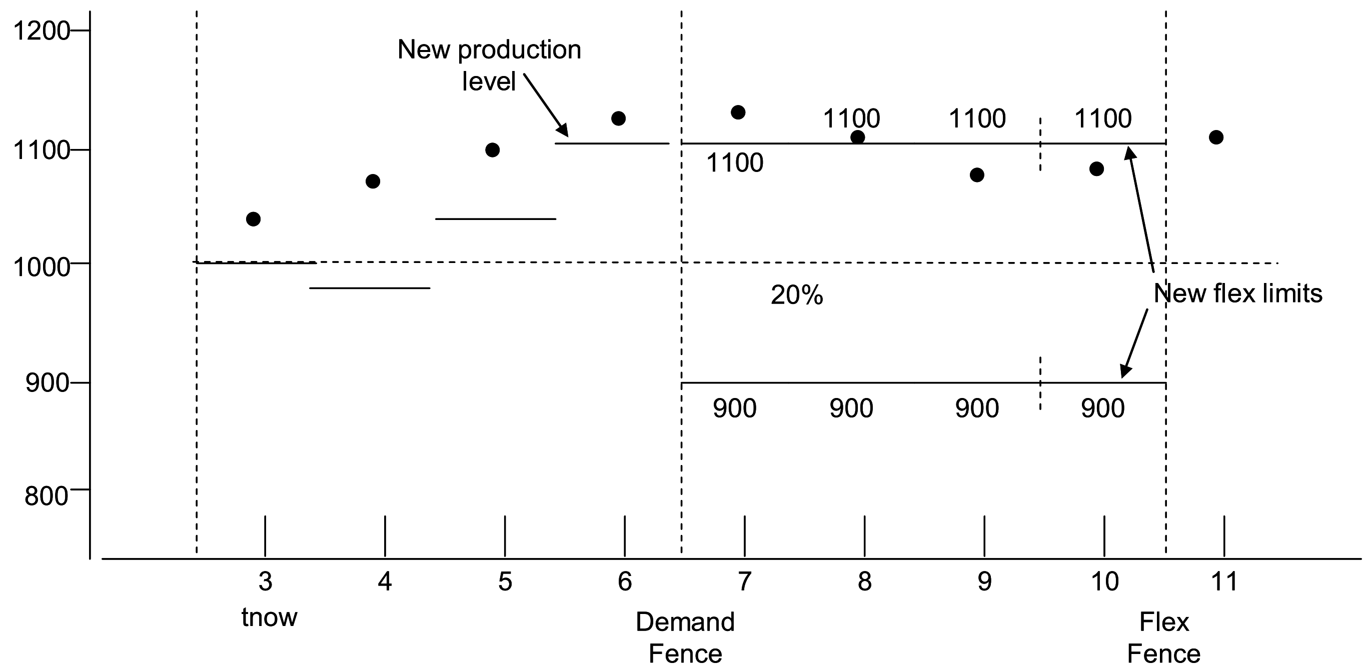

Figure 3.7. Using the Production Smoothing Strategy for Developing New Flex Bounds (Current Period is Period 3).

A result of this strategy that is not intuitive is the amount that production may increase over time. Until now, the rigidity of the PS strategy has been discussed, but the flexibility has not. If the forecast exceeds either of the limits continuously, the allowable production levels will shift accordingly. The reason is that there were phantom flex fences in the future, meaning that there are invisible limits automatically created by the PS strategy. This results from a supplier signing a contract with their customer to allow an *x* percent increase or decrease over the next *y* periods. Inherently, this agreement allows the bounds to deviate by *2x* over the next *2y* periods, by *3x* over the next *3y* periods, and so on as shown in Figure 3.8. The only rigid fences currently are the Demand Time Fence and the Flex Fence. Beyond these fences are the phantom fences which are assumed by the contract. For example, if the contract states that production may only increase/decrease five percent every four periods, then period 9 may increase/decrease ten percent since it is four periods beyond period 5.

The point of this strategy is to create a more stable production schedule by limiting the flexibility of the production schedule. By utilizing the flex bounds, the customers may change their requested amount, but only within the given percentage of the current production schedule. Instead, usually PS is a manufacturing technique and the supplier holds finished goods inventory to buffer against fluctuations in demand from the customer. The supplier must then debate between the width of the limits and the amount of inventory desired to maintain strategic goals while ensuring proper

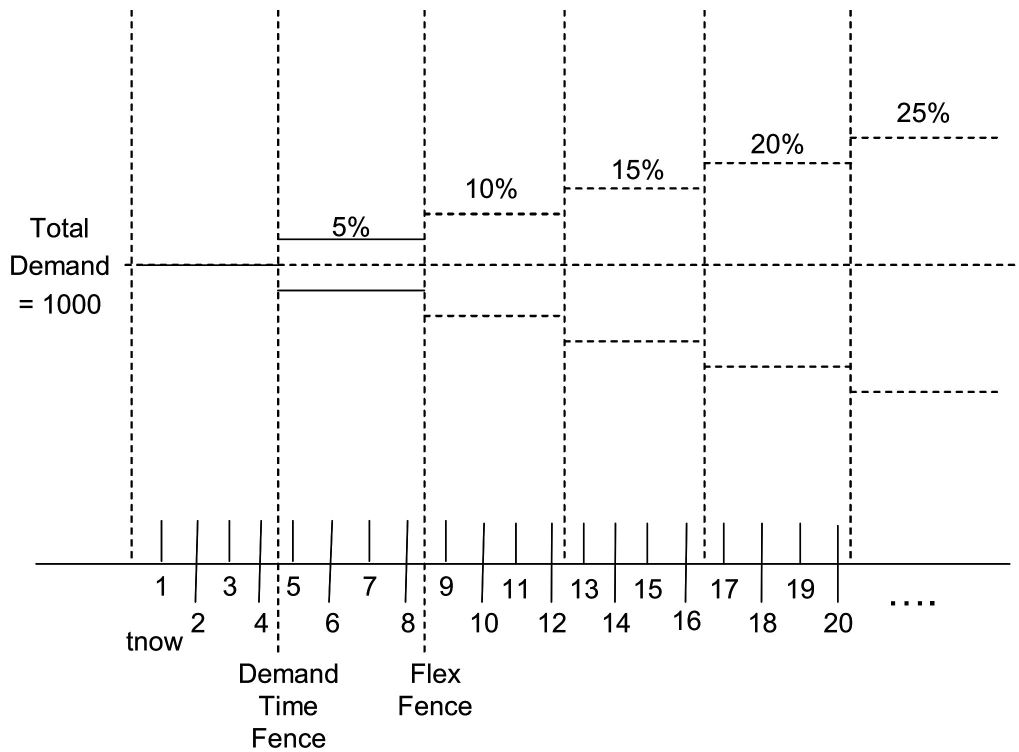

Figure 3.8. Current and Phantom Flex Fences.

customer service levels. As explained in Table 3.1, capacity is significant and inventory is insignificant when using the PS strategy. Therefore, capacity is only allowed to vary slightly over time and inventory buffers against demand variability. On the other hand, inventory is minimized for the RS approach as capacity is used to buffer against demand. This strategy would probably be used in an environment with expensive stock.

Now that the demand strategies have been discussed in detail, the model will be explained thoroughly with the use of flow charts. For clarity, examples will be provided during the discussion to more easily convey the logic of the model.

3.4 Model and Examples

The RBPS model (Figure 3.9) begins with management determining the time frame of the model. The analysis could be in terms of days, weeks, or months. However, the longer the time frame, the less flexible the process. For example, if each period represents a month, the model is not as flexible compared to daily periods. Such as in Figure 3.1, if the time frame in the figure represents 9 days, then the model will be much more flexible than if the figure symbolized 9 months. In this example, the periods will represent weeks. Once the time has been decided, management must determine the planning horizon of the process. The planning horizon (ET) is the amount of time into the future that the company will attempt to anticipate demand. This is the time frame over which forecasts will be determined. In the example, the

Table 3.1. Significance of Factors in the Demand Strategies.

Demand Strategy Factor	Production Smoothing	Retailer Smoothing
Capacity	↓	↑
Inventory	↑	↓

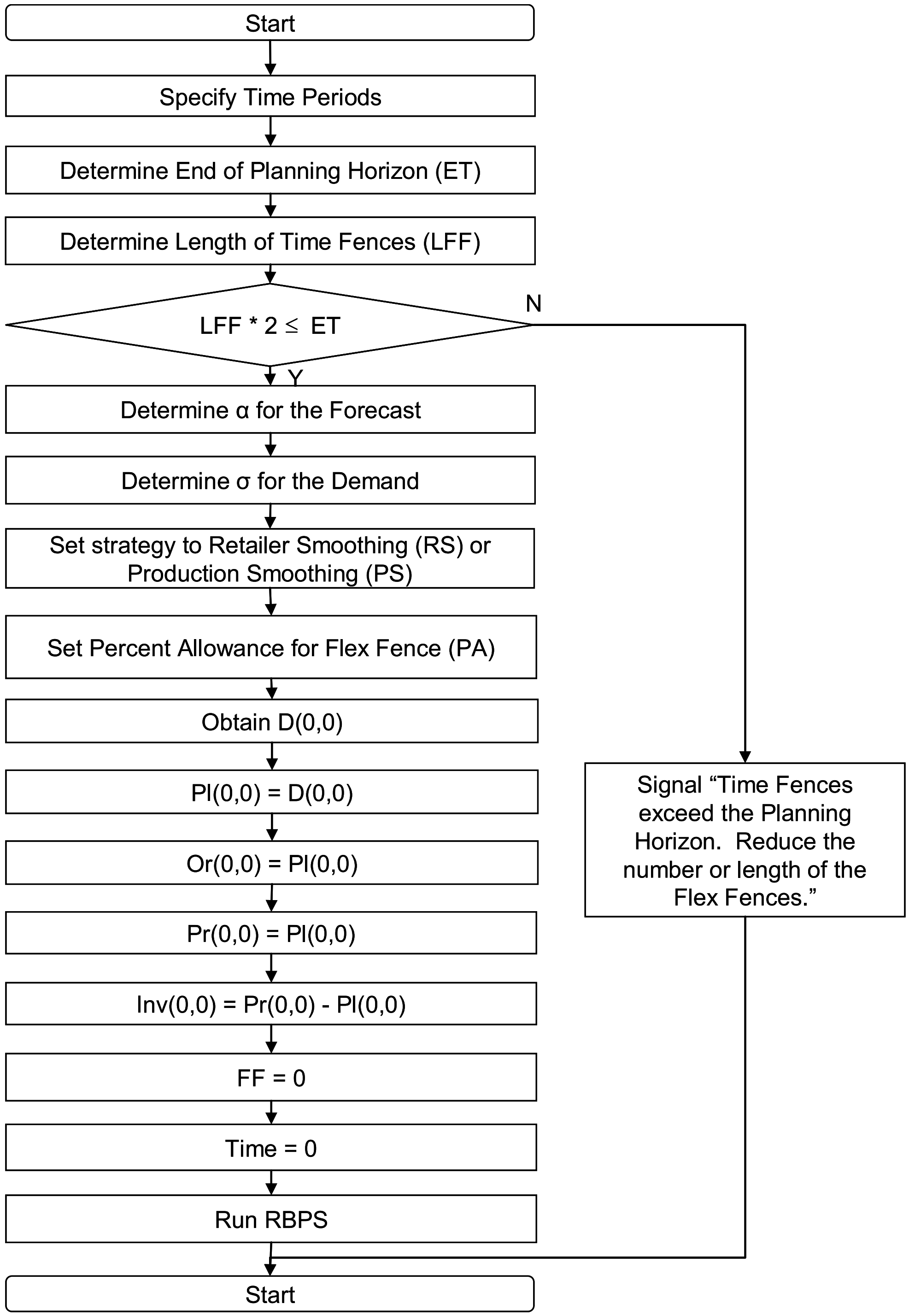

Figure 3.9. Beginning of the RBPS Algorithm.

planning horizon is 12 weeks.

Once the higher level issues of time are decided, planning and scheduling should understand the goals of management to make the next few decisions. The length of the flex fence (LFF) is the number of time periods within the demand fence and the flex fence. A constant length will be used in each run of this research. However, various levels will be tested to understand the impact of the length of the flex fence. Intuitively, the longer the flex fence, the longer the lead time to support the demand variation, which will force the producer to hold more finished goods inventory. In the example, management does not want to be too stringent on their customers. Therefore, the length of the flex fences has been set at the small value of three periods.

A check must then be made to ensure that the length of the flex fences multiplied by the number of fences is less than or equal to the planning horizon [$LFF * 2 \leq ET$]. As shown in Figure 3.1, there are two fences with one being the demand fence and the other, the flex fence. In the figure, the forecast must at least extend to period seven. If this statement is false, then the scheduler must review the scenario and adjust the inputs to ensure that the flex fences are maintained within the planning horizon. This is an important step because it ensures the company's forecasting time frame is longer than the time consumed by the flex fences. But for the example in this section, the demand and flex fences will only represent six periods together, and the planning horizon extends well beyond that point. Therefore, the company may continue with its analysis.

Continuing the initial phase of the RBPS algorithm, the analytic study will employ demand data that utilizes the past forecast added to a value from the Normal distribution that is generated from a mean (μ) of zero and a defined standard deviation (σ), as depicted in Equation 3.1. To develop the demand value, the research will include the standard deviation (σ). This value determines the volatility allowed in the demand. As the standard deviation increases, the volatility in demand will also increase. The mean is 1000 units with a standard deviation of 100 in the corresponding example.

The exponential smoothing model (Equation 3.1) will be used to characterize potential trends in demand (Chen et. al. 2000, Graves 1999, Snyder et. al. 1999, Eppen and Martin, 1988, Foote et. al., 1988). To use this model, the exponential smoothing constant, or alpha (α), must be determined. Alpha is the weighted fraction of the increase/decrease allowed in the demand and has to be greater than or equal to zero, and less than or equal to one ($0 \leq \alpha \leq 1$). For instance, if an increase of 100 units is anticipated and alpha is .2, then the new forecast will only increase by 20 units instead of the original 100. However, if the Normal variable, a_t, forces demand below zero, the demand value will be truncated at zero. There cannot be a negative demand. For the example, management wants to provide good customer service without excessive inventory. Thus, the company has set alpha (α) to .3, so the exponential smoothing model may follow the demand more closely.

$$
\begin{aligned}
D_t &= F_{t-1} + a_t \qquad\qquad a_t \text{ is } \mathit{Normal}(0,\sigma) \\
F_t &= \alpha D_t + (1-\alpha)F_{t-1}
\end{aligned}
$$

so

$$
\begin{aligned}
F_t &= \alpha(F_{t-1} + a_t\ ) + (1-\alpha)F_{t-1} \\
&= (\alpha + 1 - \alpha)F_{t-1} + \alpha(a_t) \\
&= F_{t-1} + \alpha(a_t) \qquad \text{(Equation 3.1)}
\end{aligned}
$$

where

$0 \le \alpha \le 1$

which

$F_t =$ Forecast made at time t

$D_t =$ Demand value at time t

The purpose for using this methodology stems from the fact that exponential smoothing is the most commonly used forecast model (Box and Jenkins 1970) and it is the foundation for most fixed-model time-series techniques (Mentzer and Bienstock 1998). Trends may occur since the demand point at *t+1* is dependent on the previous forecast at time *t* plus a new random value. Therefore, the fact that demand is correlated is a likely assumption when relating the scenario to industry (King et. al. 2002, Ryan 2001). Also, the demand is nonstationary (does not assume the mean stays the same) which is also applicable (Ryan 2001, Snyder et. al. 1999).

To illustrate this point, refer to Table 3.2 and Figure 3.10 displaying the Normal variant, demand, forecast, and average values over time. The values in the upper left of the table are defined by the user. The values in the lower portion of the table result from the given values. The first quantity of the forecast equals the starting demand point given at the top of the table since it

Table 3.2. Illustration of Nonstationary Demand Information.

Mean	1200
Std Dev	300
Alpha	0.2

Period	0	1	2	3	4	5	6	7	8
a_t		304	204	-56	638	-125	77	110	115
D_t		1504	1465	1245	1929	1293	1470	1518	1545
F_t	1200	1261	1302	1290	1418	1393	1408	1430	1453
Average F	1200	1230	1254	1263	1294	1311	1325	1338	1351

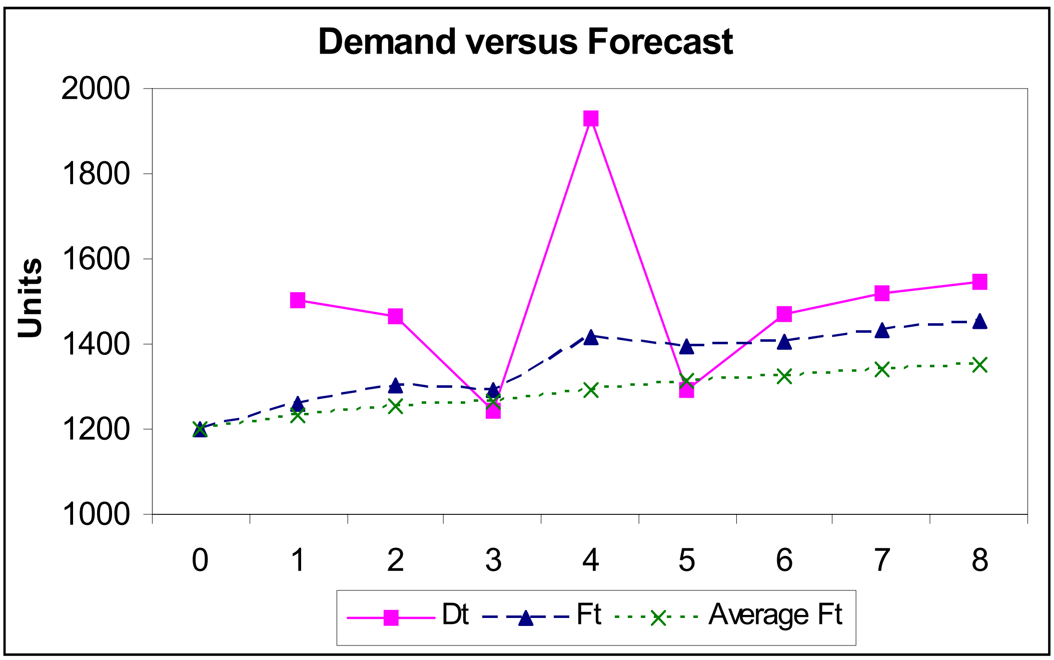

Figure 3.10. Illustration of Nonstationary Demand Information.

is the only sample to build the forecast. From this point, a_t is chosen from a random variant in the Normal distribution. The demand value, D_t, results from the previous demand point plus the error term, a_t. Then, exponential smoothing is used to provide a weighted average of the previous forecast and the demand value for the forecast beyond the current time period. As the table displays, the forecast average increases over time showing that the values are nonstationary.

Now that the exponential smoothing constant and the standard deviation have been defined, the demand strategy must be set. As discussed in the previous section, the PS strategy focuses on minimizing variability in production by constraining the fluctuations in the future by the current volume of production. Inventory is then used to buffer against the demand oscillations. On the other hand, RS strategy minimizes inventory by allowing production to buffer against the demand unpredictability. For the illustrative example, the PS strategy will be used to minimize needed changes in capacity.

Before continuing with the rest of the algorithm, the notation must be defined as to how the values are represented. In this research, iterations will be used to calculate the current demand and the forecast for future time periods. As each iteration is started, another time period has passed and the demand and forecast will be calculated again. Therefore, the iterations and time periods must be used in the notation to ensure the simulations run correctly. These values will be defined by a variable, which is identified by the iteration and period as shown in Equation 3.2. For instance, the notation D(3,5) means the research is discussing the demand value in the third iteration and fifth time period. The current demand value may be identified by examining when the iteration equals the time. For instance, as shown in Table 3.3, all of the gray boxes represent the current demand. Any values in the white boxes represent the forecast for the periods beyond the current time frame. In this example, the planning horizon is 7 periods. For example, in the fourth iteration, D(4,4) is 994 units which represents the actual demand. Every time period following (e.g. demand(4,5) = demand(4,6) = 1011, etc.) will represent the forecast.

$$\text{Var}(\text{Iteration}, \text{Time Period}) \qquad \text{(Equation 3.2)}$$

As discussed previously with the scheduling strategies, the percentage allowance (PA) must be given to establish the flex limits. If the scheduler defines the PA to be five percent, then the flex limits will be five percent of the standard deviation above and below the demand point as designated by the scheduling strategy. In Figure 3.1, the PA was set to twenty percent. This idea is stated more clearly in Equation 3.3. If FF equals 0, then the data is within the frozen demand fence. Otherwise, the FLP equals the PA for the flex fence. For the example in this chapter, management has decided to only allow thirty percent flexibility in the production process. So, during the demand fence, no flexibility will be allowed. However, for the flex fence, production may vary thirty percent of the standard deviation above and below

Table 3.3. Example of Interaction of Time and the Iterations.

		Time							
	D(Iter,Time)	0	1	2	3	4	5	6	7
Iteration	0	1000	1000	1000	1000	1000	1000	1000	1000
	1		1000	1016	1016	1016	1016	1016	1016
	2			1009	995	995	995	995	995
	3				968	988	988	988	988
	4					994	1011	1011	1011

Actual Demand Values

Forecasted Values

the origin.

$$\begin{aligned} &FLP = FF * PA \\ &\text{where :} \\ &FLP = \text{Flex Limit Percentage} \\ &FF = 0 \text{ or } 1 \end{aligned} \qquad \text{(Equation 3.3)}$$

At this point in the model, the company must input their initial demand value [D(0,0)]. The initial demand value is important because it will be the forecast for the entire initial iteration, and the basis for further forecasts. For the example, the initial demand is set at 1000 units as shown in Table 3.4. The plan [Pl(0,0)] is set equal to the demand value (1000 units in the example). This plan will be used to buffer the demand with excess inventory, or add to the demand as a result of previous shortfalls. Then, the origin [Or(0,0)] and the production level [Pr(0,0)] are set equal to the plan, which are also 1000 units in the example. When a new flex limit is determined, it is based upon the origin. Production is the amount that will be created at a given time. The production level will not always equal the plan, because the plan could be outside the allowable flex limits. Also, the inventory is calculated from the production level minus the plan. If the inventory is negative, then the volume produced could not meet the plan. Likewise, if the inventory is positive, there will be an accumulation of inventory since the production level will be above the amount consumed. But at this time, therewill be no inventory because the plan will equal the production level. Finally, the system is reset with the time and the flex fence both equal to zero.

Table 3.4. Initial Iteration of RBPS Example.

Iteration	0						
Flex Fence	0	0	0	1	1	1	0
Percentage allowance for flex fence	0%	0.0%	0.0%	30.0%	30.0%	30.0%	0.0%
Period	Current Period	1	2	3	4	5	6
Demand	1000	1000	1000	1000	1000	1000	1000
Net Requirements	1000	1000	1000	1000	1000	1000	
Origin	1000	1000	1000	1000	1000	1000	
Upper Bound		1000	1000	1030	1030	1030	
Lower Bound		1000	1000	970	970	970	
Production	1000	1000	1000	1000	1000	1000	
Inventory	0	0	0	0	0	0	

The RBPS system begins by entering the forecasted demand values into the system for iteration zero as displayed in Figure 3.11. This iteration has been designated with time zero because it represents the initial development of the system with the flex fences. For the initial iteration, every forecasted point equals the demand value [D(0,0) = D(0,1), D(0,2), D(0,3), …] since there is no other data to build the forecast yet. In the example in Table 3.4, the forecast for each period (t = 1, 2, 3, ...) in the initial iteration equals the demand [D(0,0) = 1000]. When the points have been entered, the system determines if the time period is equal to the length of the planning horizon [Time = ET?]. If not, the system continues by adding another period to the time and setting another forecast point. When the time does equal the planning horizon, the system resets by setting the time to zero to build the flex fences. In the example, the planning horizon is 12 periods (beyond the data shown in Table 3.4). Once the demand information has reached the end of the planning horizon, time is set to zero to build the rest of the table.

Since the time has been reset, the time and counter need to be increased by one to finish the initial iteration. Then, the plan for the first time period is set to equal the demand in period 1 (a.k.a. forecast since time does not equal the iteration) minus the inventory of the previous period. In Table 3.4, the period 1 plan is equal to the demand since there is no inventory to subtract. Also, the origin is set equal to the plan for the RS strategy, and equal to the production level for the PS strategy. Therefore, the origin also equals 1000 in the example.

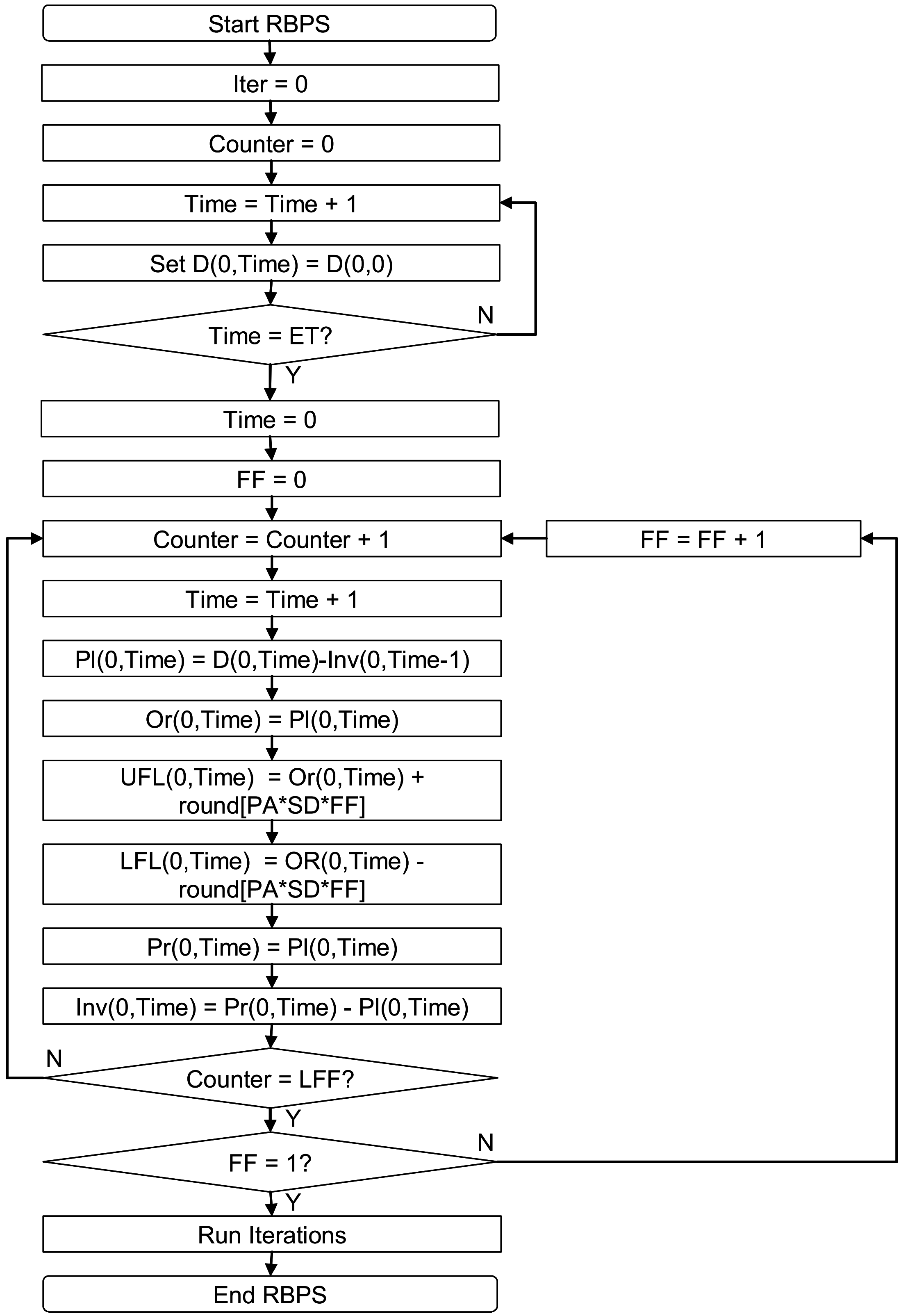

Figure 3.11. Start Rate-Based Planning and Scheduling.

Next, the upper flex limit is calculated by adding the origin to the rounded product of the percent allowance, standard deviation, and the flex fence as shown in Equation 3.4. The lower flex limit is also determined with a similar equation, but the multiplied quantity is subtracted from the origin as shown in Equation 3.5. For period 1 in the illustration, both the upper and lower flex limits equal the origin since the flex fence number is zero and negates any additional values in Equations 3.4 and 3.5. Then, the production level is set equal to the plan (1000 in the example) which allows the inventory to be calculated by subtracting the plan from the production level. All inventory values will be zero for the initial iteration since the plan and production are equal.

$$\begin{aligned}
&\mathrm{UFL}(0,\mathrm{Time}) = \mathrm{Origin}(0,0) + \mathrm{Round}[\mathrm{PA}(\mathrm{SD})(\mathrm{FF})] \\
&\text{where :} \\
&\mathrm{UFL}(\mathrm{Iteration},\mathrm{Time}) = \text{Upper Flex Limit} \\
&\qquad\qquad \text{at given Iteration and Time} \\
&\mathrm{SD} = \text{Standard Deviation}
\end{aligned} \qquad \text{(Equation 3.4)}$$

$$\begin{aligned}
&\mathrm{LFL}(0,\mathrm{Time}) = \mathrm{Origin}(0,0) - \mathrm{Round}[\mathrm{PA}(\mathrm{SD})(\mathrm{FF})] \\
&\text{where :} \\
&\mathrm{LFL}(\mathrm{Iteration},\mathrm{Time}) = \text{Lower Flex Limit} \\
&\qquad\qquad \text{at given Iteration and Time}
\end{aligned} \qquad \text{(Equation 3.5)}$$

The counter is checked to understand if the end of the flex fence has been reached. If not, another counter and time unit are added and the process is repeated. In this case study, period 1 is not the end of the flex fence. Therefore, a unit is added to the counter and the time to reference period 2. Once again, the plan, origin, upper flex limit, lower flex limit, and production will all equal 1000. Inventory is still zero since production and the plan are equal.

If the time has reached the end of the flex fence, another flex fence is added and the process is repeated. In the illustration, period 2 is the end of the demand fence. So the counter, time, and also the flex fence are all increased by 1 to represent the period 3 and flex fence 1. The plan and origin equal the demand again. However, now that the flex fence is 1, the upper flex limit and lower flex limit will widen. For the upper flex limit, the origin is added to the standard deviation (100) times the percent allowance (30%) times the flex fence number (1). This results in an upper flex limit of 1030 units. The lower flex limit equates to the origin subtracted by the extra quantity, which results in a boundary of 970 units. The production level is then set equal to the plan and no inventory is left over. This model is run again for periods 4 and 5, which are identical to the numbers calculated in Period 3 as shown in Figure 3.12. However, at the end of period 5, the last time fence is reached. Once the number of flex fences reaches the desired number (FF = 1) and the time has passed within the fence (Counter = LFF), iteration zero is complete. All of the information has been fed into the system, and the flex fences and flex limits have been formed. The system then begins the first iteration of the RBPS model.

As shown in Figure 3.13, the next iteration is initiated by adding a unit to the iteration number. This corresponds with moving from iteration 0 to iteration 1 in the example. The time is set equal to the value of the iteration,

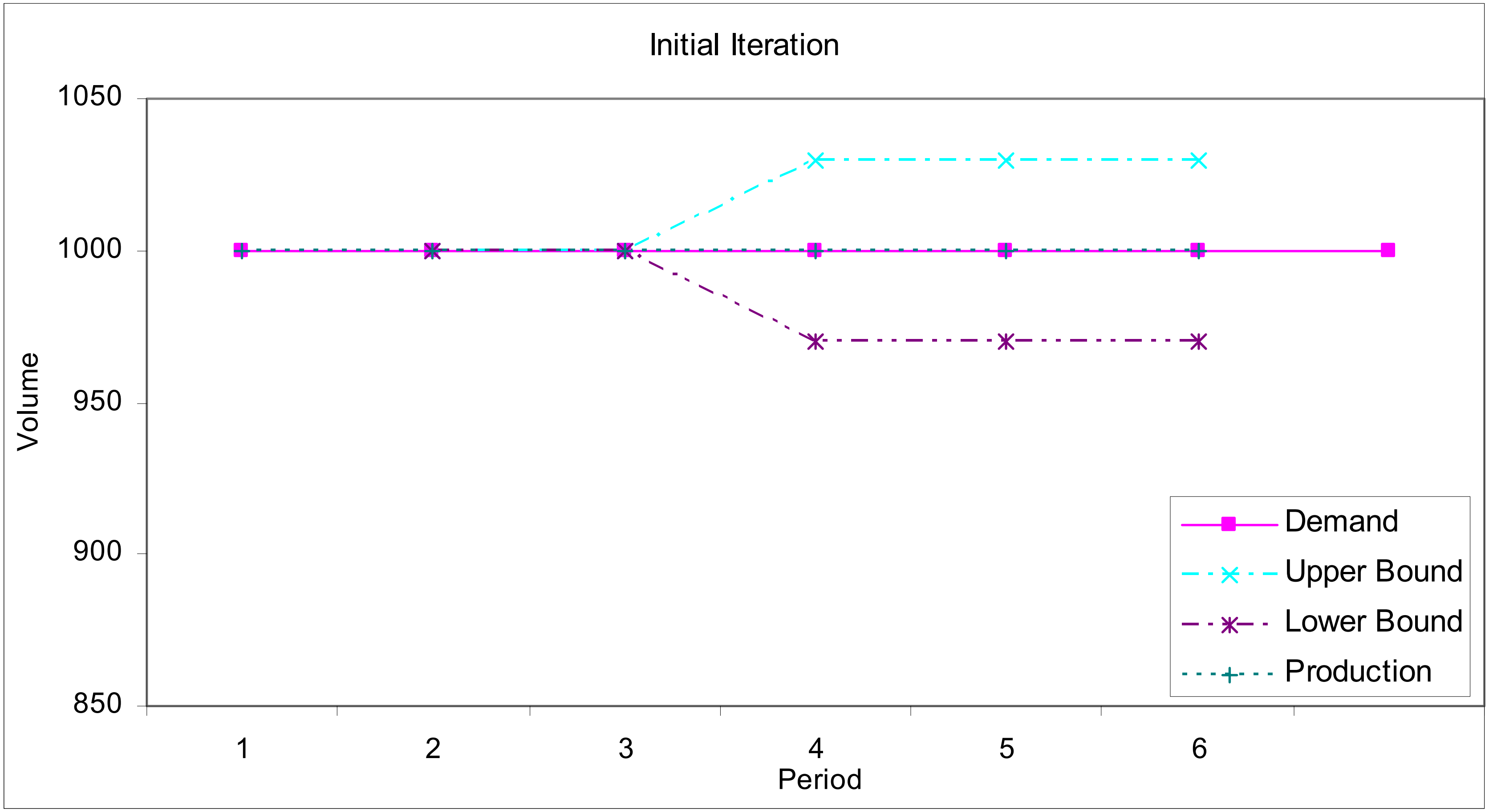

Figure 3.12. Initial Iteration of the RBPS Example.

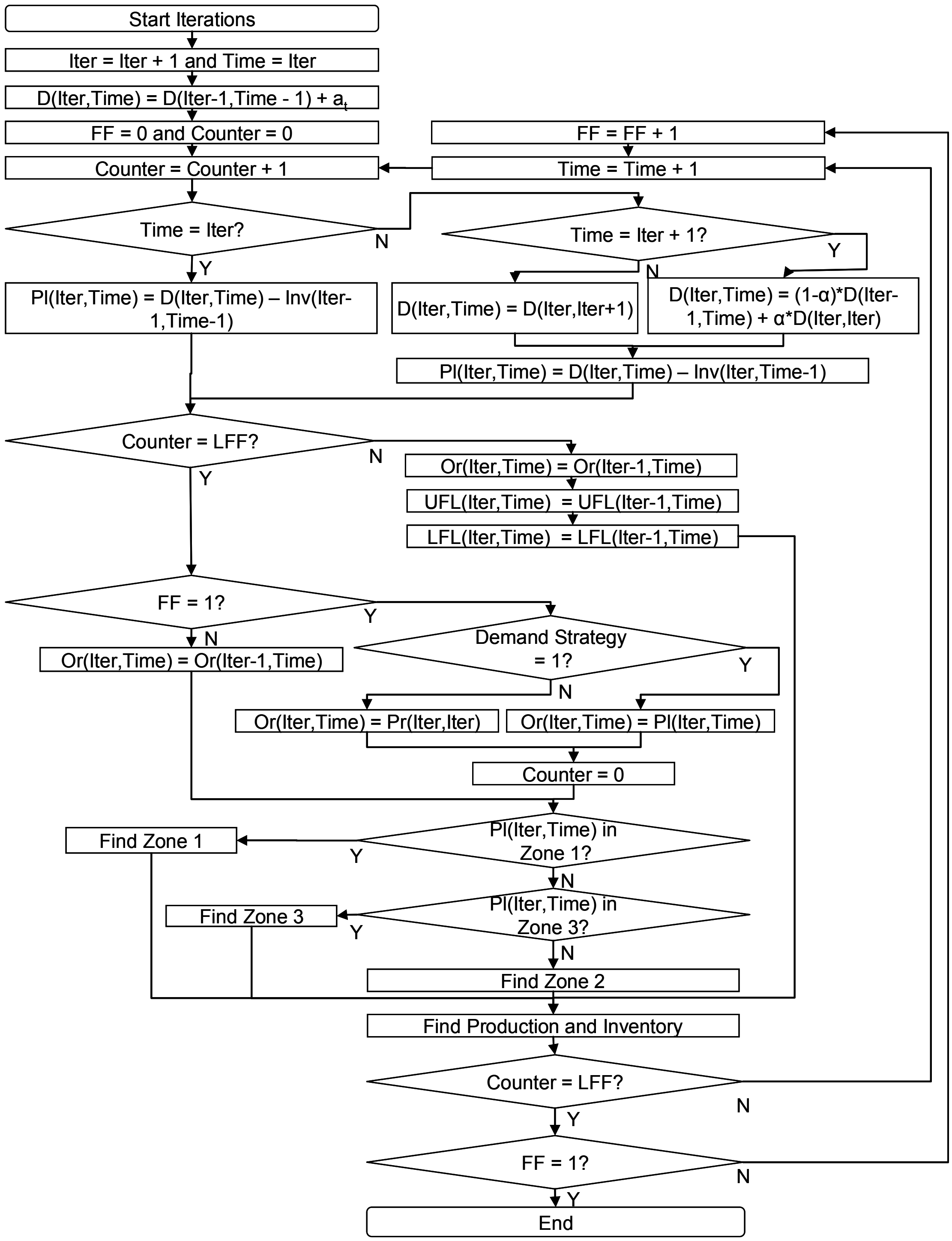

Figure 3.13. Start Iterations.

and the flex fence and counter are reset to zero. Note again that the current demand will always be when the time equals the iteration number. In the illustration, the iteration begins during period 1. The demand for the current period equals the last actual demand, in the previous iteration, plus the error term defined as a random value from the Normal distribution. For illustration, the error term is added to the previous demand of 1000 as shown in Table 3.5. The resulting demand is 861 for period 1 in iteration 1 (current period) due to the previous demand of 1000 added to the error value of -139 as defined by the normal distribution. The values for the flex fence and counter are reset and the counter is added by one.

Now, the algorithm must determine how to calculate the plan. When the current time period represents the actual demand, not the forecast, the inventory from the previous iteration is needed. Otherwise, the plan will use the forecast and inventory values from the current iteration. The demand in the current period represents the actual demand when the number of the period equals the number of iterations. If so, the plan is calculated by subtracting the current inventory (Inv), from the previous iteration and time period, from the demand at the current time. However, if the time is not equal to the iteration, the plan is found by subtracting the inventory of the previous time period from the current iteration. If the inventory value is negative, then a backlog exists. There is a surplus of inventory when the value is positive. In this illustration, the period equals the iteration number and hence, the demand during period 1 is the actual demand, not the forecast. Therefore,

Table 3.5. First Iteration of RBPS Example.

Iteration	1						
Flex Fence	0	0	0	1	1	1	0
Percentage allowance for flex fence	0%	0%	0%	30%	30%	30%	0%
Period	1	2	3	4	5	6	7
Demand	861	958	958	958	958	958	958
Net Requirements	861	819	777	765	753	741	
Origin	1000	1000	1000	1000	1000	1000	
Upper Bound		1000	970	1030	1030	1030	
Lower Bound		1000	970	970	970	970	
Production	1000	1000	970	970	970	970	
Inventory	139	181	193	205	217	229	

the plan, Pl(1,1), is equal to the actual demand minus the inventory of the previous period, 0, of the previous iteration, 0. Since the inventory was zero, the plan is equal to the demand [Pl(1,1) = D(1,1)]. Next, the production and inventory values must be established.

When determining the production and inventory values, the plan is the focal point as shown in Figure 3.14. First, the algorithm must determine if a new iteration is beginning. If this is the case, then production will equal the frozen value in the demand fence, which also equates to the upper and lower flex limits. For the rest of the time in the iteration, if the plan is less than the lower flex limit for the iteration [Pl(Iter,Time) < LFL(Iter,Time)], then production is set at the lower limit of the same iteration [Pr(Iter,Time) = LFL(Iter,Time)]. Similarly, if the plan is greater than the upper flex limit [Pl(Iter,Time) > UFL(Iter,Time)], then production is set at this upper bound [Pr(Iter,Time = UFL(Iter,Time)]. Otherwise, production will equal the forecasted plan [Pr(Iter,Time) = Pl(Iter,Time)]. Currently, in the example, time equals the iteration number, which means that the production level is equal to the frozen level (1000 units) set by the narrowed upper and lower flex limits. For the rest of the iteration, the logic *Time* = *Iter* will be false in Figure 3.14 and the production level will either be at or between the flex limits.

Then the inventory is calculated by subtracting the production by the plan [Inv(Iter,Time) = Pr(Iter,Time) - Pl(Iter,Time)]. If the value is greater than zero, there is an excess of inventory. However, there is a backlog when the inventory is negative. The goal is to keep this value stable and near zero

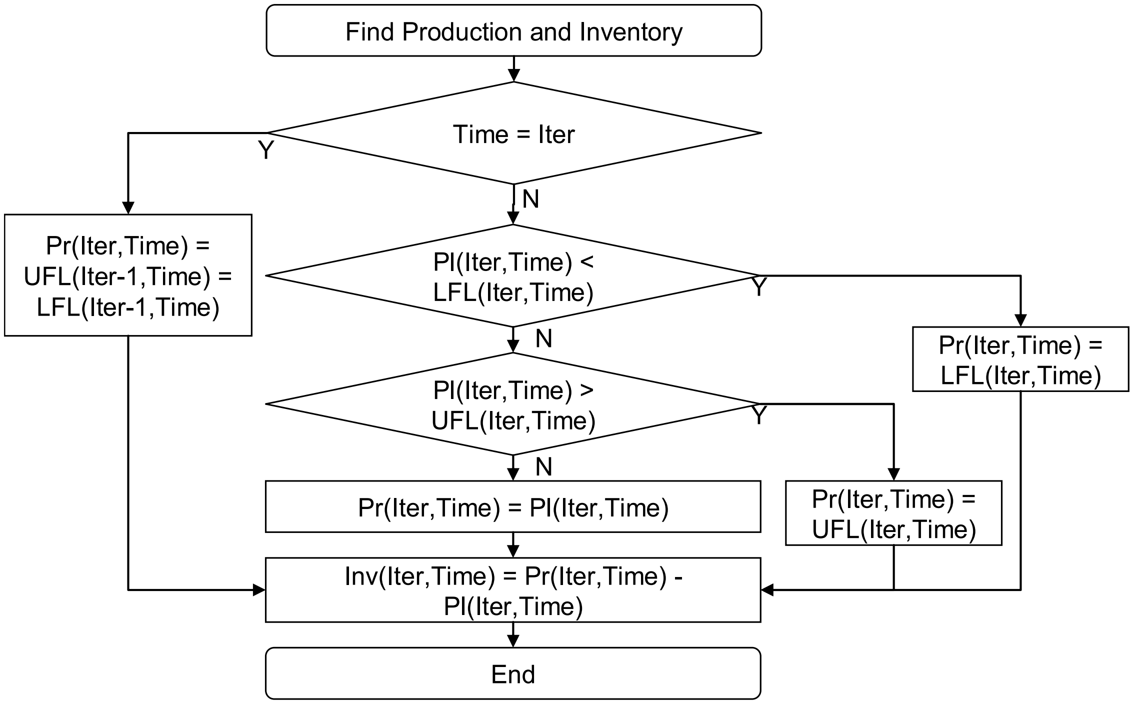

Figure 3.14. Find Production and Inventory.

inventory. For the illustration, production of 1000 units is subtracted by the plan of 861 units to finish the period with an excess of 139 units. Period 1 is now finished and the example will resume by starting period 2 in Figure 3.13.

The time period and counter are increased by one to define the next period. Since period 2 does not equal the iteration, it is not the current period. However, period 2, D(1,2), is the first period after the actual demand and is the basis for the forecast for the rest of the iteration. To calculate this value, (1-α) is multiplied by the previous forecast and is added to α times the actual demand for the iteration. The resulting forecast for period 2 is 958 units [D(1,1) x α + D(0,2) x {1 – α}] = (861 x .3) + (1000 * {1 - .3})].

Continuing in Figure 3.13, the next step is to set the flex limits and ensure that production is within these limits. First, a decision is made to understand if the counter is equal to the LFF. If not, the period is inside the flex fence and everything (origin, UFL, LFL) is simply shifted forward one time period by making them equal to the previous values in the previous iteration. One unit is added to the time and the algorithm is repeated. In this illustration, the counter is not equal to the LFF during period 2, so the origin and flex limits equal the values from the same period, but previous iteration. The origin is 1000 units, and the flex limits are also 1000 units showing that the point is within the frozen demand fence.

The logic then jumps to Figure 3.14 again to determine the production and inventory. Since time does not equal the iteration, the logic checks if the plan is less than the lower flex limit. In the example, this query is true since the plan is 819 units and the lower flex limit is 1000 units as shown in Table 3.5. Therefore, production is held at 1000 units and increases the inventory to 181 units.

Then another period is added as the logic jumps back to Figure 3.13 and the counter is reset to symbolize period 3 of iteration 1. Time is not equal to the iteration, so period 3 represents the forecast. Also, period 3 is not the period after the actual demand, therefore, the forecast for period 3 equals the forecast for period 2, 958 units. The plan, Pl(3,1), is then equal to the demand (958 units) minus the previous inventory (181 units), which equates to 777 units.

For the first time in the logic, the counter is equal to the LFF, so a new flex limit must be identified. But first, the origin must be determined to set the limit. If the FF does not equal 1, then the flex fence is simply narrowing and developing into the demand fence. Therefore, the origin is simply the same as the origin in the earlier iteration for that time period. However, if the FF equals 1, the algorithm is at the end of the flex fence and must determine the origin and the limits for the next point. If RS is used, then the origin equals the plan for the same time period and iteration [Or(Iter,Time) = Pl(Iter,Time)]. On the other hand, if PS is applied, then the origin is equal to the production level for the iteration [Or(Iter,Time = Pr(Iter,Iter)]. Then the counter is set to zero to begin a new fence. For the illustration, period three is in flex fence 0 and the origin stays the same as period 3 in the previous iteration.

Since the origin has been accepted, it is time to determine the flex limits and ensure that production is within the limits. Zones are used to determine how the flex limits will shift as they enter a new flex fence. A point is considered in zone one if the forecast is greater than the upper flex limit. When the point is within the existing flex limits, it is in zone two. And zone three is the area with forecasted values less than the lower flex limit. For instance, point X is within the second zone in Figure 3.15(a). Therefore, when the flex limits narrow to the frozen point in the demand fence, they will narrow to the point within the bounds. On the other hand, point Y will force the limits to shift higher in (b). In this case, the demand fence will be maintained at the current level of the upper flex limit. Finally, in Figure 3.15(c), point Z will force the production level to shift down toward the forecasted data. However, the lower limit will stop the decline of production from reaching point Z. Instead, production will commence at a level equal to the lower flex limit. In this scenario, production will exceed the forecast which results in excess inventory.

From this discussion, the algorithm will test the origin to understand the zone in which it is present. If the origin is in Zone 1, then the logic summons the computations for Zone 1 bounds. Likewise, computations for Zone 3 are used if the origin is below the limits. Otherwise, the Zone 2 calculations are utilized to locate the new levels. In period 3 of the example, the plan of 777 units is below the lower flex limit. Since the point is within Zone 3, the frozen production level will equal the lower limit of 970 units as shown in Figure 3.16.

Once the bounds or frozen levels are formed, the algorithm calculates

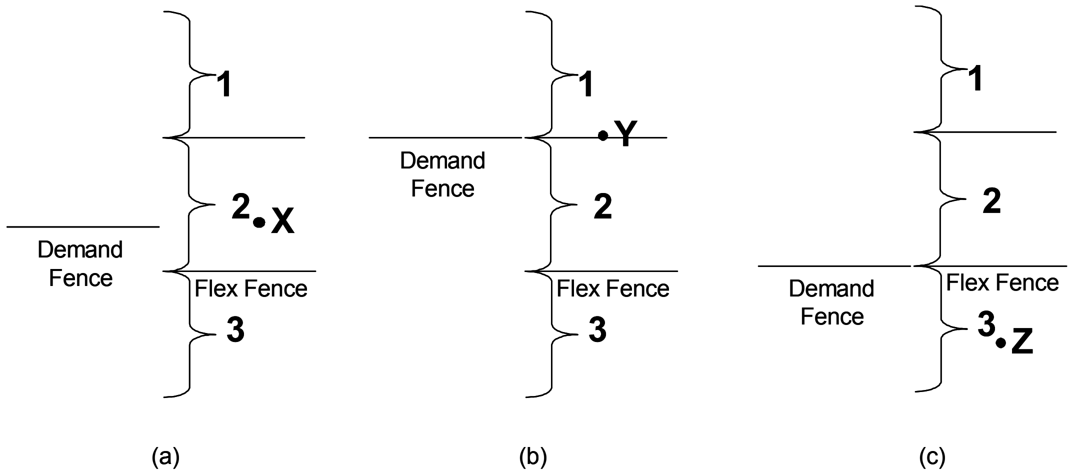

Figure 3.15. Flex Fences with Zones.

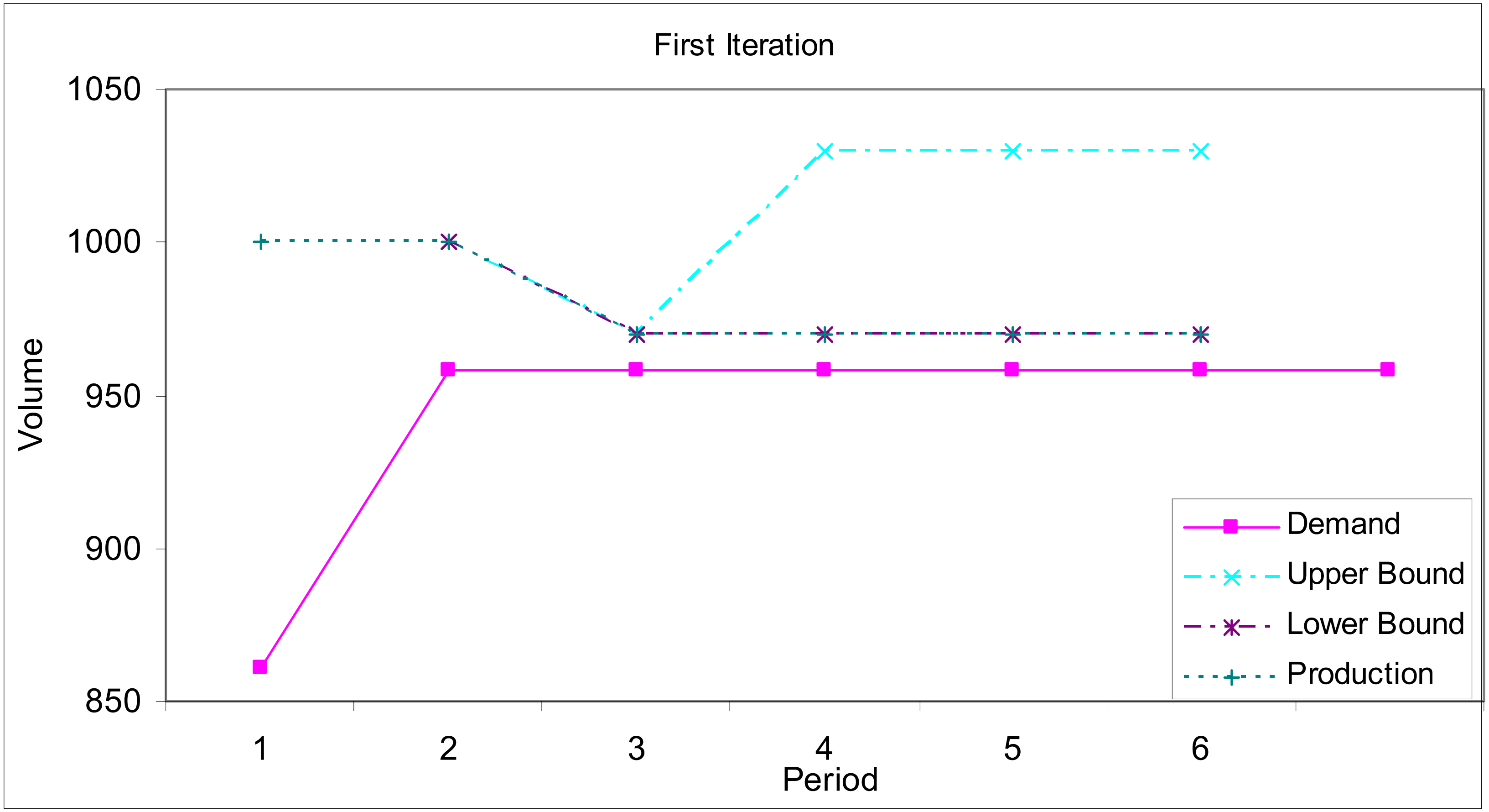

Figure 3.16. First Iteration of the RBPS Example.

the production and inventory levels. For period 3, production will be 970 units, which is higher than the plan of 777, resulting in 193 units of inventory. The algorithm then checks again to see if the last flex fence has been finalized. If so, the computer stops. If the last flex fence has not been completely adjusted, then another flex fence and time period are added to begin the next flex fence. The iterations will run until the demand and time fence have been completed.

Further elaboration of the zones will now be provided. If the origin is within zone one, the time is tested to understand if a new flex boundary must be initiated. If a new boundary must be developed, Equations 3.6 and 3.7 calculate the bounds to be equidistant from the origin. On the other hand, the Equations 3.8 and 3.9 are used to shift the limits higher (Figure 3.17) if the forecast is equal to or beyond the upper flex limit. Equation 3.8 simply shifts the upper flex limit from an earlier iteration. However, the lower flex limit uses the upper limit minus an amount twice the standard deviation, percentage allowance, and flex fence number. Notice that if the demand fence is entered, the lower limit will equal the upper limit since the number of the flex fence equals zero and cancels out the later portion of the equation.

For the third zone (Figure 3.18), Equations 3.10 and 3.11 are utilized to maintain the lower limit while shifting the upper limit down. However, whenever a new forecasted value enters the last flex fence, Equations 3.6 and 3.7 are used to find the limits. The forecasted point will be called the origin and is used as the basis for building the new limits.

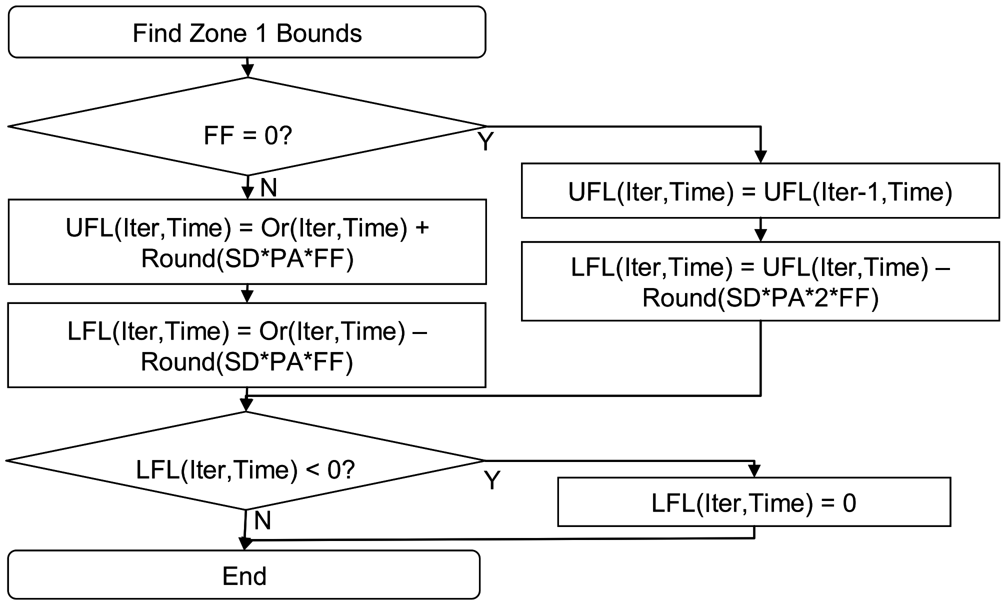

Figure 3.17. Find Zone One Bounds.

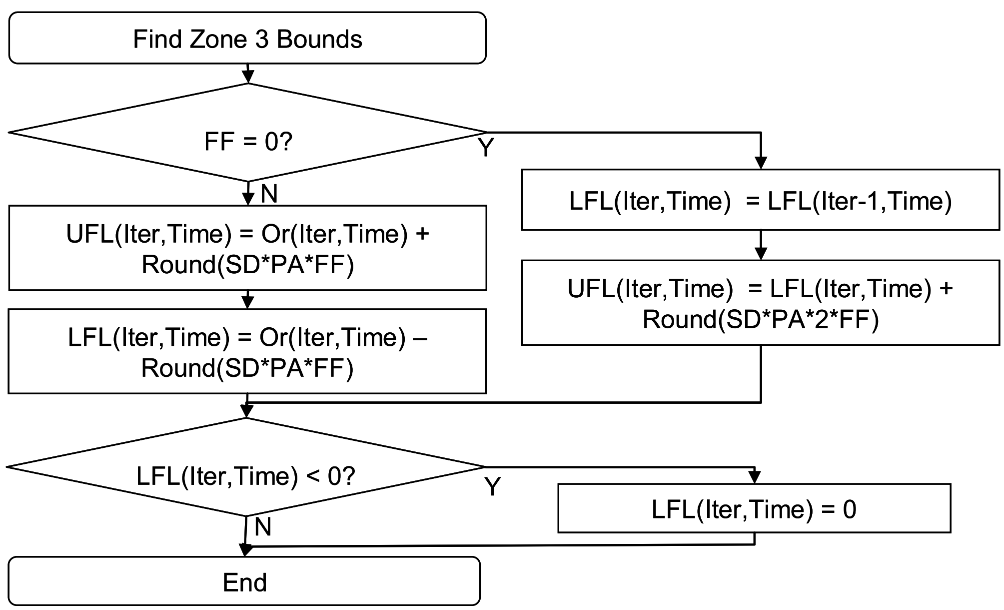

Figure 3.18. Find Zone Three Bounds.

When the forecasted value is between both the upper and lower flex limit, the bounds narrow around the point by using Equations 3.6 and 3.7 as shown in Figure 3.19 to generate the new flex limit. Explained differently, if the demand point is moving from the flex fence to the demand fence, the flex limits will move to the plan. Therefore, the flex limits are equal to the plan at the same point in time [Pl(Iter,Time) = UFL(Iter,Time) = LFL(Iter,Time)]. So, production will later equal this plan. If the plan exceeds the upper limit, the production level will equal the value of the limit and inventory will be reduced since the plan is not met. Similarly, if the plan sinks below the lower flex limit, production will equal the

$$\begin{aligned}&\mathrm{UFL(Iteration,Time)}\\&=\mathrm{Origin(Time)}+\mathrm{Round[SD\,x\,PA}\times\mathrm{FF]}\end{aligned} \quad \text{(Equation 3.6)}$$

$$\begin{aligned}&\mathrm{LFL(Iteration,Time)}\\&=\mathrm{Origin(Time)}-\mathrm{Round[SD}\times\mathrm{PA}\times\mathrm{FF]}\end{aligned} \quad \text{(Equation 3.7)}$$

$$\mathrm{UFL(Iteration,Time)}=\mathrm{UFL(Iteration-1,Time)} \quad \text{(Equation 3.8)}$$

$$\begin{aligned}&\mathrm{LFL(Iteration,Time)}\\&=\mathrm{UFL(Iteration,Time)}-\mathrm{Round[SD\,x\,PA\,x\,2\,x\,FF)]}\end{aligned} \quad \text{(Equation 3.9)}$$

$$\begin{aligned}&\mathrm{UFL(Iteration,Time)}\\&=\mathrm{LFL(Iteration,Time)}+\mathrm{Round[SD\,x\,PA\,x\,2\,x\,FF)]}\end{aligned} \quad \text{(Equation 3.10)}$$

$$\mathrm{LFL(Iteration,Time)}=\mathrm{LFL(Iteration-1,Time)} \quad \text{(Equation 3.11)}$$

lower limit and inventory will be accumulated.

Continuing the example, the forecasts for period 4, 5, 6, 7 and higher are equal to the forecast for period 2. The plan for each period depends on

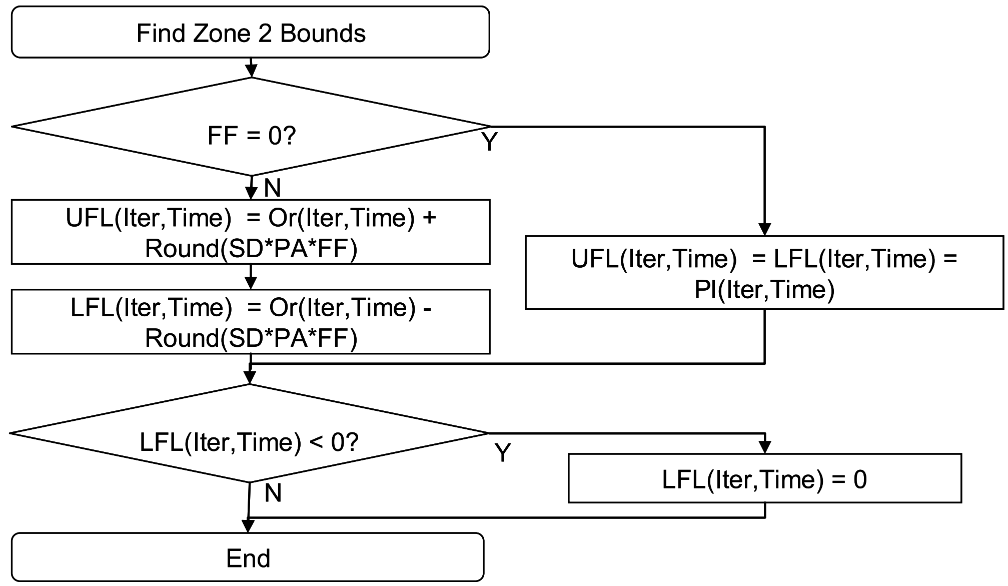

Figure 3.19. Find Zone Two Bounds.

the forecast minus the previous inventory level. The origin and flex limits simply shift one period closer for periods 4 and 5. However, period 6 is just entering the flex fence. Therefore, the flex limits must be defined for period 6. Since the PS strategy is being used, the limits are set 30 units on either side from the current production level (1000 units in period 1).

Once more, in Table 3.6, the plan is less than production and results in an excess of 115 units of inventory (1000 units of production – plan of 885). This is also easily observed in Figure 3.20 as the plan is less than the frozen level, and therefore, the rate of production. The initial demand of 1024 for iteration two is subtracted by the 139 units of leftover inventory from iteration one to provide a plan of 885. The production rate is 1000 units again and leaves an excess of 115 units of inventory. The inventory declines during time three because the plan is 863 units, but production is frozen at 970 units. Therefore, the resulting inventory decreases to 107 units. In the fourth time period, the forecast is still 978, which results in a plan of 871 units when the 107 units in inventory are subtracted. Again, new demand limits must be adjusted. Since the plan of 871 units is below the LFL of 970, the production decreases to 970 where the frozen demand flex limit will stay. This demonstrates that if demand remains low, then the schedule will change to accommodate. This time, 99 units are left. As the iteration continues, the RBPS system slowly reduces the inventory as the LFL is used during each period.

When iteration three begins in Table 3.7, the demand jumps to 1069.

Table 3.6. Second Iteration of RBPS Example.

Iteration	2						
Flex Fence	0	0	0	1	1	1	0
Percentage allowance for flex fence	0%	0%	0%	30%	30%	30%	0%
Period	2	3	4	5	6	7	8
Demand	1024	978	978	978	978	978	978
Net Requirements	885	863	871	879	887	895	
Origin	1000	1000	1000	1000	1000	1000	
Upper Bound		970	970	1030	1030	1030	
Lower Bound		970	970	970	970	970	
Production	1000	970	970	970	970	970	
Inventory	115	107	99	91	83	75	

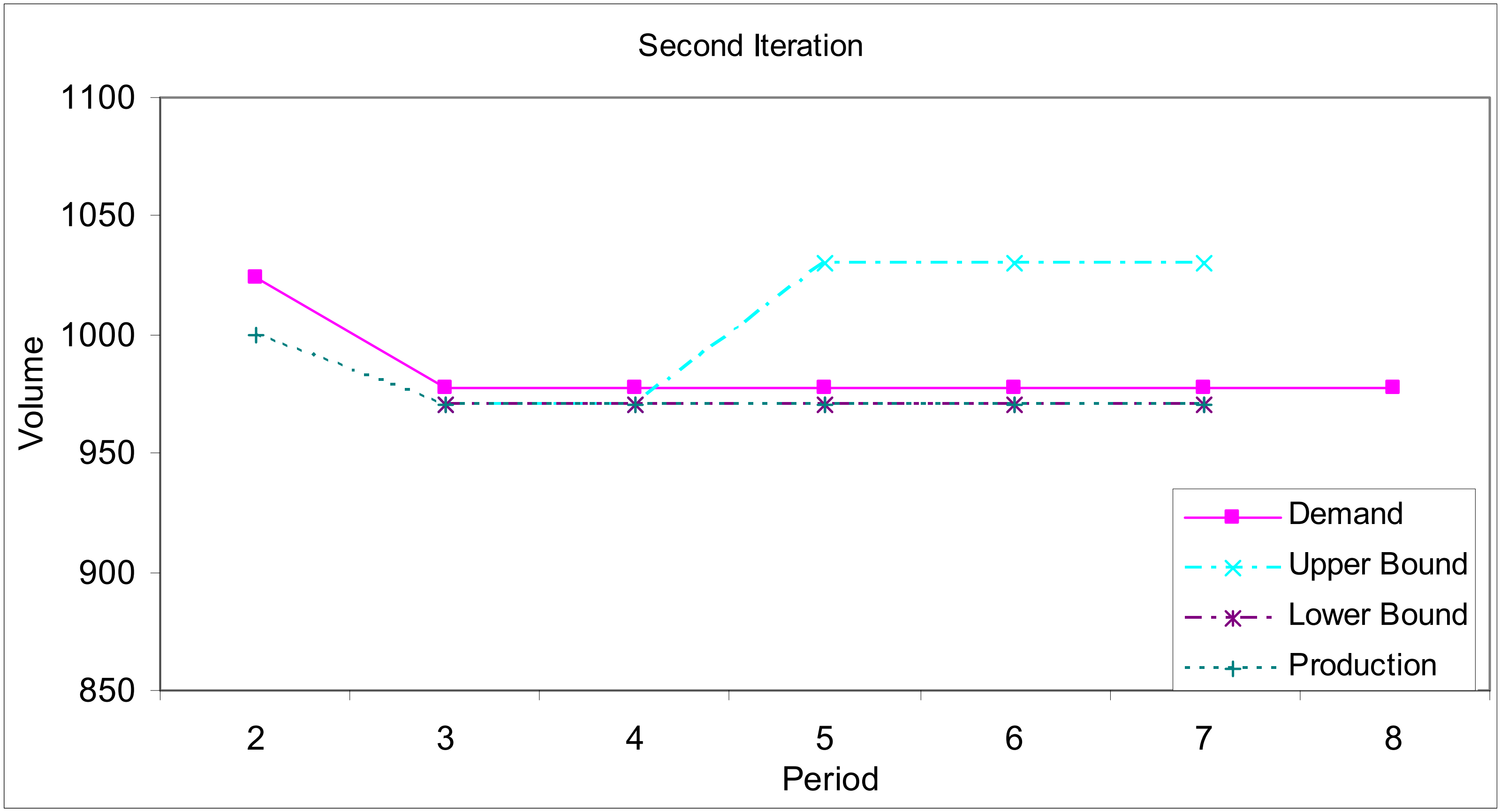

Figure 3.20. Second Iteration of the RBPS Example.

Table 3.7. Third Iteration of RBPS Example.

Iteration	3						
Flex Fence	0	0	0	1	1	1	0
Percentage allowance for flex fence	0%	0%	0%	30%	30%	30%	0%
Period	3	4	5	6	7	8	9
Demand	1069	1005	1005	1005	1005	1005	1005
Net Requirements	954	989	1024	1005	1005	1005	
Origin	1000	1000	1000	1000	1000	970	
Upper Bound		970	1024	1030	1030	1000	
Lower Bound		970	1024	970	970	940	
Production	970	970	1024	1005	1005	1000	
Inventory	16	-19	0	0	0	-5	

After subtracting the 115 units of inventory from iteration 2, the resulting plan is 954, 16 less than the production of 970. The forecast for the rest of the iteration remains high at 1005. This time for period 4, the plan is greater than production and results in a backlog of 19 units as shown in Figure 3.21. However, in period five, the plan of 1024 units is within the bounds of 1030 and 970. Therefore, the frozen schedule will equal the plan of 1024 which results in zero inventory.

The significance of this example is the forecast for the first and second iterations resulted in excess inventory. However, the third iteration achieved zero inventory when the flex limits narrowed around the demand point. Regardless, the overall plan for the system did not allow production to fluctuate much due to the bounds imposed by management.

Note that for PS, the new limits are based on the actual rate of production. Therefore, inventory or backlog may exist throughout the planning horizon for PS if the flex limits are not able to contain the variation in demand. However, for a RS system, the inventory for the last flex period is always zero. This is because the newest flex fence is created around the forecasted plan at that time. For instance, if this example used RS, the initial iteration would be the exact same to initialize the system as shown in Table 3.8 and Figure 3.22. Similarly, the first iteration is the same until period 6. When the new flex limits are created, they are based on the plan for that period, rather than the production rate. Shown in Table 3.9, the bounds for the last period in the flex

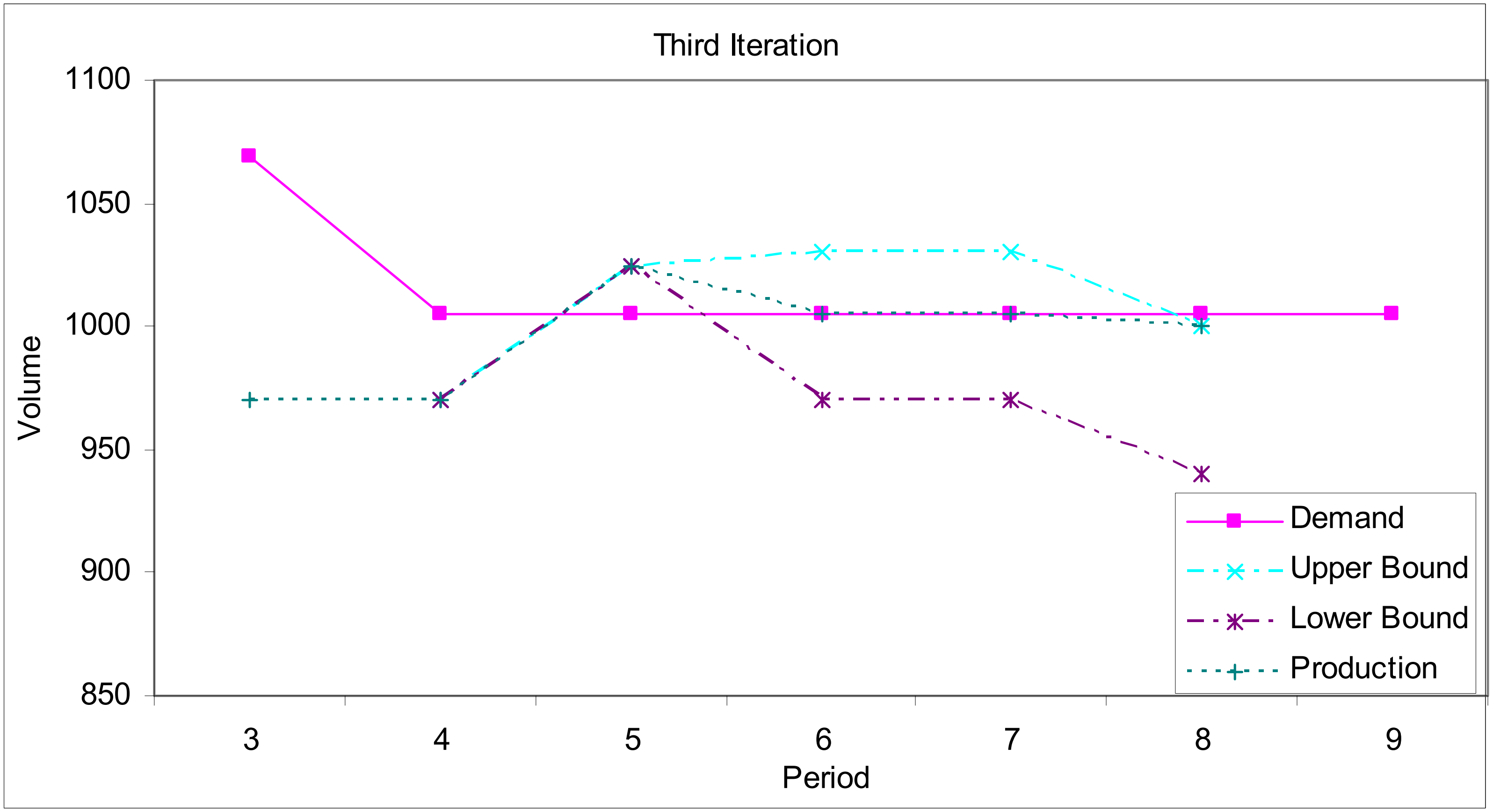

Figure 3.21. Third Iteration of the RBPS Example.

Table 3.8. Initial Iteration Utilizing the Retailer Smoothing Strategy.

Iteration	0						
Flex Fence	0	0	0	1	1	1	0
Percentage allowance for flex fence	0%	0.0%	0.0%	30.0%	30.0%	30.0%	0.0%
Period	Current Period	1	2	3	4	5	6
Demand	1000	1000	1000	1000	1000	1000	1000
Net Requirements	1000	1000	1000	1000	1000	1000	
Origin	1000	1000	1000	1000	1000	1000	
Upper Bound		1000	1000	1030	1030	1030	
Lower Bound		1000	1000	970	970	970	
Production	1000	1000	1000	1000	1000	1000	
Inventory	0	0	0	0	0	0	

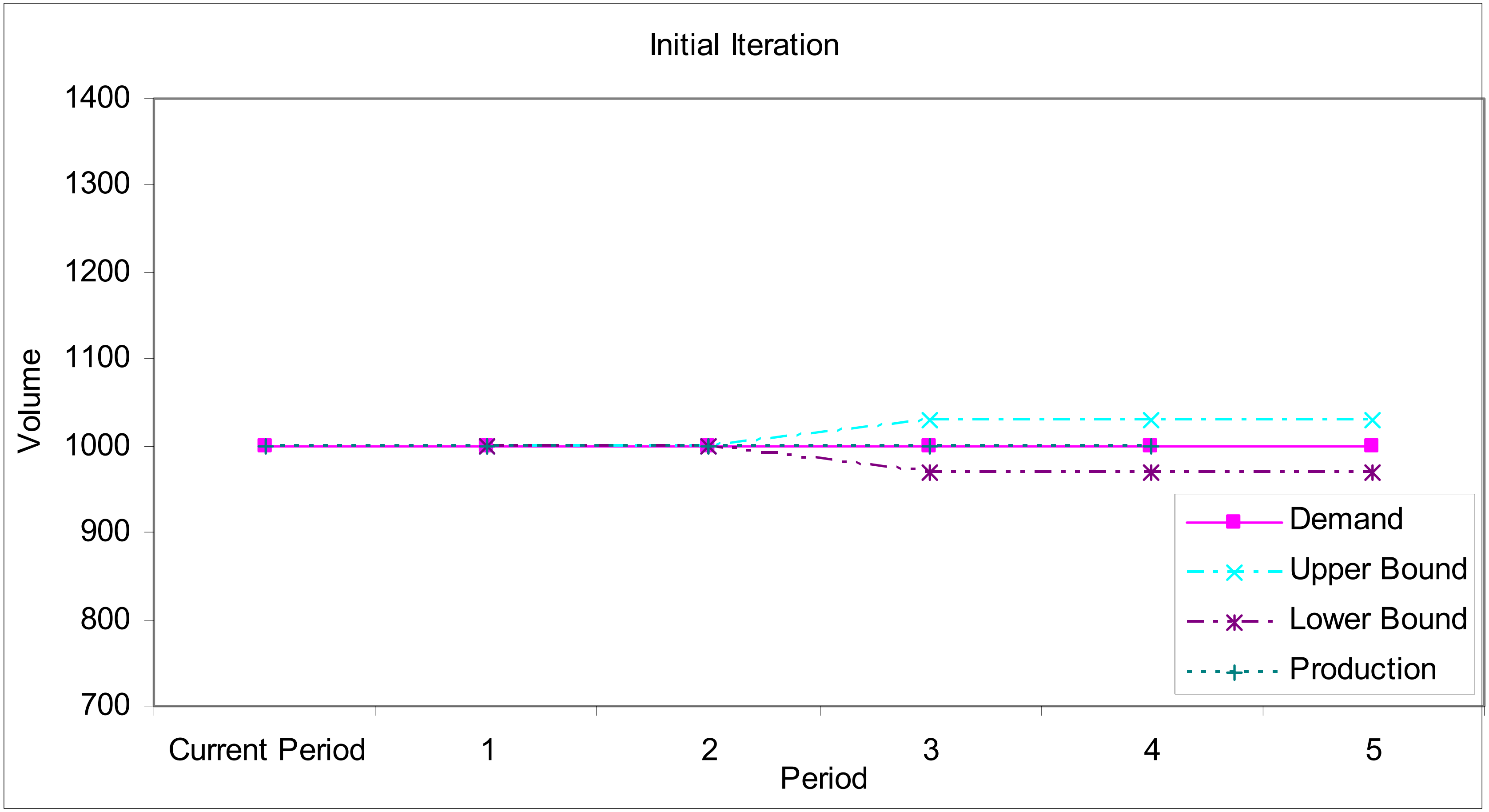

Figure 3.22. Illustration of Initial Iteration Utilizing the Retailer Smoothing Strategy.

Table 3.9. First Iteration Utilizing the Retailer Smoothing Strategy.

Iteration	1						
Flex Fence	0	0	0	1	1	1	0
Percentage allowance for flex fence	0%	0%	0%	30%	30%	30%	0%
Period	1	2	3	4	5	6	7
Demand	861	958	958	958	958	958	958
Net Requirements	861	819	777	765	753	741	
Origin	1000	1000	1000	1000	1000	741	
Upper Bound		1000	970	1030	1030	771	
Lower Bound		1000	970	970	970	711	
Production	1000	1000	970	970	970	741	
Inventory	139	181	193	205	217	0	

fence will always be around the estimated plan. In this example, the plan, and therefore the origin, is 741 units. As in the previous example, the flex limits will be 30 units above and below the origin. Hence, the flex limits are set to 711 and 771 units. Notice for the RS strategy, the last period in the flex fence will always have zero inventory since the flex limits are created around the plan and origin. This technique causes a dramatic change in the flex bounds as shown in Figure 3.23.

Likewise, the second iteration for the RS strategy will mimic the second iteration for the PS strategy. This time, however, the last two periods will differ. Period 6 changed in iteration 1 and will shift one period closer. Also, period 7 will enter the flex fence and must have its limits set. This time, the inventory for period six will encounter a shortage as the flex limits have been set much lower than the PS example and are not able to fulfill the anticipated orders as shown in Table 3.10. Note in Figure 3.24 how much higher the plan is than the flex limits in period 6. But once again, period 7's inventory is zero again as the bounds are set around the plan. There is a difference of at least 300 units between periods 6 and 7. The PS technique would not have allowed this much variation in production.

During the third iteration of the RS strategy, periods 3 through 5 imitate the PS strategy. But once again, periods 6 through 8 differ. Period 6 is still short due to limits set at low levels as shown in Table 3.11. This shortfall causes period 7's production deficiency to be even larger. But as shown in Figure 3.25, the bounds are created around the plan to zero the inventory

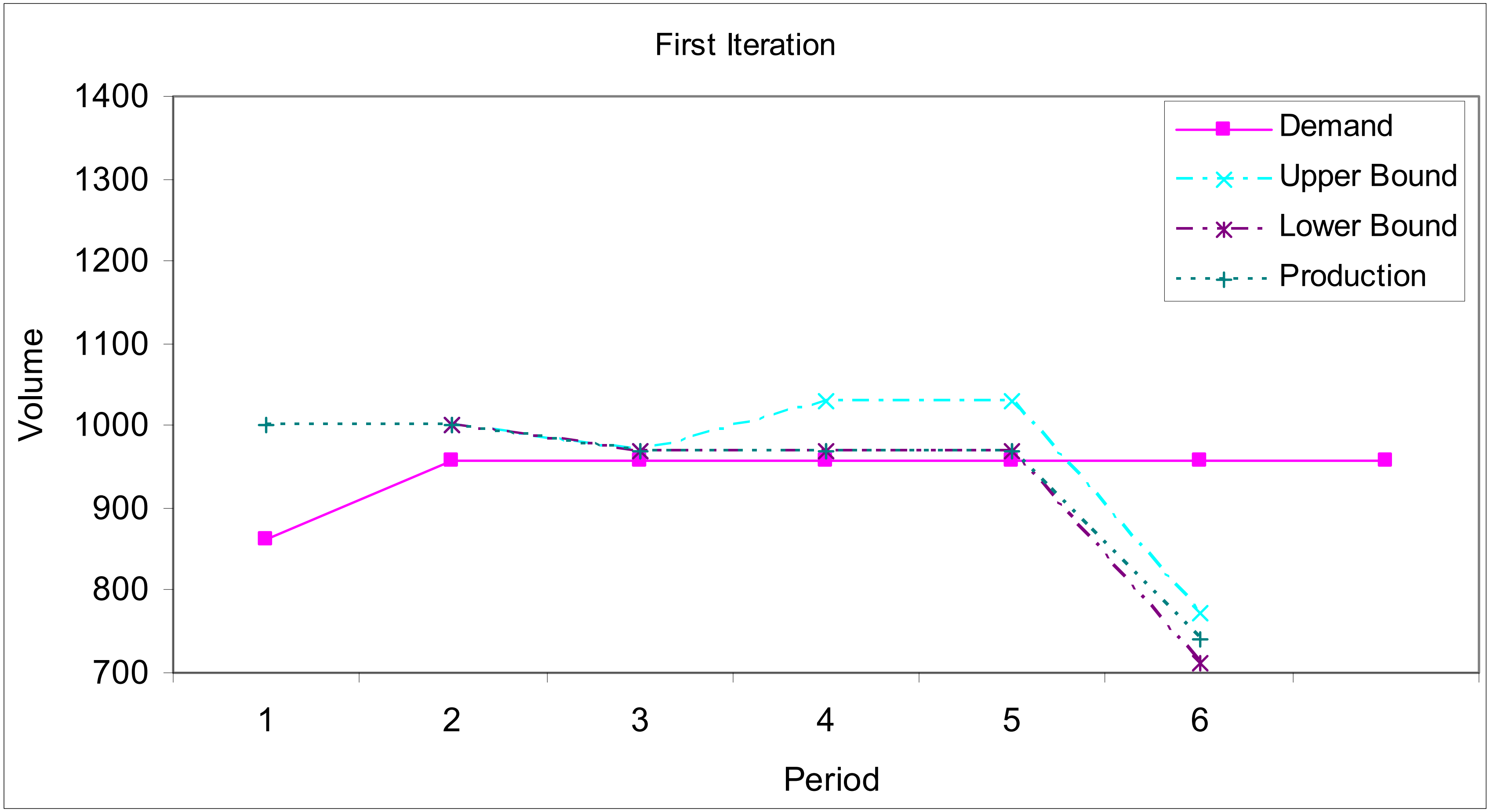

Figure 3.23. Illustration of First Iteration Utilizing the Retailer Smoothing Strategy.

Table 3.10. Second Iteration Utilizing the Retailer Smoothing Strategy.

Iteration	2						
Flex Fence	0	0	0	1	1	1	0
Percentage allowance for flex fence	0%	0%	0%	30%	30%	30%	0%
Period	2	3	4	5	6	7	8
Demand	1024	978	978	978	978	978	978
Net Requirements	885	863	871	879	887	1094	
Origin	1000	1000	1000	1000	741	1094	
Upper Bound		970	970	1030	771	1124	
Lower Bound		970	970	970	711	1064	
Production	1000	970	970	970	771	1094	
Inventory	115	107	99	91	-116	0	

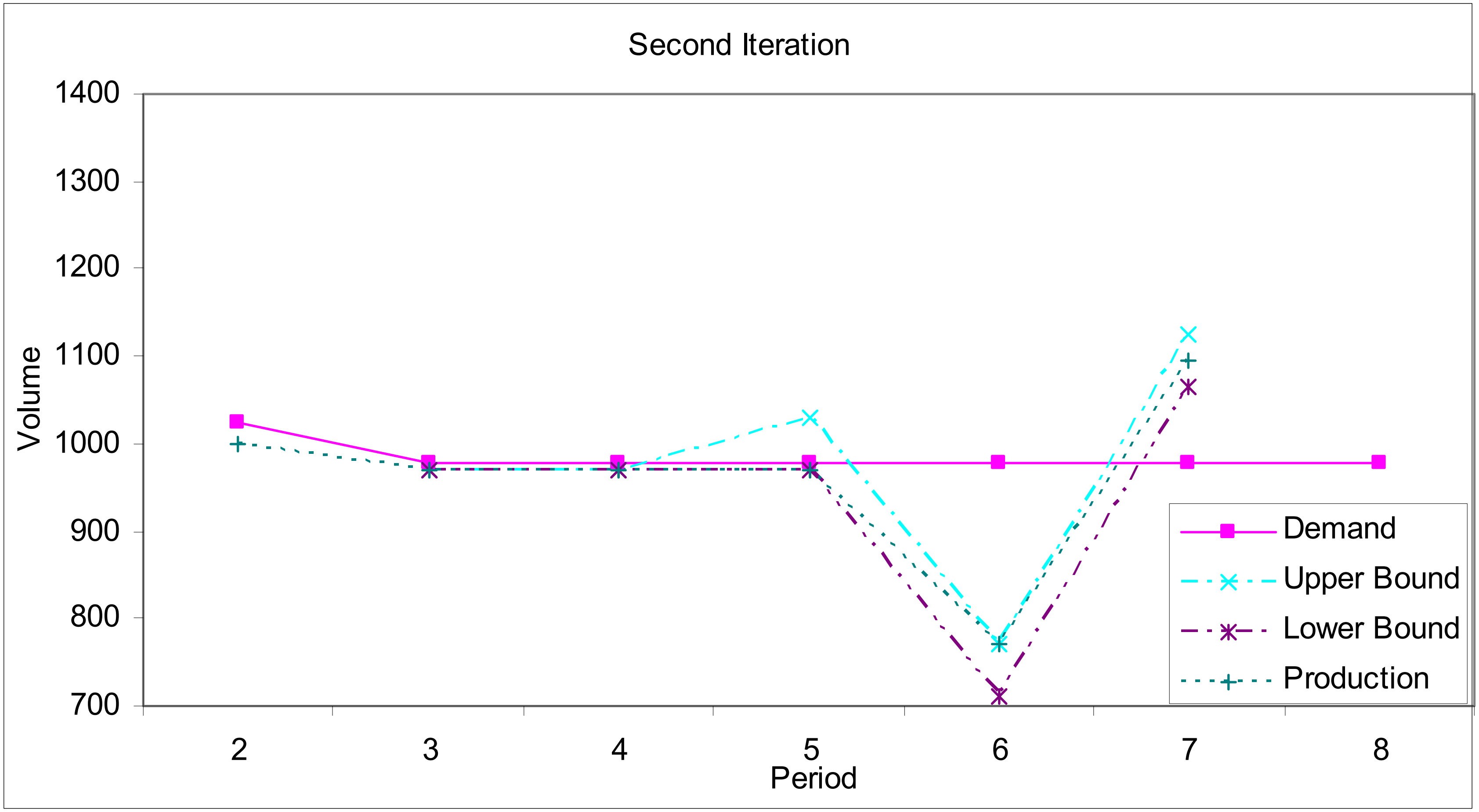

Figure 3.24. Illustration of Second Iteration Utilizing the Retailer Smoothing Strategy.

Table 3.11. Third Iteration Utilizing the Retailer Smoothing Strategy.

Iteration	3						
Flex Fence	0	0	0	1	1	1	0
Percentage allowance for flex fence	0%	0%	0%	30%	30%	30%	0%
Period	3	4	5	6	7	8	9
Demand	1069	1005	1005	1005	1005	1005	1005
Net Requirements	954	989	1024	1005	1239	1120	
Origin	1000	1000	1000	741	1094	1120	
Upper Bound		970	1024	771	1124	1150	
Lower Bound		970	1024	711	1064	1090	
Production	970	970	1024	771	1124	1120	
Inventory	16	-19	0	-234	-115	0	

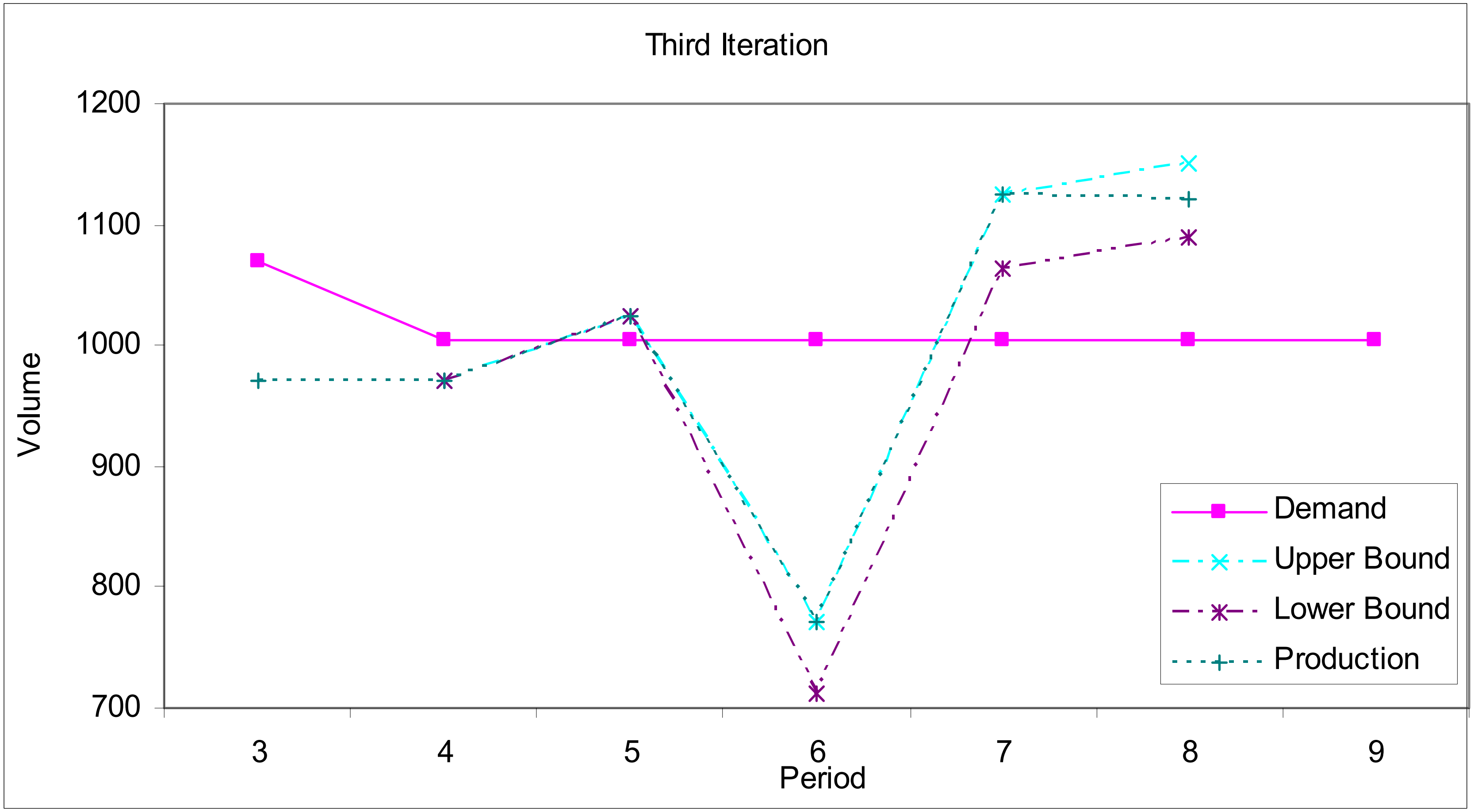

Figure 3.25. Illustration of Third Iteration Utilizing the Retailer Smoothing Strategy.

for period 8. This time, there is almost a 550 unit production difference between periods 6 and 8 as a result of the shortfalls during periods 6 and 7.

The purpose of this section was to elaborate on the model used in this research, and to understand the impacts of flex fences and flex limits on inventory and customer service level in a range of environments of varying demand. This section may be considered a roadmap to implementing the Rate-Based Planning and Scheduling concepts. Examples encompassing both the PS and the RS strategies were used to explain the similarities and differences between the two. The main difference incorporates the logic to create a new flex fence. The RS strategy is dependent on the forecasted plan which allows for more variability. The PS strategy is dependent on the current production level to smooth production over time while using inventory as a buffer.

3.5 Assumptions

As with any research, many assumptions are implicit in the methodology. However, this study tries to minimize the number of assumptions to ensure that companies from various industries may benefit from the discussion. The purpose of this section is to list the assumptions which will provide some detail that is missing in previous sections.

First of all, the orders have known and constant lead times (Brandolese and Cigolini 1999, Brandolese et. al. 2001, Melchiors 2003, Harvey and Snyder 1990, Hariharan and Zipkin 1995, Hill 1999, Ben-Daya and Raouf 1994, Graves 1999, Song 2000, Hill and Dominey 2001, Hill 1999). One half of the lead time has flexible ordering constraints; the other half is the frozen schedule. Many researchers also study the effects of dynamic lead time. Past research has used stochastic lead times (Molinder 1997, Harvey and Snyder 1990, Hariharan and Zipkin 1995, Xie 1998) with normal (Wu 2001, Eppen and Martin 1988), erlang (Bagchi and Hayya 1984), gamma (Burgin 1972, Foote et. al. 1988, Weng 1996), and exponential (Ryu and Lee 2003, Palaka et. al. 1998) distributions. Realistically, lead times are variable, but Foote et. al. (1988) state that the optimal policy is not vulnerable to varying lead times. Plus, quoted lead times are often rigid which makes this research more applicable (Pang and Yang 2002) as long as the assembly lead time is less than the quoted lead time (Brandolese and Cigolini 1999). Also, even though lead times can vary, they may be controlled by adding extra expense to ensure shorter lead times with greater customer service levels (Liao and Shyu 1991). But for this research, having fixed lead time is a simplifying assumption (Hill 2000).

To understand how the fixed lead times impact customer service levels, Inventory will be used to buffer against demand that may not be filled by production. The goal will be to maintain zero inventory. As the amount of inventory increases, it is understood that demand is below production and inventory is accumulating. On the other hand, if inventory levels stay negative, then production cannot achieve the rate of demand, and inventory will deplete or a backlog situation will occur. After the simulations have been completed, the range of inventory will be analyzed to understand how much a supplier must hold to provide the desired customer service levels to the customer.

The empirical analysis is made assuming a single product without considering multiple layers of Bills-of-Materials (Brandolese and Cigolini 1999, Silver and Smith 1981, Graves 1999, Kiesmuller and Scherer 2003, Song 2000, Vendemia et. al. 1995, Xie 1998). This assumption is sufficient as long as the demand is independent for all products in a company (Lin 1989). Also, this is applicable because typically in lean environments, only similar products are made in the same production cell. This ensures that manufacturing of various products is independent and will not affect the lead time of another product.

Demand in this experiment is unknown and stochastic (Eppen and Martin 1988, Vendemia et. al. 1995, Molinder 1997, Swaminathan and Tayur 1998, Ryan 2001). The use of exponential smoothing will allow variability in demand (Eppen and Martin 1988, Foote et. al. 1988, Snyder et. al. 1999, Enns 2002). Exponential smoothing has been used in many papers (Chen et. al. 2000, Graves 1999, Snyder et. al. 1999, Eppen and Martin, 1988, Foote et. al., 1988), and is the most commonly used forecast model (Box and Jenkins 1970). Also, most fixed-model time-series techniques are based on this technique (Mentzer and Bienstock 1998). Exponential smoothing is also applicable as Graves (1999) notes that demand histories perform like a random walk with repeated changes in the rate of growth or decline, and direction. Additionally, forecasts are typically built from historical forecasts with the assumption that the latest demand points are the best predictors for the future demand. This is the basis of exponential smoothing, which emphasizes the assumption of applicability (Graves 1999, Bagchi et. al. 1986, Hayya 1979, Hayya March 1980, Hayya June 1980).

The demand, in the exponential smoothing model, is generated using the previous demand point with a percentage increase or decrease due to an error term. These error points are independent and identically distributed (i.i.d.) (Bagchi et. al. 1986, Hayya 1979, Hayya March 1980, Hayya June 1980) using the normal distribution based on an average demand with a given standard deviation (Liao and Shyu 1991, Bagchi and Hayya 1984, Burgin 1972, Federgruen and Zipkin 1984, Eppen and Martin 1988, Ouyang and Wu 1997, Ben-Daya and Raouf 1994). The normal distribution is justified as Bagchi et. al. (1986) note that when lead times are constant, the sum of i.i.d. random variables approaches normality. New values will emerge as each iteration of the experiment is tested. Since the newest value is dependent on the previous iteration, the demand values are correlated. The assumption of correlation is important since it is applicable to industry (Toktay and Wein 2001, Chen et. al. 2000, King et. al. 2002, Swaminathan and Tayur 1998, Ryan 2001). Also, the correlation in the exponential smoothing model causes the demand to be nonstationary which is also applicable (Ryan 2001) and an assumption in many papers (Gudum et. al. 2002, Graves 1999, Federgruen and Zipkin 1984, Vendemia et. al. 1995, Harvey and Snyder 1990, Enns

2002). Although, Hill (2000) warns that research must be careful when dealing with nonstationary demand since the aggregate demand may be highly dependent on when the lead time starts and ends. As stated by Snyder et. al. (1999), the use of exponential smoothing is used to acknowledge the impact of a changing mean in nonstationary demand.

When exponential smoothing models are used, the potential of variation in demand increases over time. Gilbert (2003) provided a means to predict the amount of variation with a given lead time. The purpose was to identify the target safety stock to ensure good service levels and to determine flex capacity requirements. Gilbert calculated the standard deviation of the inventory that is necessary to fulfill demand for items with lead times (Equation 3.12). As displayed in Figure 3.26, this calculation forces the flex requirements to widen as the lead times increase. As stated by Chen et. al. (2000), "It is clear that longer lead times lead to larger increases in variability. In addition, we see that the larger the smoothing parameter, the larger the increase in variability."

$$\sigma_{\mathrm{I}} = \sigma\sqrt{1+(1+\alpha)^2+(1+2\alpha)^2+...+(1+(L-1)\alpha)^2} \qquad \text{(Equation 3.12)}$$

Some models are based solely on the use of demand data, or a feed-forward path. However, this research will base the production level on the plan for the system. The plan will consider the amount of demand minus the inventory or backlog (or lack of inventory) left from the previous period

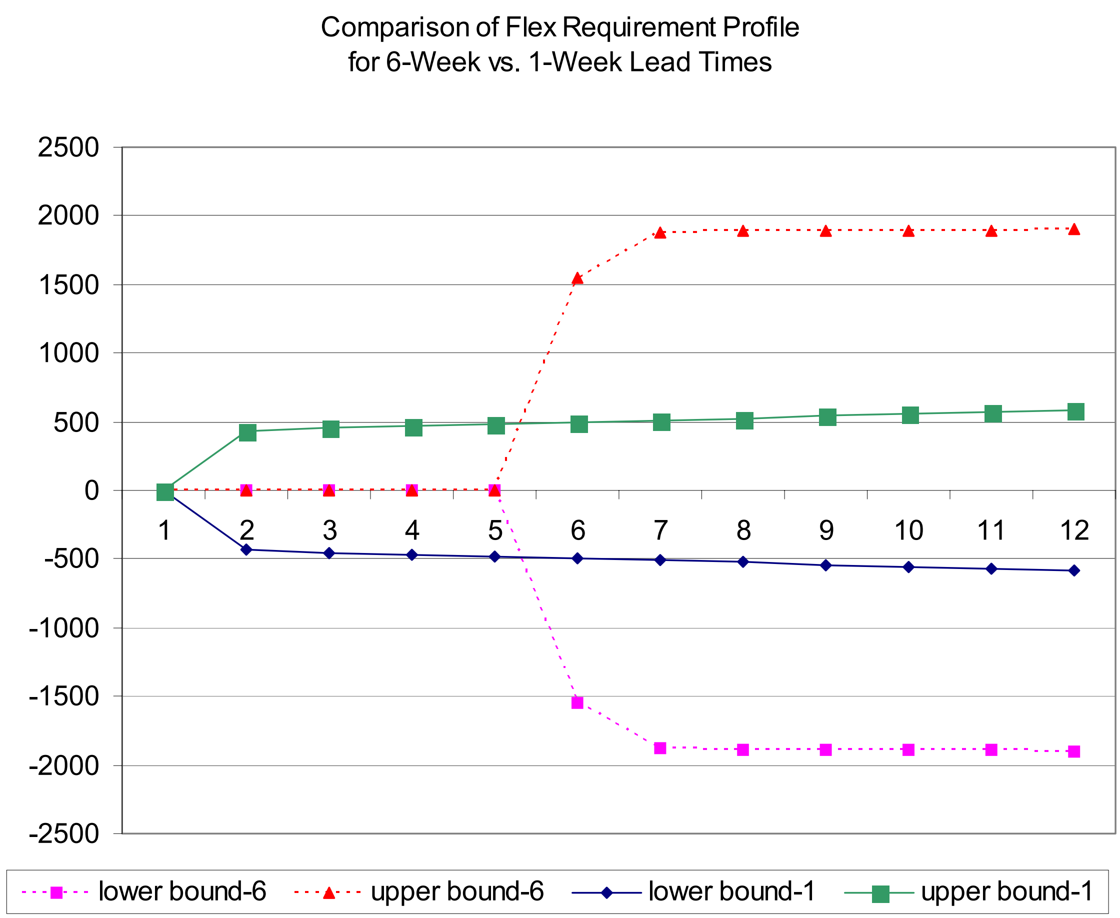

Figure 3.26. Six Week vs. One Week Lead Time Flex Requirement Profile.

(Gallego and Ozer 2001). “This control approach is based both on a feed-forward path and on a feed-back one.” The basis for this assumption is that the system will be much more robust to noise in demand data or production limitations. Even though the use of inventory makes the model more complex, it is much more realistic as the feed-back path, using inventory, is a best-practice in industry today (Brandolese and Cigolini 1999).

The demand environment would be considered a build-to-stock situation for the supplier. As orders are received, the supplier pulls the inventory from finished goods or uses the allotted production to meet the demand. The goal is to have enough inventory in finished goods to ensure that only the desired backlog exists. If demand may be met with production alone, then the environment may be considered a make-to-order situation. On the other hand, when the lead times are so long, the customer will never be able to receive items from the supplier to directly fill the consumers' orders. Therefore, the customer will always maintain the replenish-to-stock situation.

To meet the requirements in these demand environments, but yet restrict the volatility of production, limits are placed on the production level. This assumption is realistic for the fact that there is a delay between the time a shift in demand is planned, and the time in which the production rate may actually increase to meet the demand (Silver and Smith 1981). To facilitate the limitation, these bounds are a percentage of the standard deviation above and below the original point. Standard deviation is used because it provides the only information regarding the volatility of demand. Therefore, as the standard deviation increases, the flex limits will also increase to buffer the variability. And vice versa, as the demand variation decreases, the width of the limits will also decline.

3.6 Experiment

The analysis will be made using simulation over several iterations with multiple replications (Geunes et. al. 2001, Ryan 2001, Ryan 1998, Molinder 1997, Hopp and Roof Sturgis 2000, Xie 1998). Simulation will be used to enhance the lessons from Gilbert (2003) since linear programming is unable to analyze the flexibility constraints. Also simulation allows the use of stochastic demand to test the model.

Five factors (independent variables) will be considered for this study (Moen et. al. 1999). The factors and their associated levels are shown in Table 3.12. Large values of standard deviation (or demand variability) will force the demand values to fluctuate more rapidly and inconsistently. The standard deviation, which is really standard error as the variation is created period to period, will allow many organizations to relate to this research depending on their variation in demand. As explained by the Poisson distribution, the demand is totally random when the standard deviation is equal to the square root of the mean (Montgomery 1997). However, issues such as batching and shifting of demand may create more volatility in the process. The concentration on the current demand is represented by the

Table 3.12. Factors and Levels for the Research.

Factors	Levels
Demand Variability or Standard Deviation (σ)	2%, 20% of demand
Dependency on Demand (α)	.1, .5
Width of Flex Bounds	Multiple of 2.5%, 20%
Length of Time Fence	2, 20 periods
Demand Strategy	PS, RS

alpha value in the exponential smoothing model. The higher the value of alpha, the more emphasis is given to the current demand, which will add more noise and instability to the forecast. The width of the flex bounds is the percentage standard deviation away from the forecast for the period. The wider the flex bounds, the more production may shift to changes in demand. The length of the time fence refers to the amount of time each flex bound remains at the same level or may be characterized as the planning horizon. For instance, in Figure 3.27, the flex fences are four periods long and plus or minus 20% of the standard deviation around the origin. In Figure 3.28, the flex fences are three periods long and the flex limits are placed ten percent of the standard deviation around the origin. And the demand strategy factor defines whether the Production Smoothing Strategy or the Retailer Smoothing Strategy will be used in the experiment. As stated earlier, the new flex fences for the RS are determined based on the last forecasted plan within the flex fence. The purpose for RS is to allow the flexibility for the customer in their initial forecast, while minimizing the changes made to the forecast later. By maintaining the bounds around the initial plan, the supplier has time to plan for increases or decreases in production. On the other hand, PS develops the limits based on current production. This technique tries to minimize the variability to the production schedule which will also reduce the level of work-in-process needed to buffer the variation.

The factors and levels are examined using the following response (dependent) variables (Moen et. al. 1999):

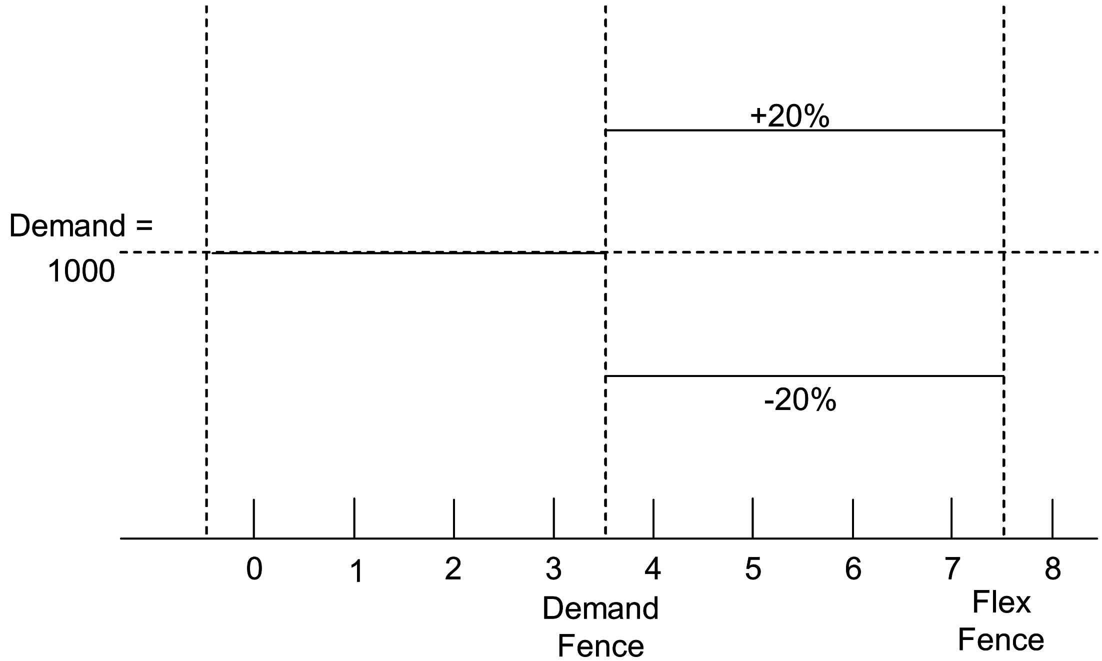

Figure 3.27. Four Period Long Flex Fences with 20% Flex Limits.

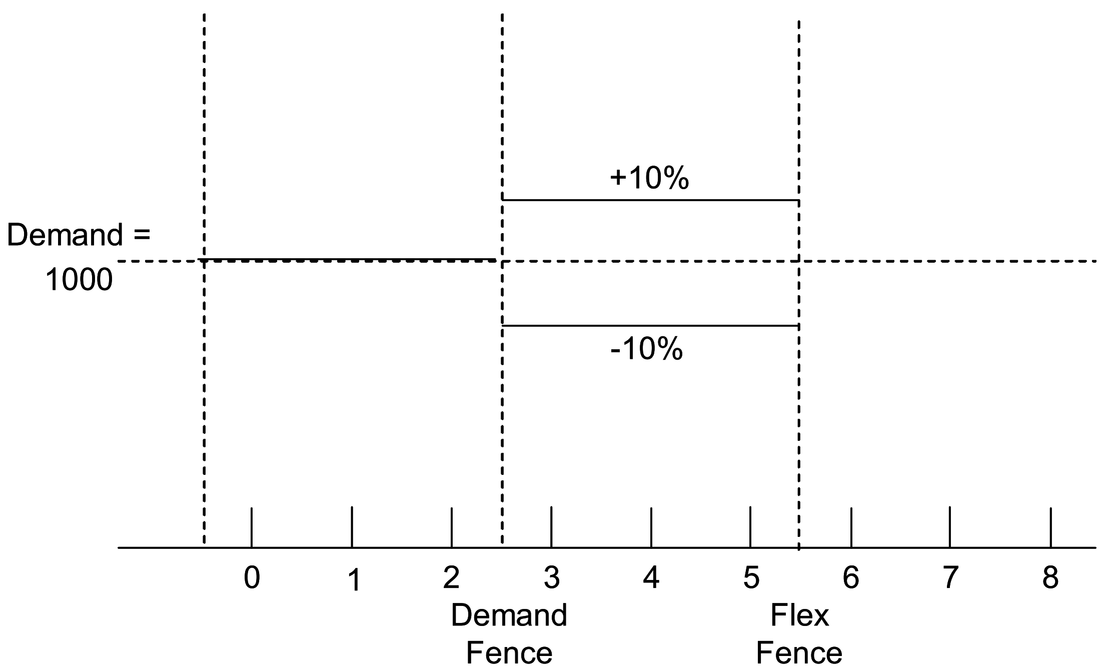

Figure 3.28. Three Period Long Flex Fences with 10% Flex Limits.

- Inventory stability (Lummus et. al. 2002)
- Schedule Stability (Sridharan et. al. 1987, Sridharan et. al. 1988)
- Production
- Inventory
- Plan

Inventory stability will provide an understanding of how much the inventory varies around its target. The more volatile the inventory, the more likely that customer orders will not be met and could potentially mean lost business. Also, schedule stability is the amount that demand varies over time as described by Sridharan et. al. (1987, 1988). The research will compare the schedule stability to the actual demand values to understand how much the flex fences limit the demand values. The schedule stability will be compared to the standard deviation of the schedule to analyze the situation in terms often used by industry. Production and the plan will be compared to demand to understand the reduction in volatility. The inventory response variable will provide insight into the level of safety stock required for a given customer service level. These results will be analyzed using statistical analyses to determine whether each factor is significant and should be controlled in industry.

3.7 Experimentation Procedure

The experimentation procedure has a three step process. The first step will provide some basis for the simulations. The mean, standard deviation, skewness, and kurtosis will be analyzed across iterations to confirm that the simulation has reached a steady state. The result of this procedure is the number of replications required for the rest of the experiment.

A factorial deisgn will be utilized in this research to understand the impact of the factors on the response variables. A total of 32 ($32 = 2^5$) runs will be made for the full factorial experiment as shown in Table 3.13. The number of replications required (mentioned in the preceding paragraph) is run to identify the significant factors in the experiment. From the results, insignificant factors will be removed from the analysis and the remaining factors will be further tested.

The end result of the experiment will be a group of tables that practitioners may use to implement RBPS in their own company. Shown in Table 3.14 is an example of how the data will appear. For each page is a given standard deviation and desired customer service level. Then, practitioners may search through the table to justify whether they should hold more inventory with less flexibility, or vice versa. The point of the tables is to allow the practitioner to weigh the benefits and disadvantages of various levels of inventory and flex limits.

3.8 Anticipated Results

In this research, the simulation will not find an optimal solution for each set of factors. Instead, readers using this methodology will be able to weigh the costs in their company regarding customer service level, safety stock level,

Table 3.13. Full Factorial for 2^5 Design.

Test	Standard Deviation	Alpha	Flex Bound Width	Flex Bound Length	Demand Strategy
1	0.02	0.1	0.025	2	PS
2	0.02	0.5	0.025	2	PS
3	0.02	0.1	0.2	2	PS
4	0.02	0.5	0.2	2	PS
5	0.02	0.1	0.025	20	PS
6	0.02	0.5	0.025	20	PS
7	0.02	0.1	0.2	20	PS
8	0.02	0.5	0.2	20	PS
9	0.02	0.1	0.025	2	RS
10	0.02	0.5	0.025	2	RS
11	0.02	0.1	0.2	2	RS
12	0.02	0.5	0.2	2	RS
13	0.02	0.1	0.025	20	RS
14	0.02	0.5	0.025	20	RS
15	0.02	0.1	0.2	20	RS
16	0.02	0.5	0.2	20	RS
17	0.2	0.1	0.025	2	PS
18	0.2	0.5	0.025	2	PS
19	0.2	0.1	0.2	2	PS
20	0.2	0.5	0.2	2	PS
21	0.2	0.1	0.025	20	PS
22	0.2	0.5	0.025	20	PS
23	0.2	0.1	0.2	20	PS
24	0.2	0.5	0.2	20	PS
25	0.2	0.1	0.025	2	RS
26	0.2	0.5	0.025	2	RS
27	0.2	0.1	0.2	2	RS
28	0.2	0.5	0.2	2	RS
29	0.2	0.1	0.025	20	RS
30	0.2	0.5	0.025	20	RS
31	0.2	0.1	0.2	20	RS
32	0.2	0.5	0.2	20	RS

Table 3.14 Example of Output Table.

		Flexible Capacity									
		5	10	15	20	25	30	35	40	45	50
Length of Fence	1										
	2										
	3										
	4					Inv					
	5										
	6										
	7										
	8										

and the allowed limits of flexibility. All of this information will be based on the standard deviation and the alpha for the exponential smoothing model.

However, trends are anticipated in this analysis. As shown in Table 3.15:

- If all of the factors stay the same except safety stock increases, then the customer service level will increase (row 1);
- If the safety stock increases in proportion to demand, the customer service level should stay about the same (row 2);
- If the flex limits increase with the demand variation, production will tend to shift more as the boundaries are further apart. This may cause customer service to diminish as production may not be able to change quick enough to meet demand (row 3);
- If only alpha and the standard deviation increase, the customer service level will definitely drop (row 4);
- When alpha and the standard deviation increase, the system may have to increase the flex boundaries to try to catch demand and help the customer service level (row 5); and,
- An environment with an increase of alpha, standard deviation, and flex limits must also have an increase in safety stock in order to combat the high variation in demand caused by the high standard deviation and the alpha (row 6).

Table 3.15. Anticipated Results from the Research.

	Standard Deviation	Flex Limits	Alpha	Safety Stock	Production Shift	Customer Service Level
1	—	—	—	↑	—	↑
2	↑	—	—	↑	—	—
3	↑	↑	—	—	↑	↓
4	↑	—	↑	—	—	↓
5	↑	↑	↑	—	↑	↓
6	↑	↑	↑	↑	↑	↑

Chapter 4

Results

4.1 Introduction

No study is conclusive without data. This chapter is dedicated to the results of the study. First, an initial test is performed and the results are summarized. The significance of factors is determined and irrelevant factors are eliminated from the study. A set of tables is then provided to understand how to implement either the Retailer Smoothing or Production Smoothing techniques. Finally, a summary of the trends is provided as a result of the tables.

4.2 Initial Test

The factorial design from Table 3.13 was run and the data were analyzed using the JMP statistical software. The main effects were consistently significant (or not significant) for all of the response variables and the reaction to changes in the levels was observed. As shown in Tables 4.1, 4.2, and 4.3, the statistical model represented the Production Smoothing technique well since RSquare and the ANOVA F-Ratio are both high and the lack of fit error is insignificant. By utilizing the Pareto chart and parameter estimates, the flex bound length, flex bound width, and standard deviation are significant for the Production Smoothing technique (Figure 4.1 and Table 4.4).

Similarly for the Retailer Smoothing strategy, Tables 4.5, 4.6, and 4.7,

Table 4.1. Inventory Summary of Fit for the Initial Production Smoothing Analysis.

RSquare	0.97868
RSquare Adj	0.968686
Root Mean Square Error	2926.153
Mean of Response	22799.77
Observations (or Sum Wgts)	48

Table 4.2. Initial ANOVA for Inventory using Production Smoothing.

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	1.25775e10	838501250	97.9286
Error	32	273995882	8562371.3	Prob > F
C. Total	47	1.28515e10		<.0001

Table 4.3. Initial Lack of Fit for the Inventory Model using Production Smoothing.

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	16	163056275	10191017	1.4698
Pure Error	16	110939607	6933725.4	Prob > F
Total Error	32	273995882		0.2248
				Max RSq
				0.9914

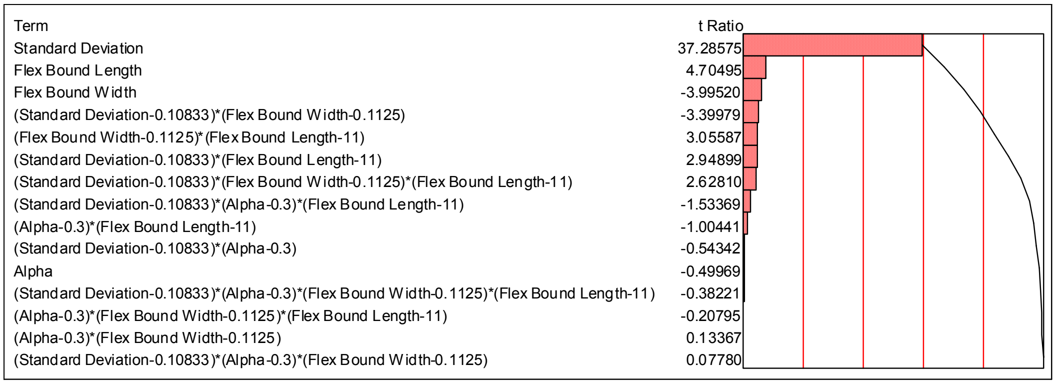

Figure 4.1. Initial Pareto for Inventory using Production Smoothing.

Table 4.4. Initial Parameter Estimates for Inventory using Production Smoothing.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2143.7569	1237.291	1.73	0.0928
Standard Deviation	191478.96	5135.446	37.29	<.0001
Alpha	-1155.954	2313.347	-0.50	0.6207
(Standard Deviation-0.10833)*(Alpha-0.3)	-15597.24	28702.12	-0.54	0.5906
Flex Bound Width	-19284.41	4826.901	-4.00	0.0004
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	-199536.6	58690.81	-3.40	0.0018
(Alpha-0.3)*(Flex Bound Width-0.1125)	3533.937	26438.25	0.13	0.8945
(Standard Deviation-0.10833)*(Alpha-0.3)*(Flex Bound Width-0.1125)	25521.592	328024.3	0.08	0.9385
Flex Bound Length	220.79505	46.9282	4.70	<.0001
(Standard Deviation-0.10833)*(Flex Bound Length-11)	1682.7062	570.6051	2.95	0.0059
(Alpha-0.3)*(Flex Bound Length-11)	-258.1717	257.0385	-1.00	0.3227
(Standard Deviation-0.10833)*(Alpha-0.3)*(Flex Bound Length-11)	-4891.122	3189.125	-1.53	0.1349
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	1638.9323	536.3223	3.06	0.0045
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	17138.39	6521.201	2.63	0.0131
(Alpha-0.3)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-610.8612	2937.583	-0.21	0.8366
(Standard Deviation-0.10833)*(Alpha-0.3)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-13930.38	36447.14	-0.38	0.7048

Table 4.5. Inventory Summary of Fit for the Initial Retailer Smoothing Analysis.

RSquare	0.995159
RSquare Adj	0.992889
Root Mean Square Error	714.9816
Mean of Response	6291.256
Observations (or Sum Wgts)	48

Table 4.6. Initial ANOVA for Inventory using Retailer Smoothing.

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	3362543188	224169546	438.5175
Error	32	16358357.4	511198.67	Prob > F
C. Total	47	3378901546		<.0001

Table 4.7. Initial Lack of Fit for the Inventory Model using Retailer Smoothing.

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	16	12815426	800964	3.6172
Pure Error	16	3542931	221433	Prob > F
Total Error	32	16358357		0.0071
				Max RSq
				0.9990

the model explains the data well since RSquare and the F-Ratio for ANOVA are both high. Again, the lack of fit error does not describe much of the model. However, this time, the standard deviation, alpha, and flex bound length are significant, and flex bound width is not significant (Figure 4.2 and Table 4.8). Therefore, it is clear that flex bound width may be eliminated from the Retailer Smoothing study.

However, there were two issues with the analysis. The first problem may be seen in the residual of the variation versus the predicted values plots (Figures 4.3 and 4.4). The predicted variation grows as the residual increases. For a proper analysis, the residuals should have remained consistent. Due to this issue, a transformation of the data must be made in hope that the variation will be consistent. The transformation should also lead toward a more accurate statistical model that may predict values better than the points in Figures 4.5 and 4.6.

Also, the range between the minimum and the maximum values was too large. When the values vary this much, it is hard to create and quantify a model to understand changes in the factors. When the range is this large and the variation is not constant, a transformation is needed to review the information. Performing the transformation will not impact the results since every data point will be altered by the same nonlinear function.

The second issue is that there is not enough information in the data to statistically identify trends in the Retailer Smoothing study. As in Figure 4.6, there are very few points in the upper right-hand corner to derive a proper

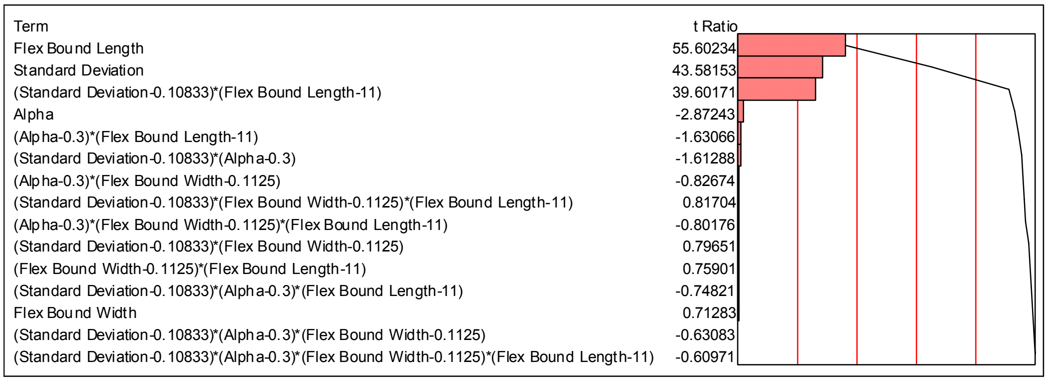

Figure 4.2. Initial Pareto for Inventory using Retailer Smoothing.

Table 4.8. Initial Parameter Estimates for Inventory using Retailer Smoothing.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-6253.804	302.322	-20.69	<.0001
Standard Deviation	54686.288	1254.804	43.58	<.0001
Alpha	-1623.632	565.2474	-2.87	0.0072
(Standard Deviation-0.10833)*(Alpha-0.3)	-11311.37	7013.129	-1.61	0.1166
Flex Bound Width	840.71858	1179.414	0.71	0.4811
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	11422.46	14340.62	0.80	0.4316
(Alpha-0.3)*(Flex Bound Width-0.1125)	-5340.726	6459.97	-0.83	0.4145
(Standard Deviation-0.10833)*(Alpha-0.3)*(Flex Bound Width-0.1125)	-50560.75	80150.05	-0.63	0.5326
Flex Bound Length	637.5655	11.46652	55.60	<.0001
(Standard Deviation-0.10833)*(Flex Bound Length-11)	5521.3774	139.4227	39.60	<.0001
(Alpha-0.3)*(Flex Bound Length-11)	-102.4138	62.80527	-1.63	0.1128
(Standard Deviation-0.10833)*(Alpha-0.3)*(Flex Bound Length-11)	-583.0313	779.2366	-0.75	0.4598
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	99.465255	131.046	0.76	0.4534
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	1301.8676	1593.402	0.82	0.4199
(Alpha-0.3)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-575.4818	717.7745	-0.80	0.4286
(Standard Deviation-0.10833)*(Alpha-0.3)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-5429.834	8905.561	-0.61	0.5464

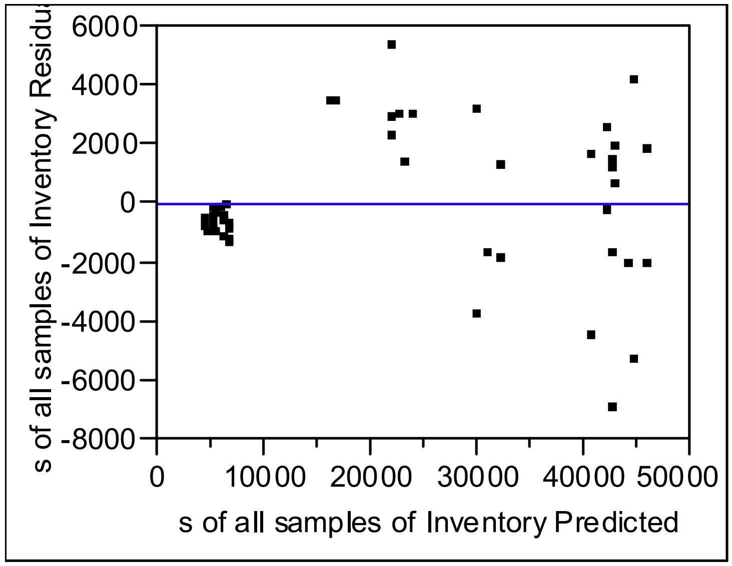

Figure 4.3. Initial Residual versus Prediction for Production Smoothing.

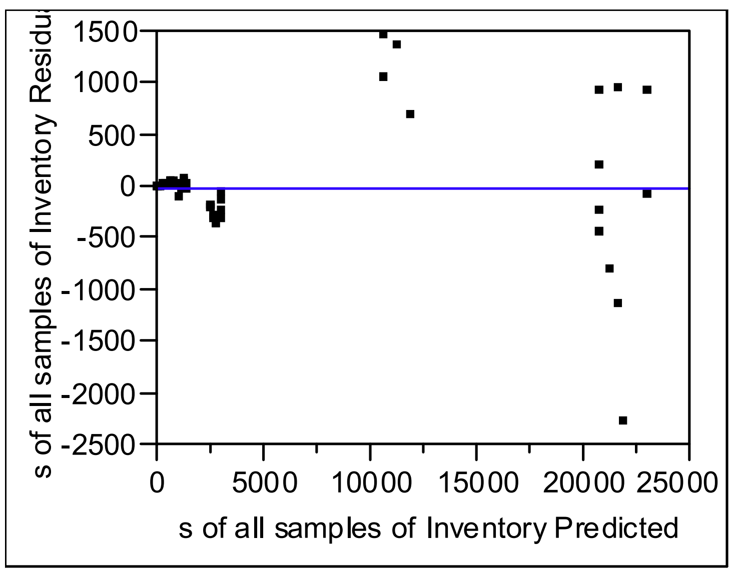

Figure 4.4. Initial Residual versus Prediction for Retailer Smoothing.

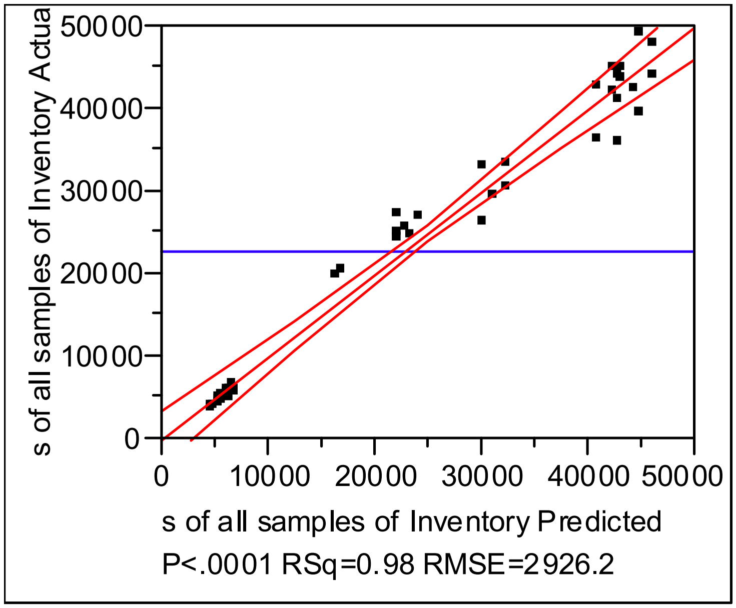

Figure 4.5. Actual Inventory Versus Predicted for the Initial Production Smoothing Analysis.

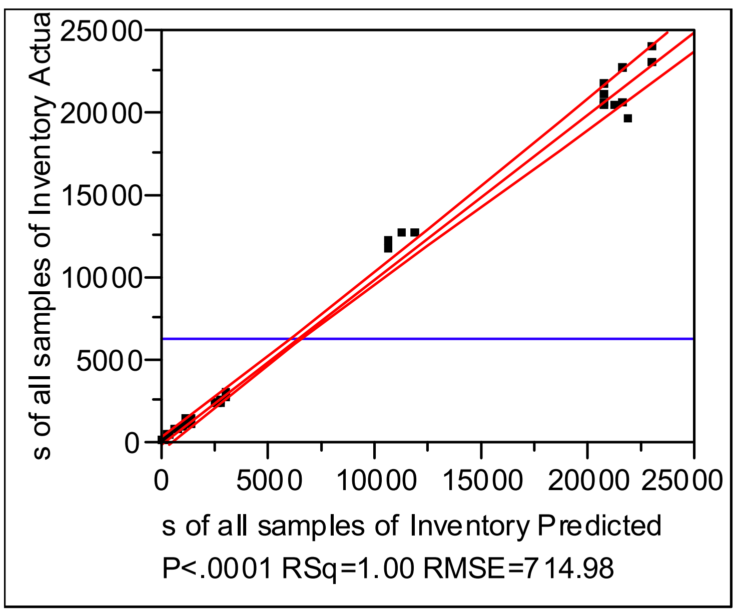

Figure 4.6. Actual Inventory Versus Predicted for the Initial Retailer Smoothing Analysis.

model. To resolve this issue, more data points are necessary to provide a sound analysis. Therefore, the number of replications will be increased for the next series of analyses for the RS method.

4.3 Further Results with Transformations

As discussed by Box and Cox (1964), there are normally four assumptions supporting the examination techniques of linear models using analysis of variance and regression: 1) simplicity of structure for the expected response variable; 2) consistent error variance; 3) normal distribution for errors; and 4) independent errors. Any time that the first three assumptions are not followed, a non-linear transformation is considered to improve the model fit and to ensure a constant variance. Box and Cox continue to explain that the transformations may not be used to validate the assumptions, but rather to express the model in terms of its input factors. As stated by Box and Cox, the purpose of the transformation is to provide a “more efficient and valid analysis.” The most popular transformation is the log transformation, which will be used in this research. The goal is to develop a predictable model with constant variance. However, Box and Cox wrote that the transformation is strictly to be used for the analysis. The concluding statistics must use the original and untransformed scale to explain the results.

Therefore, the log of each response was used to identify the statistical significance of each factor. As shown in Table 4.9, the maximum value

Table 4.9. Comparison of the Maximum and Minimum Response Variables Before and After the Transformation.

	Standard Deviation	Alpha	Flex Bound Width	Flex Bound Length	s of all samples of Inventory	log(s of all samples of Inventory)
Maximum	0.2	0.1	0.2	20	24019.94	10.09
Minimum	0.02	0.5	0.2	2	77.74	4.35
				Max / Min	308.98	2.32

divided by the minimum was almost 309 in the original study; thus showing that the difference between these two values was too large to expect constant error variance over this range of conditions. However, after the transformation, the ratio between the max and min was just 2.32. The resulting data will be much easier to model since the ratio is much smaller. Also, as may be seen in Figure 4.7, the resulting Residual vs. Predicted plot for average inventory displays a more constant variance. In addition, the model is better defined due to an increase in replication data points as shown in Figure 4.8. These changes in the research have improved the statistical analysis (see Appendix) to achieve the results in the next section.

4.4 Final Synopsis and Trends

As stated earlier in the analysis, but solidified from the transformation, there are consistent results in the research. For the Production Smoothing technique, the alpha variable had a negligible effect. Therefore, the analysis was only performed with the standard deviation, flex bound length, and flex bound width factors. On the other hand, flex bound width was not significant for Retailer Smoothing. Hence, the analysis was performed using the alpha, standard deviation, and the flex bound length factors. The statistical analyses that lead to these results may be found in the Appendix. The next two sections will describe in detail the results from the Retailer Smoothing analysis and the Production Smoothing analysis.

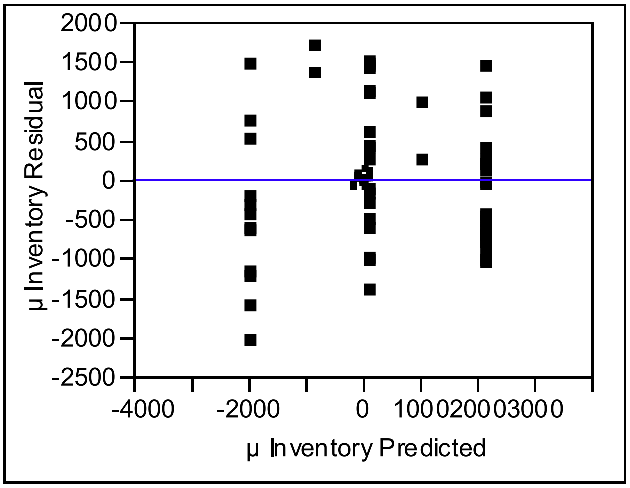

Figure 4.7. Residual versus Predicted Values for Average Inventory After the Transformation.

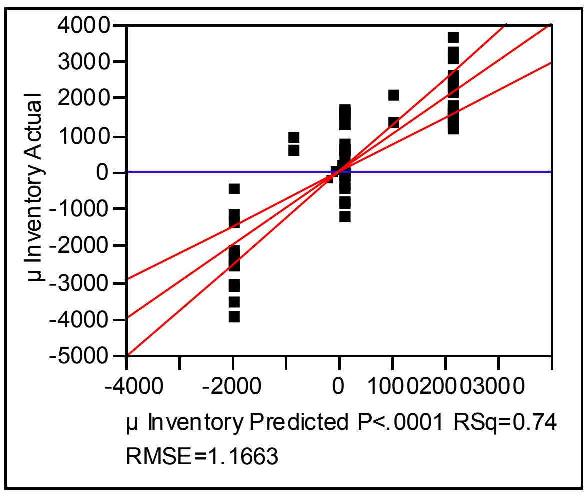

Figure 4.8. Actual vs. Predicted Values for Standard Deviation of Inventory with More Data for the Extreme Points.

4.4.1 Retailer Smoothing Results and Trends

The average inventory is mostly dependent on the interactions between the standard deviation, alpha, and flex bound length factors. However, these individual factors have a significant impact on the variation of inventory. The larger the standard deviation and the longer the flex bound length, the more variable the inventory will be. Though, as alpha is set larger, the variation of inventory is reduced since the alpha allows production to follow the demand more closely.

Standard deviation is the most significant factor on the average shift in production. As the standard deviation increases, the shift will also increase. Additionally, standard deviation, alpha, and the flex bound length are all significant in regards to the volatility of the shift in production. The interaction between alpha and flex bound length is also significant. As all of the factors increase, the production shift variation will also increase.

As may be seen in Tables 4.10 through 4.19, as alpha increases, the necessary inventory to buffer the demand will lessen since production will more closely follow demand. Conversely, as standard deviation increases, the inventory buffer must also increase to buffer the demand variation. Also, as the flex bound length increases, a significantly larger amount of inventory must be stored as the system is constrained from following changes in demand requirements. The summary of the inventory necessary for RS is valid as the data represents a normal distribution and was found to be a good estimation of the actual inventory needed.

Table 4.10. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 2.

Retailer Smoothing
Flex Bound Length = 2
Standard Deviation

			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Alpha	5%	99.5%	0.463		1.184		2.254		3.209		4.164		5.024		5.841		6.882	
		99.0%	0.418		1.070		2.037		2.900		3.763		4.540		5.279		6.219	
		97.5%	0.352	0.022417	0.901	0.056066	1.716	0.109052	2.443	0.161543	3.170	0.214585	3.824	0.263817	4.446	0.314231	5.238	0.362196
		95.0%	0.296		0.756		1.440		2.050		2.660		3.209		3.732		4.396	
		90.0%	0.230		0.589		1.121		1.596		2.072		2.499		2.906		3.423	
	10%	99.5%	0.356		0.906		1.764		2.533		3.283		4.134		4.887		5.364	
		99.0%	0.321		0.819		1.594		2.289		2.967		3.736		4.417		4.848	
		97.5%	0.271	0.025060	0.689	0.062959	1.342	0.122679	1.928	0.181233	2.499	0.240180	3.147	0.297458	3.720	0.358480	4.083	0.407202
		95.0%	0.227		0.579		1.127		1.618		2.097		2.641		3.122		3.427	
		90.0%	0.177		0.451		0.877		1.260		1.633		2.057		2.431		2.669	
	15%	99.5%	0.303		0.762		1.547		2.206		2.888		3.607		4.166		4.845	
		99.0%	0.274		0.689		1.398		1.993		2.610		3.260		3.765		4.378	
		97.5%	0.231	0.027709	0.580	0.070276	1.178	0.136861	1.679	0.202870	2.198	0.263740	2.746	0.330434	3.171	0.391786	3.688	0.458173
		95.0%	0.194		0.487		0.989		1.409		1.845		2.304		2.661		3.095	
		90.0%	0.151		0.379		0.770		1.097		1.437		1.795		2.073		2.410	
	20%	99.5%	0.273		0.688		1.347		2.022		2.656		3.305		3.923		4.472	
		99.0%	0.247		0.622		1.217		1.828		2.400		2.986		3.545		4.041	
		97.5%	0.208	0.031034	0.524	0.078231	1.025	0.151295	1.539	0.224548	2.022	0.295899	2.515	0.363128	2.986	0.437813	3.404	0.497865
		95.0%	0.174		0.440		0.860		1.292		1.697		2.111		2.506		2.857	
		90.0%	0.136		0.342		0.670		1.006		1.321		1.644		1.951		2.225	
	25%	99.5%	0.251		0.643		1.255		1.881		2.461		3.034		3.651		4.231	
		99.0%	0.227		0.581		1.134		1.700		2.224		2.742		3.300		3.823	
		97.5%	0.191	0.034202	0.489	0.085249	0.955	0.167937	1.432	0.245317	1.873	0.322862	2.309	0.394896	2.779	0.470880	3.220	0.542662
		95.0%	0.161		0.411		0.801		1.202		1.572		1.938		2.333		2.703	
		90.0%	0.125		0.320		0.624		0.936		1.224		1.509		1.817		2.105	
	30%	99.5%	0.241		0.603		1.194		1.772		2.371		2.899		3.510		4.049	
		99.0%	0.217		0.545		1.079		1.601		2.143		2.620		3.172		3.659	
		97.5%	0.183	0.037485	0.459	0.094306	0.909	0.181251	1.349	0.267173	1.805	0.351427	2.207	0.434516	2.672	0.515713	3.082	0.594291
		95.0%	0.154		0.385		0.763		1.132		1.515		1.852		2.243		2.586	
		90.0%	0.120		0.300		0.594		0.882		1.179		1.442		1.746		2.014	
	35%	99.5%	0.227		0.575		1.153		1.726		2.234		2.768		3.329		3.861	
		99.0%	0.205		0.520		1.042		1.559		2.019		2.501		3.008		3.489	
		97.5%	0.173	0.040260	0.438	0.102495	0.878	0.197246	1.313	0.289745	1.700	0.375124	2.107	0.467824	2.534	0.545978	2.938	0.645306
		95.0%	0.145		0.367		0.737		1.102		1.427		1.768		2.127		2.466	
		90.0%	0.113		0.286		0.574		0.858		1.111		1.377		1.656		1.921	
	40%	99.5%	0.219		0.551		1.114		1.666		2.214		2.675		3.273		3.666	
		99.0%	0.198		0.498		1.007		1.505		2.000		2.418		2.958		3.313	
		97.5%	0.167	0.043635	0.420	0.111938	0.848	0.213977	1.268	0.313400	1.685	0.410751	2.036	0.499696	2.491	0.600359	2.790	0.690871
		95.0%	0.140		0.352		0.712		1.064		1.414		1.709		2.091		2.342	
		90.0%	0.109		0.274		0.554		0.829		1.101		1.331		1.628		1.824	
	45%	99.5%	0.212		0.534		1.083		1.603		2.125		2.632		3.099		3.626	
		99.0%	0.192		0.482		0.978		1.449		1.920		2.378		2.801		3.277	
		97.5%	0.161	0.047320	0.406	0.119390	0.824	0.231159	1.220	0.338658	1.617	0.436539	2.003	0.538270	2.359	0.634315	2.760	0.741127
		95.0%	0.136		0.341		0.692		1.024		1.357		1.681		1.980		2.317	
		90.0%	0.106		0.266		0.539		0.797		1.057		1.309		1.542		1.804	
	50%	99.5%	0.209		0.515		1.052		1.546		2.073		2.541		3.009		3.526	
		99.0%	0.189		0.466		0.951		1.397		1.874		2.296		2.719		3.187	
		97.5%	0.159	0.050841	0.392	0.129250	0.801	0.245471	1.177	0.351719	1.578	0.470320	1.934	0.577978	2.291	0.682694	2.684	0.788113
		95.0%	0.134		0.329		0.672		0.988		1.324		1.623		1.922		2.253	
		90.0%	0.104		0.256		0.523		0.769		1.031		1.264		1.497		1.754	

Table 4.11. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 4.

Retailer Smoothing
Flex Bound Length = 4

			Standard Deviation															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Alpha	5%	99.5%	1.150		2.736		5.566		7.895		10.121		12.053		13.843		17.475	
		99.0%	1.039		2.472		5.030		7.135		9.146		10.892		12.509		15.792	
		97.5%	0.875	0.025544	2.082	0.064136	4.237	0.124355	6.009	0.181350	7.704	0.241044	9.174	0.296251	10.536	0.353782	13.302	0.415935
		95.0%	0.734		1.748		3.556		5.044		6.466		7.700		8.843		11.164	
		90.0%	0.572		1.361		2.769		3.928		5.035		5.996		6.886		8.693	
	10%	99.5%	0.918		2.216		4.413		6.496		8.467		10.308		12.156		13.706	
		99.0%	0.829		2.003		3.988		5.870		7.651		9.315		10.985		12.386	
		97.5%	0.699	0.032164	1.687	0.081491	3.359	0.155845	4.945	0.226539	6.445	0.298003	7.846	0.370085	9.253	0.436689	10.432	0.508304
		95.0%	0.586		1.416		2.819		4.150		5.409		6.585		7.766		8.756	
		90.0%	0.457		1.102		2.196		3.232		4.212		5.128		6.047		6.818	
	15%	99.5%	0.819		1.979		4.163		5.859		7.773		9.530		11.472		12.876	
		99.0%	0.740		1.788		3.762		5.295		7.025		8.612		10.368		11.636	
		97.5%	0.623	0.038851	1.506	0.098375	3.169	0.188754	4.460	0.268776	5.917	0.362510	7.254	0.443401	8.732	0.528340	9.801	0.606276
		95.0%	0.523		1.264		2.660		3.743		4.966		6.088		7.329		8.226	
		90.0%	0.407		0.984		2.071		2.915		3.867		4.741		5.707		6.405	
	20%	99.5%	0.749		1.809		3.694		5.526		7.218		8.503		10.363		11.981	
		99.0%	0.677		1.635		3.338		4.994		6.523		7.684		9.365		10.827	
		97.5%	0.570	0.046314	1.377	0.116470	2.812	0.220601	4.206	0.319852	5.494	0.415596	6.472	0.512488	7.888	0.612562	9.120	0.705296
		95.0%	0.479		1.156		2.360		3.530		4.611		5.432		6.620		7.654	
		90.0%	0.373		0.900		1.838		2.749		3.591		4.230		5.155		5.960	
	25%	99.5%	0.710		1.746		3.597		5.212		6.806		8.490		10.236		11.186	
		99.0%	0.642		1.578		3.251		4.710		6.151		7.673		9.250		10.109	
		97.5%	0.540	0.053454	1.329	0.133311	2.738	0.252336	3.967	0.364462	5.181	0.480227	6.463	0.586505	7.791	0.696337	8.514	0.785090
		95.0%	0.454		1.115		2.298		3.329		4.348		5.424		6.539		7.146	
		90.0%	0.353		0.869		1.790		2.593		3.386		4.224		5.092		5.565	
	30%	99.5%	0.708		1.704		3.444		5.127		6.643		8.249		9.458		11.172	
		99.0%	0.640		1.540		3.112		4.633		6.003		7.455		8.547		10.096	
		97.5%	0.539	0.060792	1.297	0.153101	2.621	0.284419	3.902	0.407114	5.056	0.537171	6.279	0.664123	7.199	0.771517	8.504	0.898661
		95.0%	0.452		1.089		2.200		3.275		4.244		5.270		6.042		7.137	
		90.0%	0.352		0.848		1.713		2.551		3.305		4.104		4.705		5.558	
	35%	99.5%	0.662		1.609		3.326		5.037		6.268		8.095		9.330		10.960	
		99.0%	0.598		1.454		3.006		4.551		5.665		7.315		8.431		9.904	
		97.5%	0.504	0.068744	1.225	0.172180	2.532	0.318215	3.834	0.463682	4.771	0.599964	6.162	0.725359	7.102	0.873321	8.342	1.007235
		95.0%	0.423		1.028		2.125		3.218		4.004		5.171		5.960		7.002	
		90.0%	0.329		0.800		1.655		2.506		3.118		4.027		4.641		5.452	
	40%	99.5%	0.652		1.634		3.284		4.907		6.422		7.835		9.342		10.820	
		99.0%	0.589		1.476		2.968		4.435		5.803		7.080		8.442		9.778	
		97.5%	0.496	0.076396	1.244	0.192157	2.500	0.357081	3.735	0.518486	4.888	0.647038	5.963	0.804306	7.111	0.966305	8.236	1.098603
		95.0%	0.416		1.044		2.098		3.135		4.103		5.005		5.968		6.912	
		90.0%	0.324		0.813		1.634		2.441		3.195		3.898		4.647		5.383	
	45%	99.5%	0.638		1.599		3.102		4.677		6.218		7.478		8.949		10.603	
		99.0%	0.576		1.445		2.803		4.227		5.619		6.758		8.087		9.582	
		97.5%	0.485	0.084989	1.217	0.212586	2.361	0.396828	3.560	0.561857	4.733	0.719092	5.692	0.871086	6.812	1.027144	8.071	1.227084
		95.0%	0.407		1.022		1.982		2.988		3.973		4.777		5.717		6.774	
		90.0%	0.317		0.796		1.543		2.327		3.093		3.720		4.452		5.275	
	50%	99.5%	0.624		1.582		3.168		4.718		6.315		7.710		9.352		10.381	
		99.0%	0.564		1.429		2.862		4.264		5.707		6.967		8.451		9.381	
		97.5%	0.475	0.093041	1.204	0.232645	2.411	0.436445	3.591	0.613162	4.807	0.794270	5.868	0.974364	7.118	1.153868	7.902	1.306280
		95.0%	0.399		1.010		2.024		3.014		4.034		4.925		5.974		6.632	
		90.0%	0.310		0.787		1.576		2.347		3.142		3.835		4.652		5.164	

Table 4.12. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 6.

Retailer Smoothing
Flex Bound Length = 6

Alpha			Standard Deviation 2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
	5%	99.5%	1.876		4.881		8.934		12.952		16.215		19.299		22.400		27.151	
		99.0%	1.695		4.411		8.073		11.705		14.653		17.440		20.243		24.536	
		97.5%	1.428	0.029022	3.715	0.072446	6.800	0.138026	9.859	0.198877	12.342	0.265421	14.690	0.330575	17.050	0.386048	20.667	0.456901
		95.0%	1.198		3.118		5.707		8.274		10.359		12.329		14.310		17.345	
		90.0%	0.933		2.428		4.444		6.443		8.066		9.601		11.144		13.507	
	10%	99.5%	1.529		3.864		7.525		10.970		14.294		17.000		19.694		22.626	
		99.0%	1.382		3.492		6.800		9.913		12.918		15.363		17.798		20.447	
		97.5%	1.164	0.039187	2.941	0.097635	5.728	0.184138	8.350	0.268878	10.880	0.351565	12.940	0.428704	14.991	0.516114	17.222	0.601822
		95.0%	0.977		2.469		4.807		7.008		9.132		10.860		12.581		14.454	
		90.0%	0.761		1.922		3.744		5.457		7.111		8.457		9.797		11.256	
	15%	99.5%	1.406		3.536		7.114		9.858		13.297		16.220		18.887		22.042	
		99.0%	1.271		3.195		6.429		8.909		12.016		14.658		17.068		19.919	
		97.5%	1.070	0.049910	2.691	0.124669	5.415	0.233568	7.504	0.341045	10.121	0.436583	12.346	0.537221	14.376	0.646171	16.777	0.755491
		95.0%	0.898		2.259		4.545		6.298		8.494		10.362		12.065		14.081	
		90.0%	0.699		1.759		3.539		4.904		6.615		8.069		9.396		10.965	
	20%	99.5%	1.329		3.281		6.577		9.931		12.537		15.299		17.775		20.477	
		99.0%	1.201		2.965		5.944		8.975		11.329		13.826		16.063		18.505	
		97.5%	1.012	0.060674	2.497	0.152468	5.006	0.279470	7.559	0.403754	9.543	0.540977	11.645	0.638618	13.529	0.768761	15.586	0.880434
		95.0%	0.849		2.096		4.202		6.344		8.009		9.774		11.355		13.081	
		90.0%	0.661		1.632		3.272		4.941		6.237		7.611		8.842		10.187	
	25%	99.5%	1.277		3.188		6.280		9.049		12.096		14.169		17.139		19.793	
		99.0%	1.154		2.881		5.675		8.177		10.931		12.804		15.488		17.887	
		97.5%	0.972	0.071824	2.427	0.180446	4.780	0.331105	6.888	0.467085	9.207	0.608680	10.785	0.734206	13.045	0.876800	15.066	1.025630
		95.0%	0.816		2.037		4.012		5.781		7.728		9.051		10.949		12.645	
		90.0%	0.636		1.586		3.124		4.502		6.018		7.049		8.526		9.847	
	30%	99.5%	1.193		3.086		6.211		9.133		11.964		14.582		16.837		20.022	
		99.0%	1.078		2.789		5.613		8.253		10.812		13.178		15.215		18.093	
		97.5%	0.908	0.082461	2.349	0.209264	4.728	0.376286	6.952	0.548361	9.106	0.705162	11.099	0.853651	12.816	1.014800	15.240	1.175105
		95.0%	0.762		1.972		3.968		5.834		7.643		9.316		10.756		12.791	
		90.0%	0.594		1.535		3.090		4.543		5.952		7.254		8.376		9.960	
	35%	99.5%	1.194		3.098		5.974		9.207		11.817		14.025		16.450		19.596	
		99.0%	1.079		2.800		5.399		8.320		10.679		12.674		14.865		17.708	
		97.5%	0.909	0.096363	2.358	0.239557	4.547	0.433733	7.008	0.602753	8.995	0.807172	10.675	0.973737	12.521	1.127718	14.916	1.285397
		95.0%	0.763		1.979		3.816		5.882		7.549		8.959		10.509		12.518	
		90.0%	0.594		1.541		2.972		4.580		5.879		6.977		8.183		9.748	
	40%	99.5%	1.194		2.934		6.000		8.764		11.177		14.173		16.796		18.686	
		99.0%	1.079		2.651		5.422		7.920		10.101		12.808		15.178		16.886	
		97.5%	0.909	0.107754	2.233	0.266173	4.567	0.486829	6.671	0.665484	8.508	0.849153	10.788	1.063668	12.784	1.284378	14.223	1.417054
		95.0%	0.763		1.874		3.833		5.599		7.140		9.054		10.730		11.937	
		90.0%	0.594		1.459		2.985		4.360		5.560		7.051		8.355		9.296	
	45%	99.5%	1.174		2.972		5.933		8.726		11.428		14.085		16.558		18.511	
		99.0%	1.061		2.686		5.362		7.885		10.327		12.729		14.964		16.729	
		97.5%	0.894	0.120288	2.262	0.300932	4.516	0.539903	6.642	0.741860	8.698	0.955038	10.721	1.178885	12.604	1.352923	14.090	1.566041
		95.0%	0.750		1.899		3.790		5.574		7.300		8.998		10.578		11.826	
		90.0%	0.584		1.479		2.952		4.341		5.685		7.007		8.237		9.209	
	50%	99.5%	1.131		2.884		5.806		8.758		11.547		13.646		16.476		19.458	
		99.0%	1.022		2.606		5.247		7.914		10.435		12.332		14.889		17.584	
		97.5%	0.861	0.133743	2.195	0.331817	4.419	0.588603	6.666	0.829166	8.789	1.055053	10.387	1.263553	12.541	1.500825	14.810	1.756493
		95.0%	0.722		1.842		3.709		5.595		7.377		8.718		10.525		12.430	
		90.0%	0.562		1.435		2.888		4.357		5.744		6.789		8.196		9.680	

Table 4.13. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 8.

Retailer Smoothing
Flex Bound Length = 8

		Standard Deviation															
		2%		5%		10%		15%		20%		25%		30%		35%	
Alpha		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
5%	99.5%	2.660		6.756		12.362		17.809		22.348		28.106		30.623		34.777	
	99.0%	2.404		6.105		11.171		16.093		20.196		25.399		27.674		31.427	
	97.5%	2.025	0.031971	5.143	0.079122	9.410	0.152407	13.555	0.219443	17.010	0.284196	21.393	0.355247	23.309	0.417621	26.471	0.482550
	95.0%	1.700		4.316		7.897		11.377		14.277		17.955		19.563		22.217	
	90.0%	1.324		3.361		6.150		8.859		11.118		13.982		15.234		17.301	
10%	99.5%	2.338		5.760		10.828		15.488		19.651		24.391		30.000		31.323	
	99.0%	2.113		5.205		9.785		13.996		17.758		22.042		27.110		28.306	
	97.5%	1.779	0.046018	4.384	0.114940	8.242	0.211697	11.789	0.306354	14.957	0.401803	18.566	0.491562	22.835	0.595433	23.842	0.664883
	95.0%	1.493		3.680		6.917		9.894		12.554		15.582		19.165		20.010	
	90.0%	1.163		2.865		5.387		7.705		9.776		12.134		14.924		15.582	
15%	99.5%	2.039		5.234		10.265		14.612		18.783		23.201		28.138		31.382	
	99.0%	1.843		4.730		9.277		13.205		16.974		20.967		25.428		28.359	
	97.5%	1.552	0.060019	3.984	0.150902	7.814	0.272682	11.122	0.396222	14.297	0.512091	17.660	0.637669	21.418	0.770093	23.887	0.863628
	95.0%	1.303		3.343		6.558		9.335		11.999		14.822		17.976		20.048	
	90.0%	1.015		2.604		5.107		7.269		9.344		11.542		13.998		15.612	
20%	99.5%	1.936		5.131		9.988		14.463		18.494		21.859		26.346		30.186	
	99.0%	1.749		4.637		9.026		13.070		16.713		19.753		23.808		27.279	
	97.5%	1.473	0.074577	3.906	0.184733	7.603	0.340485	11.009	0.478227	14.077	0.628652	16.638	0.761096	20.054	0.931834	22.977	1.057086
	95.0%	1.237		3.278		6.381		9.239		11.814		13.964		16.831		19.284	
	90.0%	0.963		2.553		4.969		7.195		9.200		10.874		13.106		15.017	
25%	99.5%	1.870		4.701		9.756		13.899		17.998		21.291		24.530		29.448	
	99.0%	1.690		4.248		8.816		12.561		16.264		19.240		22.168		26.612	
	97.5%	1.423	0.089913	3.578	0.219303	7.426	0.393941	10.580	0.563537	13.699	0.722656	16.206	0.888297	18.672	1.037134	22.415	1.227208
	95.0%	1.195		3.003		6.232		8.879		11.498		13.601		15.671		18.813	
	90.0%	0.930		2.339		4.853		6.915		8.953		10.592		12.203		14.650	
30%	99.5%	1.831		4.715		9.416		13.983		17.714		21.250		25.787		29.610	
	99.0%	1.654		4.261		8.509		12.636		16.008		19.204		23.303		26.758	
	97.5%	1.393	0.104389	3.589	0.258339	7.167	0.465752	10.643	0.645390	13.483	0.820199	16.175	1.017159	19.628	1.227751	22.538	1.438550
	95.0%	1.169		3.012		6.015		8.933		11.316		13.575		16.473		18.916	
	90.0%	0.911		2.346		4.684		6.956		8.812		10.572		12.828		14.730	
35%	99.5%	1.830		4.564		9.426		13.353		17.220		22.097		25.200		29.943	
	99.0%	1.654		4.125		8.518		12.067		15.562		19.969		22.773		27.059	
	97.5%	1.393	0.122535	3.474	0.297775	7.175	0.519387	10.164	0.722674	13.107	0.953177	16.820	1.177617	19.182	1.391791	22.792	1.608552
	95.0%	1.169		2.916		6.022		8.530		11.001		14.116		16.099		19.129	
	90.0%	0.911		2.271		4.689		6.643		8.567		10.993		12.537		14.896	
40%	99.5%	1.772		4.456		9.031		13.783		17.054		21.374		24.672		28.626	
	99.0%	1.601		4.026		8.161		12.455		15.411		19.315		22.296		25.869	
	97.5%	1.349	0.137112	3.391	0.340032	6.874	0.588950	10.491	0.813324	12.981	1.068987	16.269	1.260544	18.779	1.511717	21.789	1.772716
	95.0%	1.132		2.846		5.769		8.805		10.894		13.654		15.761		18.288	
	90.0%	0.881		2.217		4.493		6.857		8.484		10.633		12.274		14.241	
45%	99.5%	1.786		4.447		9.284		13.155		17.650		21.517		24.630		28.582	
	99.0%	1.614		4.019		8.390		11.888		15.950		19.445		22.258		25.829	
	97.5%	1.360	0.156151	3.385	0.380069	7.067	0.650918	10.013	0.893445	13.434	1.162288	16.378	1.433361	18.747	1.651276	21.755	1.912456
	95.0%	1.141		2.841		5.931		8.404		11.275		13.746		15.734		18.259	
	90.0%	0.889		2.212		4.619		6.544		8.780		10.704		12.253		14.219	
50%	99.5%	1.763		4.394		8.810		13.265		17.489		20.723		24.584		28.346	
	99.0%	1.593		3.971		7.962		11.987		15.805		18.727		22.216		25.616	
	97.5%	1.342	0.173194	3.344	0.419440	6.706	0.706003	10.097	0.978218	13.312	1.264126	15.774	1.504932	18.712	1.746231	21.576	2.109667
	95.0%	1.126		2.807		5.628		8.474		11.173		13.238		15.705		18.109	
	90.0%	0.877		2.186		4.383		6.599		8.700		10.309		12.230		14.102	

Table 4.14. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 10.

Retailer Smoothing
Flex Bound Length = 10

		Standard Deviation															
		2%		5%		10%		15%		20%		25%		30%		35%	
Alpha		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
5%	99.5%	3.431		8.724		16.683		22.867		29.757		34.432		42.372		48.772	
	99.0%	3.101		7.883		15.076		20.665		26.891		31.116		38.291		44.075	
	97.5%	2.612	0.035326	6.640	0.086501	12.698	0.162983	17.406	0.236018	22.650	0.307362	26.208	0.380289	32.252	0.455339	37.124	0.524160
	95.0%	2.192		5.573		10.657		14.608		19.010		21.996		27.069		31.157	
	90.0%	1.707		4.340		8.299		11.376		14.803		17.129		21.079		24.263	
10%	99.5%	2.929		7.459		14.408		21.316		26.309		32.183		37.546		44.223	
	99.0%	2.647		6.741		13.020		19.263		23.775		29.084		33.930		39.964	
	97.5%	2.229	0.052262	5.678	0.129307	10.967	0.239038	16.225	0.342403	20.025	0.450140	24.497	0.540289	28.579	0.649814	33.661	0.750790
	95.0%	1.871		4.765		9.204		13.617		16.807		20.560		23.986		28.251	
	90.0%	1.457		3.711		7.167		10.604		13.088		16.010		18.678		22.000	
15%	99.5%	2.787		7.062		14.067		18.805		25.873		29.897		35.948		40.160	
	99.0%	2.519		6.382		12.712		16.994		23.381		27.017		32.486		36.292	
	97.5%	2.122	0.070335	5.375	0.172937	10.707	0.309734	14.314	0.432771	19.694	0.573300	22.756	0.701109	27.362	0.845619	30.569	0.969285
	95.0%	1.781		4.511		8.986		12.014		16.529		19.099		22.965		25.656	
	90.0%	1.387		3.513		6.998		9.355		12.871		14.873		17.883		19.979	
20%	99.5%	2.642		6.704		13.076		19.066		25.256		29.593		35.807		40.128	
	99.0%	2.387		6.058		11.817		17.230		22.823		26.743		32.358		36.263	
	97.5%	2.011	0.088331	5.103	0.212730	9.953	0.392148	14.513	0.544247	19.224	0.700606	22.525	0.846009	27.255	1.032175	30.544	1.192913
	95.0%	1.688		4.283		8.354		12.180		16.134		18.905		22.875		25.635	
	90.0%	1.314		3.335		6.505		9.485		12.564		14.722		17.813		19.963	
25%	99.5%	2.530		6.294		13.293		18.936		24.473		30.315		33.492		39.535	
	99.0%	2.286		5.688		12.013		17.112		22.116		27.395		30.266		35.728	
	97.5%	1.925	0.106490	4.791	0.259600	10.118	0.464566	14.414	0.647647	18.628	0.840065	23.074	0.993300	25.493	1.204553	30.093	1.410073
	95.0%	1.616		4.021		8.492		12.097		15.634		19.366		21.396		25.257	
	90.0%	1.258		3.131		6.613		9.420		12.175		15.081		16.661		19.668	
30%	99.5%	2.471		6.230		13.026		19.015		24.268		29.031		34.293		40.188	
	99.0%	2.233		5.630		11.772		17.184		21.931		26.235		30.990		36.318	
	97.5%	1.881	0.126057	4.742	0.309542	9.915	0.526990	14.474	0.767991	18.472	0.955015	22.098	1.171640	26.103	1.382899	30.590	1.649163
	95.0%	1.578		3.980		8.321		12.148		15.503		18.546		21.908		25.674	
	90.0%	1.229		3.099		6.480		9.460		12.073		14.442		17.060		19.993	
35%	99.5%	2.428		6.322		12.864		18.015		23.861		28.841		33.286		38.772	
	99.0%	2.194		5.713		11.625		16.280		21.563		26.063		30.080		35.038	
	97.5%	1.848	0.145793	4.812	0.356193	9.791	0.602791	13.713	0.841008	18.162	1.098537	21.953	1.324814	25.336	1.584857	29.512	1.810197
	95.0%	1.551		4.039		8.218		11.509		15.243		18.424		21.264		24.769	
	90.0%	1.208		3.145		6.399		8.962		11.870		14.348		16.559		19.288	
40%	99.5%	2.484		6.303		12.911		17.688		23.034		28.187		33.393		39.444	
	99.0%	2.245		5.696		11.667		15.985		20.815		25.472		30.177		35.645	
	97.5%	1.891	0.168433	4.798	0.400389	9.827	0.691725	13.464	0.925845	17.533	1.167969	21.455	1.445454	25.418	1.705185	30.023	1.997199
	95.0%	1.587		4.027		8.248		11.300		14.715		18.007		21.333		25.198	
	90.0%	1.236		3.136		6.423		8.799		11.459		14.022		16.612		19.622	
45%	99.5%	2.464		6.041		12.440		17.572		23.465		28.800		33.148		38.744	
	99.0%	2.226		5.459		11.242		15.879		21.205		26.026		29.955		35.013	
	97.5%	1.875	0.189131	4.598	0.447060	9.469	0.733881	13.375	1.020451	17.861	1.296944	21.921	1.621666	25.231	1.916569	29.491	2.143494
	95.0%	1.574		3.859		7.947		11.225		14.990		18.398		21.176		24.751	
	90.0%	1.226		3.005		6.189		8.742		11.673		14.327		16.490		19.274	
50%	99.5%	2.450		6.306		12.491		18.329		23.569		29.249		34.000		37.841	
	99.0%	2.214		5.698		11.288		16.564		21.299		26.432		30.725		34.197	
	97.5%	1.865	0.209699	4.800	0.493044	9.508	0.818271	13.951	1.149901	17.940	1.427943	22.264	1.779591	25.879	2.095434	28.803	2.415441
	95.0%	1.565		4.028		7.980		11.709		15.057		18.685		21.720		24.174	
	90.0%	1.219		3.137		6.214		9.118		11.725		14.551		16.914		18.825	

Table 4.15. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 12.

Retailer Smoothing
Flex Bound Length = 12

		Standard Deviation															
		2%		5%		10%		15%		20%		25%		30%		35%	
Alpha		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
5%	99.5%	4.185		10.712		19.917		28.779		34.304		44.343		52.143		58.463	
	99.0%	3.782		9.680		17.999		26.007		31.000		40.073		47.121		52.832	
	97.5%	3.185	0.038279	8.154	0.093523	15.160	0.170695	21.906	0.248505	26.111	0.322220	33.753	0.402476	39.689	0.477526	44.500	0.565045
	95.0%	2.673		6.843		12.724		18.385		21.915		28.328		33.311		37.348	
	90.0%	2.082		5.329		9.908		14.317		17.065		22.060		25.940		29.084	
10%	99.5%	3.795		9.025		18.460		25.622		32.160		41.637		45.685		54.269	
	99.0%	3.430		8.155		16.682		23.154		29.063		37.627		41.285		49.043	
	97.5%	2.889	0.058409	6.869	0.142757	14.051	0.259186	19.502	0.371532	24.479	0.482333	31.692	0.588717	34.774	0.712792	41.308	0.813036
	95.0%	2.424		5.765		11.793		16.368		20.545		26.599		29.185		34.669	
	90.0%	1.888		4.490		9.184		12.746		15.999		20.713		22.727		26.998	
15%	99.5%	3.481		9.091		18.265		24.529		31.350		38.216		46.879		49.723	
	99.0%	3.146		8.216		16.506		22.167		28.331		34.536		42.364		44.934	
	97.5%	2.650	0.078529	6.920	0.192348	13.903	0.341757	18.671	0.480422	23.863	0.617202	29.089	0.790165	35.683	0.937983	37.847	1.043544
	95.0%	2.224		5.808		11.669		15.670		20.028		24.414		29.948		31.765	
	90.0%	1.732		4.523		9.087		12.203		15.596		19.012		23.321		24.736	
20%	99.5%	3.445		8.764		16.864		23.701		29.844		36.435		44.465		50.164	
	99.0%	3.113		7.920		15.240		21.418		26.969		32.926		40.183		45.333	
	97.5%	2.622	0.100662	6.671	0.243342	12.836	0.431507	18.040	0.600353	22.716	0.791426	27.733	0.958894	33.846	1.145726	38.183	1.319956
	95.0%	2.201		5.599		10.773		15.141		19.065		23.276		28.406		32.047	
	90.0%	1.714		4.360		8.389		11.791		14.846		18.126		22.120		24.956	
25%	99.5%	3.416		8.184		16.689		23.801		29.269		36.332		44.740		50.146	
	99.0%	3.087		7.396		15.081		21.509		26.450		32.833		40.431		45.317	
	97.5%	2.600	0.124109	6.230	0.295822	12.703	0.511014	18.117	0.699950	22.278	0.902575	27.655	1.108820	34.054	1.350617	38.170	1.544115
	95.0%	2.182		5.228		10.661		15.205		18.698		23.210		28.581		32.035	
	90.0%	1.699		4.071		8.302		11.840		14.561		18.074		22.257		24.946	
30%	99.5%	3.326		8.376		16.188		24.007		29.701		37.070		44.064		48.481	
	99.0%	3.005		7.569		14.629		21.695		26.841		33.500		39.820		43.812	
	97.5%	2.531	0.145127	6.376	0.343489	12.322	0.587781	18.274	0.820365	22.607	1.061944	28.216	1.321501	33.540	1.553753	36.902	1.748549
	95.0%	2.125		5.351		10.342		15.337		18.974		23.682		28.150		30.971	
	90.0%	1.654		4.167		8.053		11.943		14.776		18.441		21.921		24.118	
35%	99.5%	3.214		8.214		16.591		23.619		30.079		34.569		42.342		47.630	
	99.0%	2.904		7.423		14.993		21.344		27.182		31.239		38.264		43.042	
	97.5%	2.446	0.170054	6.252	0.404343	12.629	0.667305	17.978	0.924327	22.895	1.196746	26.312	1.425339	32.230	1.791636	36.254	1.999458
	95.0%	2.053		5.248		10.599		15.089		19.216		22.084		27.050		30.427	
	90.0%	1.599		4.086		8.254		11.750		14.964		17.197		21.064		23.695	
40%	99.5%	3.096		7.946		16.425		23.506		29.421		35.902		42.641		48.119	
	99.0%	2.798		7.181		14.843		21.242		26.588		32.445		38.534		43.484	
	97.5%	2.357	0.193829	6.048	0.453755	12.502	0.769077	17.892	1.033480	22.395	1.320863	27.328	1.599429	32.457	1.900502	36.626	2.233599
	95.0%	1.978		5.076		10.493		15.016		18.795		22.936		27.241		30.740	
	90.0%	1.540		3.953		8.171		11.693		14.636		17.861		21.213		23.938	
45%	99.5%	3.172		7.983		16.165		23.721		30.628		35.322		43.074		49.130	
	99.0%	2.867		7.214		14.608		21.436		27.678		31.921		38.926		44.398	
	97.5%	2.415	0.218886	6.076	0.497888	12.304	0.836522	18.056	1.154009	23.313	1.461610	26.886	1.751181	32.787	2.083150	37.396	2.470563
	95.0%	2.027		5.100		10.327		15.154		19.566		22.565		27.517		31.386	
	90.0%	1.578		3.971		8.042		11.801		15.237		17.572		21.428		24.441	
50%	99.5%	3.181		8.090		16.182		22.842		29.186		35.727		41.076		47.651	
	99.0%	2.875		7.311		14.624		20.642		26.375		32.286		37.120		43.062	
	97.5%	2.421	0.246279	6.158	0.553257	12.317	0.903395	17.386	1.215348	22.215	1.604664	27.194	1.942602	31.265	2.301728	36.270	2.628975
	95.0%	2.032		5.168		10.338		14.592		18.645		22.823		26.241		30.441	
	90.0%	1.583		4.025		8.050		11.363		14.519		17.773		20.434		23.705	

Table 4.16. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 14.

Retailer Smoothing
Flex Bound Length = 14

			Standard Deviation															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Alpha	5%	99.5%	5.076		12.905		24.686		34.112		40.004		51.331		59.765		67.841	
		99.0%	4.587		11.662		22.309		30.827		36.151		46.388		54.009		61.307	
		97.5%	3.863	0.040608	9.823	0.099630	18.790	0.184683	25.965	0.266384	30.449	0.337546	39.072	0.420719	45.491	0.494907	51.638	0.587209
		95.0%	3.242		8.244		15.770		21.792		25.556		32.792		38.180		43.339	
		90.0%	2.525		6.420		12.281		16.970		19.901		25.536		29.732		33.749	
	10%	99.5%	4.522		11.984		22.048		30.599		39.973		46.292		58.557		62.482	
		99.0%	4.086		10.830		19.925		27.652		36.123		41.834		52.918		56.464	
		97.5%	3.442	0.063692	9.122	0.154923	16.782	0.281228	23.291	0.397678	30.426	0.510889	35.236	0.620223	44.572	0.790009	47.559	0.851732
		95.0%	2.889		7.656		14.085		19.548		25.536		29.573		37.409		39.916	
		90.0%	2.249		5.962		10.968		15.222		19.886		23.029		29.131		31.083	
	15%	99.5%	4.310		10.958		20.369		29.443		39.565		44.354		51.861		63.129	
		99.0%	3.895		9.903		18.407		26.608		35.754		40.082		46.867		57.049	
		97.5%	3.280	0.088547	8.341	0.211762	15.504	0.375870	22.411	0.515046	30.115	0.668763	33.760	0.847756	39.475	0.983304	48.052	1.171492
		95.0%	2.753		7.001		13.012		18.809		25.275		28.335		33.131		40.329	
		90.0%	2.144		5.451		10.133		14.647		19.683		22.065		25.800		31.405	
	20%	99.5%	4.219		10.859		20.642		28.318		38.085		44.366		52.366		61.925	
		99.0%	3.813		9.813		18.654		25.591		34.417		40.093		47.323		55.961	
		97.5%	3.212	0.113029	8.266	0.271381	15.712	0.464086	21.555	0.649697	28.989	0.879131	33.770	1.033653	39.860	1.234341	47.135	1.411807
		95.0%	2.696		6.937		13.187		18.091		24.330		28.342		33.454		39.560	
		90.0%	2.099		5.402		10.269		14.088		18.946		22.071		26.051		30.806	
	25%	99.5%	4.164		10.720		21.367		30.206		36.228		45.094		51.022		59.515	
		99.0%	3.763		9.688		19.310		27.297		32.739		40.751		46.108		53.783	
		97.5%	3.170	0.138059	8.160	0.321099	16.264	0.555097	22.992	0.755517	27.576	0.994583	34.324	1.249046	38.836	1.445309	45.301	1.673833
		95.0%	2.660		6.849		13.650		19.297		23.144		28.808		32.595		38.020	
		90.0%	2.072		5.333		10.630		15.027		18.023		22.433		25.382		29.607	
	30%	99.5%	3.970		10.191		21.068		28.059		38.321		45.686		49.933		59.033	
		99.0%	3.588		9.210		19.039		25.356		34.630		41.286		45.124		53.347	
		97.5%	3.022	0.164525	7.757	0.378270	16.036	0.644527	21.357	0.913056	29.169	1.175724	34.774	1.415255	38.007	1.693147	44.934	1.958657
		95.0%	2.536		6.510		13.459		17.925		24.481		29.186		31.899		37.712	
		90.0%	1.975		5.070		10.481		13.958		19.064		22.728		24.840		29.367	
	35%	99.5%	4.029		10.354		20.837		28.639		36.411		44.612		51.227		62.783	
		99.0%	3.641		9.357		18.830		25.881		32.904		40.316		46.293		56.737	
		97.5%	3.067	0.190712	7.881	0.445724	15.860	0.729146	21.799	1.024556	27.715	1.307899	33.957	1.590333	38.992	1.873787	47.789	2.198828
		95.0%	2.574		6.615		13.311		18.296		23.261		28.500		32.726		40.108	
		90.0%	2.004		5.151		10.366		14.247		18.114		22.194		25.484		31.233	
	40%	99.5%	3.878		10.669		20.285		28.980		36.054		42.337		51.544		57.351	
		99.0%	3.504		9.641		18.332		26.189		32.581		38.260		46.579		51.828	
		97.5%	2.952	0.219631	8.121	0.490488	15.440	0.809782	22.059	1.126734	27.443	1.413743	32.226	1.717441	39.233	2.113994	43.654	2.429229
		95.0%	2.477		6.815		12.959		18.514		23.032		27.047		32.928		36.638	
		90.0%	1.929		5.307		10.091		14.417		17.936		21.062		25.642		28.531	
	45%	99.5%	3.841		10.120		20.569		28.331		37.105		43.441		52.730		59.103	
		99.0%	3.471		9.145		18.588		25.602		33.532		39.257		47.652		53.411	
		97.5%	2.924	0.246264	7.703	0.554164	15.656	0.919851	21.565	1.241368	28.243	1.608797	33.066	1.925063	40.137	2.312660	44.987	2.704669
		95.0%	2.454		6.465		13.140		18.099		23.704		27.752		33.686		37.757	
		90.0%	1.911		5.034		10.232		14.094		18.459		21.611		26.232		29.402	
	50%	99.5%	3.908		10.367		19.550		29.235		35.757		42.999		51.748		58.030	
		99.0%	3.532		9.368		17.667		26.419		32.313		38.858		46.765		52.441	
		97.5%	2.975	0.277178	7.891	0.606633	14.881	0.979986	22.253	1.356406	27.217	1.716875	32.730	2.097378	39.389	2.463107	44.170	2.941494
		95.0%	2.497		6.623		12.489		18.676		22.843		27.469		33.059		37.071	
		90.0%	1.944		5.157		9.726		14.544		17.788		21.391		25.744		28.868	

Table 4.17. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 16.

Retailer Smoothing
Flex Bound Length = 16
Standard Deviation

Alpha			2%		5%		10%		15%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
		99.5%	6.014		14.935		27.893		39.191	
		99.0%	5.435		13.497		25.206		35.416	
	5%	97.5%	4.578	0.042685	11.368	0.105343	21.231	0.190814	29.830	0.278908
		95.0%	3.842		9.541		17.819		25.036	
		90.0%	2.992		7.430		13.876		19.496	
		99.5%	5.124		13.026		26.610		38.275	
		99.0%	4.630		11.771		24.047		34.589	
	10%	97.5%	3.900	0.069018	9.915	0.167415	20.255	0.299898	29.134	0.420718
		95.0%	3.273		8.321		16.999		24.451	
		90.0%	2.549		6.480		13.238		19.041	
		99.5%	4.849		13.234		25.889		35.476	
		99.0%	4.382		11.959		23.396		32.059	
	15%	97.5%	3.691	0.096182	10.073	0.229404	19.706	0.386728	27.003	0.565202
		95.0%	3.098		8.454		16.539		22.663	
		90.0%	2.412		6.584		12.879		17.648	
		99.5%	4.982		13.228		23.876		34.209	
		99.0%	4.502		11.954		21.577		30.914	
	20%	97.5%	3.792	0.123064	10.069	0.289603	18.174	0.488776	26.038	0.709306
		95.0%	3.183		8.451		15.253		21.854	
		90.0%	2.478		6.581		11.878		17.018	
		99.5%	4.843		12.779		25.063		34.717	
		99.0%	4.376		11.548		22.649		31.374	
	25%	97.5%	3.686	0.152044	9.727	0.347065	19.077	0.582367	26.426	0.816897
		95.0%	3.094		8.163		16.011		22.179	
		90.0%	2.409		6.357		12.468		17.271	
		99.5%	4.817		12.453		24.019		32.948	
		99.0%	4.353		11.254		21.706		29.775	
	30%	97.5%	3.667	0.179351	9.479	0.410336	18.282	0.708604	25.079	0.937723
		95.0%	3.077		7.956		15.344		21.049	
		90.0%	2.396		6.195		11.949		16.391	
		99.5%	4.797		12.459		24.123		33.952	
		99.0%	4.335		11.259		21.799		30.682	
	35%	97.5%	3.651	0.209030	9.483	0.471064	18.361	0.761145	25.843	1.069267
		95.0%	3.064		7.959		15.410		21.689	
		90.0%	2.386		6.198		12.000		16.890	
		99.5%	4.737		12.312		25.230		34.294	
		99.0%	4.281		11.126		22.800		30.991	
	40%	97.5%	3.605	0.244199	9.371	0.529804	19.204	0.887661	26.103	1.194441
		95.0%	3.026		7.865		16.118		21.908	
		90.0%	2.356		6.125		12.551		17.060	
		99.5%	4.709		12.617		23.988		33.642	
		99.0%	4.255		11.402		21.678		30.402	
	45%	97.5%	3.584	0.278825	9.604	0.595089	18.259	0.936021	25.607	1.309918
		95.0%	3.008		8.060		15.324		21.491	
		90.0%	2.342		6.277		11.933		16.736	
		99.5%	4.852		12.117		24.612		32.253	
		99.0%	4.384		10.950		22.242		29.147	
	50%	97.5%	3.693	0.304142	9.223	0.667837	18.734	1.066390	24.550	1.480073
		95.0%	3.099		7.741		15.723		20.605	
		90.0%	2.414		6.028		12.244		16.045	

Alpha			20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
		99.5%	47.954		59.643		71.913		72.330	
		99.0%	43.336		53.899		64.987		65.364	
	5%	97.5%	36.501	0.349647	45.398	0.439536	54.737	0.511336	55.055	0.610126
		95.0%	30.635		38.102		45.940		46.207	
		90.0%	23.856		29.671		35.775		35.983	
		99.5%	44.010		53.140		62.463		75.063	
		99.0%	39.772		48.022		56.447		67.834	
	10%	97.5%	33.499	0.539000	40.448	0.670934	47.544	0.778768	57.135	0.947394
		95.0%	28.115		33.948		39.903		47.953	
		90.0%	21.894		26.436		31.074		37.342	
		99.5%	43.941		50.541		64.750		70.937	
		99.0%	39.709		45.674		58.513		64.105	
	15%	97.5%	33.447	0.725247	38.470	0.882539	49.285	1.064374	53.995	1.241965
		95.0%	28.071		32.287		41.364		45.317	
		90.0%	21.860		25.143		32.211		35.289	
		99.5%	43.803		50.031		62.579		74.075	
		99.0%	39.584		45.212		56.552		66.941	
	20%	97.5%	33.341	0.885991	38.082	1.095044	47.633	1.340169	56.383	1.526877
		95.0%	27.983		31.961		39.978		47.322	
		90.0%	21.791		24.889		31.132		36.850	
		99.5%	45.214		49.669		60.595		71.106	
		99.0%	40.859		44.885		54.759		64.258	
	25%	97.5%	34.415	1.084856	37.806	1.300176	46.123	1.524541	54.123	1.795523
		95.0%	28.884		31.730		38.710		45.425	
		90.0%	22.493		24.709		30.144		35.373	
		99.5%	43.619		51.515		61.127		69.974	
		99.0%	39.418		46.554		55.240		63.235	
	30%	97.5%	33.201	1.215473	39.212	1.504881	46.528	1.800480	53.262	2.089667
		95.0%	27.865		32.910		39.050		44.702	
		90.0%	21.699		25.628		30.409		34.810	
		99.5%	40.734		51.673		57.900		68.885	
		99.0%	36.811		46.697		52.324		62.251	
	35%	97.5%	31.005	1.313442	39.332	1.658271	44.072	2.043382	52.433	2.311862
		95.0%	26.022		33.011		36.989		44.006	
		90.0%	20.264		25.706		28.804		34.269	
		99.5%	42.110		51.025		57.182		70.099	
		99.0%	38.054		46.110		51.675		63.347	
	40%	97.5%	32.053	1.512337	38.838	1.823201	43.525	2.173094	53.357	2.641374
		95.0%	26.901		32.596		36.530		44.781	
		90.0%	20.949		25.384		28.447		34.872	
		99.5%	40.021		50.870		55.829		68.227	
		99.0%	36.167		45.970		50.452		61.656	
	45%	97.5%	30.463	1.620154	38.720	2.034060	42.495	2.278609	51.932	2.927850
		95.0%	25.567		32.497		35.666		43.586	
		90.0%	19.909		25.306		27.774		33.941	
		99.5%	42.952		51.307		62.505		69.573	
		99.0%	38.816		46.366		56.485		62.873	
	50%	97.5%	32.694	1.818246	39.053	2.244144	47.577	2.717078	52.957	3.063222
		95.0%	27.439		32.777		39.931		44.446	
		90.0%	21.368		25.524		31.095		34.611	

Table 4.18. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 18.

Retailer Smoothing
Flex Bound Length = 18

			Standard Deviation															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Alpha	5%	99.5%	7.121		16.366		32.089		44.141		52.462		68.421		78.371		89.981	
		99.0%	6.435		14.790		28.999		39.890		47.410		61.832		70.823		81.314	
		97.5%	5.420	0.044875	12.457	0.109268	24.425	0.203387	33.599	0.282103	39.933	0.360836	52.080	0.466589	59.653	0.525221	68.490	0.626977
		95.0%	4.549		10.455		20.500		28.199		33.515		43.710		50.066		57.483	
		90.0%	3.542		8.142		15.964		21.959		26.099		34.038		38.988		44.763	
	10%	99.5%	6.094		16.327		29.576		40.207		49.818		61.780		68.080		85.291	
		99.0%	5.507		14.754		26.728		36.335		45.020		55.830		61.524		77.077	
		97.5%	4.638	0.073641	12.427	0.176833	22.512	0.309661	30.604	0.431964	37.920	0.563375	47.025	0.694188	51.820	0.833956	64.920	0.964425
		95.0%	3.893		10.430		18.894		25.686		31.825		39.467		43.492		54.487	
		90.0%	3.032		8.122		14.713		20.002		24.783		30.734		33.868		42.430	
	15%	99.5%	5.709		15.030		29.195		40.688		50.089		57.983		70.328		82.604	
		99.0%	5.159		13.583		26.384		36.770		45.265		52.399		63.554		74.649	
		97.5%	4.345	0.102693	11.440	0.240302	22.223	0.409132	30.971	0.597341	38.126	0.776145	44.135	0.918902	53.531	1.115574	62.875	1.326137
		95.0%	3.647		9.602		18.651		25.993		31.999		37.042		44.928		52.770	
		90.0%	2.840		7.477		14.524		20.241		24.918		28.845		34.986		41.094	
	20%	99.5%	5.579		14.081		28.260		40.032		50.150		57.817		68.979		84.029	
		99.0%	5.042		12.725		25.538		36.176		45.320		52.249		62.336		75.936	
		97.5%	4.247	0.133001	10.718	0.310723	21.510	0.522807	30.471	0.728975	38.173	0.959409	44.008	1.164554	52.504	1.388065	63.960	1.623626
		95.0%	3.564		8.996		18.053		25.574		32.038		36.936		44.066		53.681	
		90.0%	2.775		7.005		14.059		19.915		24.949		28.763		34.315		41.803	
	25%	99.5%	5.733		14.639		28.207		37.207		49.796		56.718		73.615		79.958	
		99.0%	5.181		13.229		25.491		33.624		45.000		51.256		66.525		72.257	
		97.5%	4.364	0.163846	11.143	0.374593	21.471	0.626221	28.321	0.875033	37.903	1.143034	43.172	1.323597	56.033	1.639399	60.861	1.931341
		95.0%	3.662		9.352		18.020		23.769		31.812		36.234		47.028		51.080	
		90.0%	2.852		7.283		14.033		18.510		24.773		28.216		36.622		39.777	
	30%	99.5%	5.391		13.025		28.835		40.063		47.913		57.091		65.540		79.991	
		99.0%	4.872		11.770		26.058		36.205		43.299		51.592		59.228		72.287	
		97.5%	4.104	0.195379	9.914	0.448890	21.948	0.728194	30.495	1.038391	36.470	1.304949	43.456	1.594798	49.887	1.860970	60.887	2.235164
		95.0%	3.444		8.321		18.421		25.594		30.609		36.472		41.869		51.101	
		90.0%	2.682		6.480		14.345		19.930		23.836		28.401		32.605		39.794	
	35%	99.5%	5.402		14.498		27.582		37.219		49.558		62.090		72.351		83.172	
		99.0%	4.881		13.102		24.926		33.635		44.785		56.110		65.383		75.161	
		97.5%	4.111	0.227890	11.035	0.497741	20.995	0.816475	28.330	1.135793	37.722	1.476630	47.260	1.817206	55.071	2.136063	63.307	2.505882
		95.0%	3.451		9.262		17.620		23.777		31.659		39.665		46.221		53.133	
		90.0%	2.687		7.212		13.721		18.516		24.654		30.888		35.993		41.376	
	40%	99.5%	5.407		14.688		26.733		41.142		48.089		59.407		67.297		76.595	
		99.0%	4.887		13.273		24.158		37.180		43.458		53.686		60.815		69.218	
		97.5%	4.116	0.264050	11.180	0.572775	20.348	0.874838	31.316	1.304871	36.604	1.610948	45.219	2.003743	51.224	2.318619	58.301	2.797525
		95.0%	3.454		9.383		17.078		26.283		30.721		37.952		42.991		48.931	
		90.0%	2.690		7.307		13.299		20.467		23.923		29.554		33.478		38.104	
	45%	99.5%	5.642		14.375		26.819		37.263		47.963		59.991		70.362		81.136	
		99.0%	5.099		12.990		24.236		33.675		43.344		54.213		63.585		73.321	
		97.5%	4.294	0.294617	10.942	0.616165	20.414	1.059979	28.364	1.392693	36.508	1.742626	45.663	2.223138	53.557	2.614946	61.758	3.144117
		95.0%	3.604		9.183		17.133		23.805		30.640		38.324		44.950		51.832	
		90.0%	2.807		7.151		13.342		18.538		23.860		29.844		35.003		40.363	
	50%	99.5%	5.496		14.077		27.559		40.345		47.998		58.728		69.868		76.871	
		99.0%	4.967		12.721		24.905		36.459		43.375		53.072		63.139		69.467	
		97.5%	4.183	0.333212	10.715	0.695555	20.977	1.110728	30.709	1.504891	36.534	1.925658	44.702	2.369040	53.181	2.829022	58.511	3.257378
		95.0%	3.511		8.993		17.606		25.774		30.663		37.518		44.634		49.108	
		90.0%	2.734		7.003		13.710		20.071		23.878		29.216		34.758		38.241	

Table 4.19. Resulting Table for Retailer Smoothing Analysis with Flex Bound Length = 20.

Retailer Smoothing

Flex Bound Length = 20

			Standard Deviation															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Alpha	5%	99.5%	7.566		18.994		35.829		47.415		61.251		72.909		84.821		96.233	
		99.0%	6.838		17.165		32.378		42.848		55.352		65.887		76.652		86.965	
		97.5%	5.759	0.047677	14.457	0.113071	27.272	0.202328	36.091	0.279583	46.622	0.367307	55.496	0.455549	64.563	0.559543	73.249	0.627843
		95.0%	4.834		12.134		22.889		30.290		39.129		46.577		54.187		61.477	
		90.0%	3.764		9.449		17.824		23.588		30.471		36.270		42.196		47.874	
	10%	99.5%	6.736		18.079		32.906		47.636		56.074		72.087		81.705		102.487	
		99.0%	6.088		16.338		29.737		43.048		50.674		65.145		73.836		92.617	
		97.5%	5.127	0.077946	13.761	0.186871	25.047	0.324732	36.259	0.472247	42.682	0.577750	54.870	0.742788	62.191	0.867802	78.010	1.047375
		95.0%	4.303		11.550		21.022		30.432		35.822		46.052		52.196		65.473	
		90.0%	3.351		8.994		16.370		23.698		27.896		35.862		40.646		50.985	
	15%	99.5%	6.452		17.738		33.893		46.336		58.539		65.214		78.137		85.540	
		99.0%	5.830		16.029		30.629		41.873		52.901		58.933		70.611		77.302	
		97.5%	4.911	0.108728	13.501	0.256183	25.798	0.446129	35.269	0.618384	44.558	0.790790	49.638	0.954579	59.475	1.172919	65.110	1.359838
		95.0%	4.122		11.331		21.652		29.601		37.397		41.661		49.917		54.646	
		90.0%	3.210		8.824		16.861		23.051		29.122		32.442		38.871		42.554	
	20%	99.5%	6.551		17.302		32.478		44.658		54.916		67.668		76.551		91.389	
		99.0%	5.920		15.636		29.350		40.357		49.627		61.151		69.178		82.587	
		97.5%	4.987	0.142430	13.170	0.327654	24.721	0.548446	33.992	0.776915	41.800	0.978017	51.506	1.197409	58.268	1.393094	69.562	1.709087
		95.0%	4.185		11.053		20.748		28.529		35.082		43.229		48.903		58.383	
		90.0%	3.259		8.607		16.157		22.216		27.319		33.663		38.082		45.464	
	25%	99.5%	6.611		17.187		32.196		46.334		57.353		69.508		78.592		88.466	
		99.0%	5.974		15.532		29.096		41.871		51.829		62.813		71.023		79.946	
		97.5%	5.032	0.174930	13.082	0.392613	24.507	0.653932	35.268	0.911151	43.655	1.181681	52.907	1.470280	59.821	1.753480	67.337	1.960438
		95.0%	4.223		10.980		20.568		29.600		36.639		44.404		50.207		56.515	
		90.0%	3.289		8.550		16.017		23.050		28.532		34.578		39.098		44.010	
	30%	99.5%	6.184		15.993		32.409		44.885		53.820		66.409		78.379		89.180	
		99.0%	5.588		14.453		29.288		40.562		48.636		60.013		70.830		80.591	
		97.5%	4.707	0.209115	12.174	0.465848	24.669	0.764373	34.165	1.045359	40.966	1.316128	50.548	1.591997	59.659	1.990698	67.881	2.292842
		95.0%	3.950		10.217		20.704		28.674		34.382		42.424		50.071		56.971	
		90.0%	3.076		7.956		16.123		22.329		26.774		33.037		38.992		44.365	
	35%	99.5%	6.374		16.297		31.166		42.689		58.223		65.865		75.755		88.762	
		99.0%	5.760		14.727		28.164		38.578		52.615		59.521		68.459		80.213	
		97.5%	4.851	0.247378	12.405	0.526510	23.722	0.880852	32.493	1.186897	44.317	1.555946	50.134	1.842368	57.662	2.261523	67.563	2.586521
		95.0%	4.072		10.411		19.910		27.271		37.195		42.077		48.395		56.704	
		90.0%	3.171		8.107		15.504		21.237		28.964		32.766		37.686		44.157	
	40%	99.5%	6.379		16.138		31.172		45.472		56.633		65.548		77.479		87.384	
		99.0%	5.765		14.584		28.170		41.092		51.179		59.235		70.017		78.968	
		97.5%	4.856	0.278378	12.284	0.600494	23.727	0.981363	34.611	1.351074	43.107	1.735400	49.892	2.057433	58.974	2.529558	66.513	2.844851
		95.0%	4.075		10.309		19.914		29.049		36.179		41.874		49.496		55.824	
		90.0%	3.174		8.028		15.507		22.621		28.174		32.608		38.544		43.471	
	45%	99.5%	6.546		16.207		32.180		44.448		56.449		66.010		77.398		86.146	
		99.0%	5.916		14.646		29.081		40.167		51.012		59.652		69.944		77.849	
		97.5%	4.983	0.319922	12.336	0.664360	24.494	1.043408	33.832	1.425919	42.967	1.841502	50.244	2.266688	58.913	2.712662	65.572	3.156097
		95.0%	4.182		10.354		20.558		28.395		36.061		42.169		49.445		55.033	
		90.0%	3.256		8.063		16.009		22.112		28.082		32.838		38.504		42.856	
	50%	99.5%	6.195		16.127		32.486		43.516		55.493		67.920		78.446		87.025	
		99.0%	5.598		14.574		29.357		39.325		50.148		61.379		70.891		78.644	
		97.5%	4.715	0.352674	12.275	0.703618	24.727	1.176996	33.123	1.610687	42.239	2.079848	51.698	2.533967	59.711	2.931861	66.240	3.376675
		95.0%	3.957		10.303		20.753		27.800		35.451		43.390		50.114		55.595	
		90.0%	3.082		8.023		16.161		21.648		27.606		33.789		39.025		43.293	

4.4.2 Production Smoothing Results and Trends

There was a significant difference between the PS and RS techniques. The response variables change as the length of the analysis increases for the PS strategy. For instance, a company may use this technique in their facility during a year's time before refreshing the system. If the company uses the fences weekly to provide flexibility, then the variation of production will increase over time due to the bounds increasing every week as shown in Figure 4.9. As the desired customer service level increases, the amount of inventory required will increase. On the other hand, if the organization only changes the flex limits monthly, the fluctuations in production will be minimized due to only twelve updates a year, rather than the previous 52. The positive aspect of reducing the time periods is that changes in production are minimized. The negative position states that the more production is constrained, the more inventory is necessary to buffer against demand. Hence, the more periods in the study, the more flexibility that is allowed in the system as demonstrated in Figure 4.10 for Production Smoothing. The impact of standard deviation, flex bound width, and flex bound length on inventory and the production shift is displayed in Tables 4.20 through 4.51. However, the data in the PS tables do not represent a normal distribution due to a changing amount of variation in the process that is time dependent as shown in Figure 4.9. Therefore, the estimates in the tables are understating the necessary amount of inventory. Better estimates for inventory may be found through an exorbitant amount of simulations.

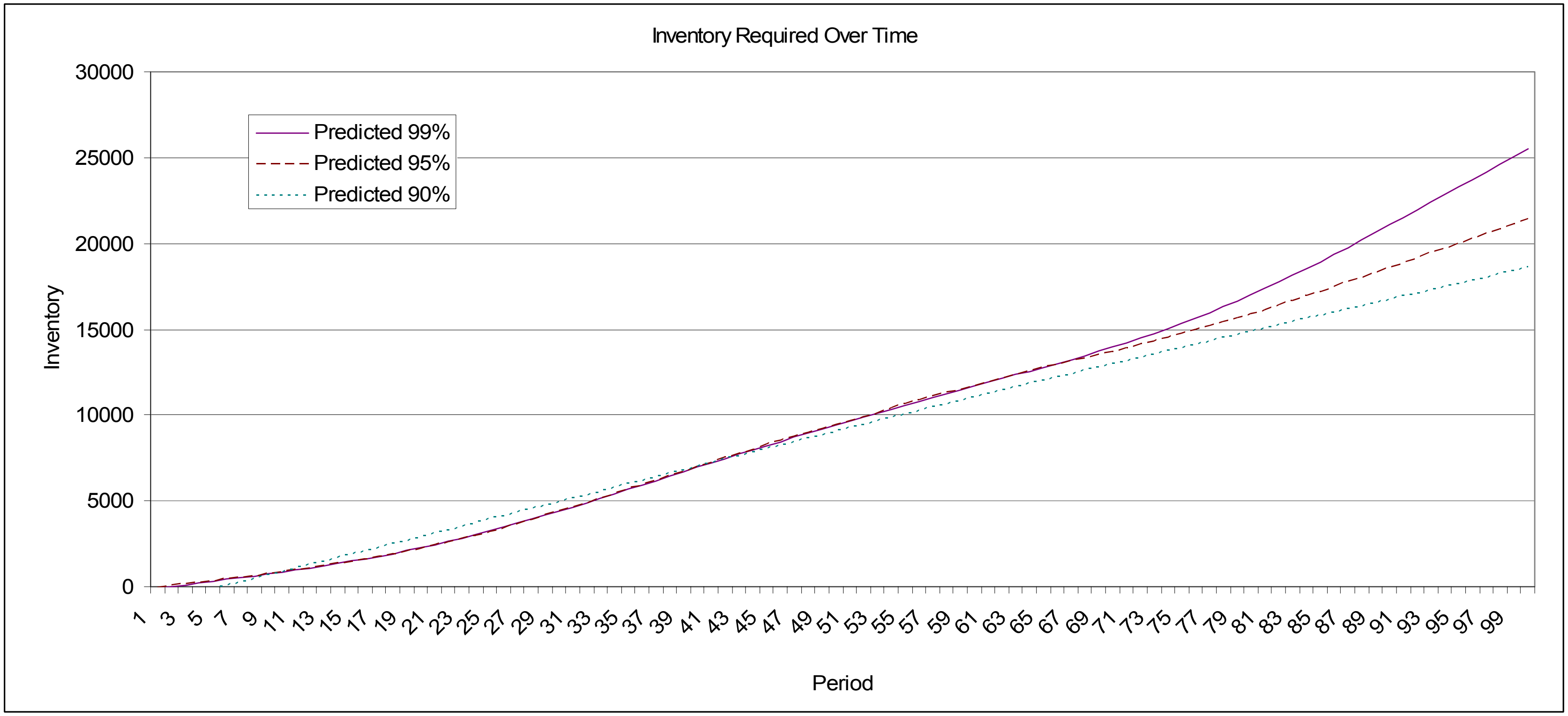

Figure 4.9. Increasing Amount of Inventory Required Over Time for the Production Smoothing Strategy.

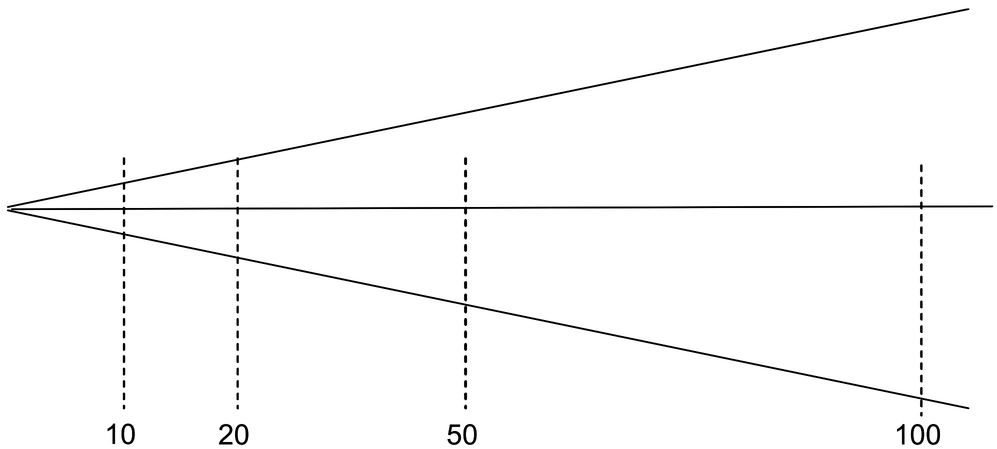

Figure 4.10. Impact on the Response Variable Increases as the Number of Periods Increase for Production Smoothing.

Table 4.20. Table for Production Smoothing Analysis with Standard Deviation = 2% and Time = 100 Periods.

Production Smoothing

Standard Deviation = 2%, Time Frame = 100 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	15.468		14.167		11.508		12.094		10.174		9.733		10.210		8.684	
		99.0%	13.978		12.802		10.400		10.929		9.194		8.795		9.227		7.847	
		97.5%	11.774	0.000000	10.783	0.001168	8.760	0.002382	9.205	0.003894	7.744	0.004635	7.408	0.006242	7.772	0.006815	6.610	0.008753
		95.0%	9.881		9.050		7.352		7.726		6.500		6.218		6.523		5.548	
		90.0%	7.695		7.048		5.725		6.016		5.061		4.842		5.079		4.320	
	4	99.5%	14.909		15.193		13.908		14.430		14.663		13.449		11.355		11.556	
		99.0%	13.473		13.730		12.568		13.040		13.251		12.153		10.261		10.443	
		97.5%	11.348	0.000000	11.564	0.000839	10.586	0.001817	10.983	0.002711	11.161	0.003363	10.237	0.004651	8.643	0.005573	8.796	0.006320
		95.0%	9.524		9.706		8.885		9.218		9.367		8.592		7.254		7.383	
		90.0%	7.417		7.558		6.919		7.178		7.295		6.690		5.649		5.749	
	6	99.5%	15.047		14.879		14.755		13.713		14.279		13.309		12.962		14.369	
		99.0%	13.598		13.446		13.333		12.392		12.904		12.027		11.713		12.985	
		97.5%	11.454	0.000000	11.326	0.000736	11.231	0.001487	10.438	0.002229	10.869	0.002953	10.130	0.003612	9.866	0.004456	10.937	0.005166
		95.0%	9.613		9.505		9.426		8.760		9.122		8.502		8.280		9.180	
		90.0%	7.486		7.402		7.340		6.822		7.103		6.621		6.448		7.148	
	8	99.5%	14.349		12.917		13.590		13.197		12.348		14.874		11.449		14.559	
		99.0%	12.967		11.673		12.282		11.926		11.159		13.442		10.346		13.157	
		97.5%	10.922	0.000000	9.832	0.000676	10.345	0.001232	10.045	0.002007	9.399	0.002871	11.322	0.003128	8.714	0.003974	11.082	0.004651
		95.0%	9.167		8.252		8.682		8.431		7.888		9.502		7.314		9.301	
		90.0%	7.138		6.426		6.761		6.565		6.143		7.400		5.695		7.243	
	10	99.5%	14.908		14.778		16.040		14.932		14.966		12.720		12.804		13.602	
		99.0%	13.473		13.355		14.495		13.494		13.525		11.495		11.570		12.292	
		97.5%	11.348	0.000000	11.249	0.000602	12.209	0.001086	11.365	0.001749	11.392	0.002318	9.682	0.003143	9.746	0.003392	10.353	0.004057
		95.0%	9.524		9.441		10.247		9.539		9.561		8.126		8.179		8.689	
		90.0%	7.417		7.352		7.979		7.428		7.445		6.328		6.369		6.767	
	12	99.5%	13.183		15.555		15.792		13.558		15.310		16.191		14.815		13.348	
		99.0%	11.913		14.057		14.271		12.253		13.835		14.631		13.388		12.062	
		97.5%	10.034	0.000000	11.840	0.000577	12.021	0.001001	10.320	0.001522	11.653	0.002152	12.324	0.002559	11.277	0.003194	10.160	0.003843
		95.0%	8.422		9.937		10.089		8.662		9.780		10.343		9.464		8.527	
		90.0%	6.558		7.738		7.856		6.745		7.616		8.054		7.370		6.640	
	14	99.5%	15.886		16.916		14.991		14.103		14.593		11.746		14.978		13.079	
		99.0%	14.356		15.287		13.547		12.745		13.187		10.615		13.535		11.819	
		97.5%	12.092	0.000000	12.876	0.000524	11.410	0.001029	10.735	0.001461	11.107	0.002135	8.941	0.002520	11.401	0.003130	9.955	0.003652
		95.0%	10.149		10.807		9.576		9.010		9.322		7.504		9.568		8.355	
		90.0%	7.903		8.416		7.457		7.016		7.260		5.843		7.451		6.507	
	16	99.5%	15.162		14.930		14.585		14.730		13.686		13.521		15.012		15.473	
		99.0%	13.702		13.492		13.181		13.312		12.368		12.219		13.566		13.983	
		97.5%	11.541	0.000000	11.364	0.000472	11.102	0.001014	11.212	0.001458	10.417	0.001844	10.292	0.002475	11.426	0.002667	11.778	0.003258
		95.0%	9.686		9.538		9.318		9.410		8.743		8.638		9.590		9.885	
		90.0%	7.543		7.427		7.256		7.328		6.808		6.726		7.468		7.697	
	18	99.5%	15.993		14.013		14.931		15.282		12.304		14.331		14.439		15.990	
		99.0%	14.453		12.663		13.493		13.810		11.119		12.951		13.048		14.450	
		97.5%	12.173	0.000000	10.666	0.000500	11.365	0.000953	11.632	0.001386	9.366	0.001832	10.908	0.002308	10.990	0.002818	12.171	0.003301
		95.0%	10.217		8.952		9.538		9.763		7.860		9.155		9.224		10.215	
		90.0%	7.956		6.971		7.428		7.603		6.121		7.129		7.183		7.955	
	20	99.5%	14.179		14.050		15.146		13.798		14.018		13.622		16.887		13.796	
		99.0%	12.814		12.696		13.688		12.469		12.667		12.310		15.261		12.468	
		97.5%	10.793	0.000000	10.694	0.000452	11.529	0.000801	10.503	0.001247	10.670	0.001700	10.369	0.002216	12.854	0.002646	10.501	0.003089
		95.0%	9.058		8.975		9.676		8.815		8.955		8.703		10.788		8.814	
		90.0%	7.054		6.989		7.535		6.864		6.973		6.777		8.401		6.863	

Table 4.21. Table for Production Smoothing Analysis with Standard Deviation = 5% and Time = 100 Periods.

Production Smoothing
Standard Deviation = 5%, Time Frame = 100 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	33.682		35.172		29.007		28.668		31.215		25.849		21.482		19.724	
		99.0%	30.438		31.785		26.213		25.907		28.209		23.360		19.413		17.824	
		97.5%	25.638	0.001178	26.772	0.003264	22.079	0.005659	21.821	0.008491	23.760	0.012182	19.676	0.015074	16.351	0.019356	15.013	0.022429
		95.0%	21.517		22.469		18.531		18.314		19.941		16.514		13.723		12.600	
		90.0%	16.756		17.497		14.430		14.262		15.529		12.859		10.687		9.812	
	4	99.5%	34.321		35.997		33.620		30.395		32.680		29.217		28.719		29.127	
		99.0%	31.015		32.530		30.382		27.468		29.532		26.403		25.953		26.322	
		97.5%	26.124	0.000900	27.400	0.002689	25.590	0.004184	23.136	0.006408	24.875	0.009325	22.239	0.012597	21.860	0.013747	22.171	0.016915
		95.0%	21.925		22.996		21.477		19.417		20.877		18.665		18.346		18.608	
		90.0%	17.074		17.908		16.725		15.121		16.257		14.535		14.287		14.490	
	6	99.5%	39.742		34.820		36.315		35.927		33.743		35.234		30.941		28.819	
		99.0%	35.914		31.466		32.818		32.467		30.493		31.841		27.961		26.043	
		97.5%	30.250	0.000746	26.504	0.002343	27.642	0.003444	27.346	0.006092	25.684	0.007793	26.819	0.009810	23.551	0.011791	21.936	0.014229
		95.0%	25.389		22.244		23.199		22.951		21.556		22.509		19.766		18.411	
		90.0%	19.771		17.322		18.066		17.873		16.786		17.528		15.392		14.337	
	8	99.5%	40.574		33.384		34.964		34.056		37.011		33.385		29.407		30.876	
		99.0%	36.666		30.169		31.596		30.776		33.447		30.170		26.575		27.902	
		97.5%	30.883	0.000616	25.411	0.002107	26.613	0.003258	25.922	0.004911	28.172	0.006486	25.412	0.008415	22.384	0.009690	23.502	0.011576
		95.0%	25.920		21.327		22.336		21.756		23.644		21.328		18.786		19.725	
		90.0%	20.184		16.608		17.394		16.942		18.412		16.608		14.629		15.360	
	10	99.5%	38.304		36.362		38.974		38.005		34.531		36.428		32.966		30.630	
		99.0%	34.615		32.860		35.221		34.344		31.206		32.920		29.791		27.680	
		97.5%	29.156	0.000609	27.678	0.001723	29.666	0.003072	28.928	0.004611	26.284	0.005540	27.728	0.007070	25.093	0.008537	23.315	0.011404
		95.0%	24.470		23.230		24.898		24.279		22.060		23.272		21.060		19.568	
		90.0%	19.055		18.089		19.389		18.906		17.179		18.122		16.400		15.238	
	12	99.5%	32.911		39.414		40.823		37.920		34.468		37.236		37.713		36.726	
		99.0%	29.741		35.618		36.891		34.268		31.149		33.649		34.081		33.189	
		97.5%	25.050	0.000534	30.001	0.001731	31.073	0.002540	28.863	0.004309	26.236	0.005572	28.342	0.007194	28.706	0.007950	27.954	0.010373
		95.0%	21.024		25.179		26.079		24.224		22.020		23.787		24.092		23.462	
		90.0%	16.372		19.608		20.308		18.864		17.147		18.524		18.761		18.270	
	14	99.5%	38.219		39.121		34.914		31.880		30.147		36.438		31.153		37.649	
		99.0%	34.538		35.353		31.552		28.810		27.243		32.928		28.152		34.023	
		97.5%	29.091	0.000496	29.778	0.001497	26.575	0.002493	24.266	0.004208	22.947	0.004857	27.735	0.006820	23.712	0.008249	28.657	0.009495
		95.0%	24.416		24.992		22.304		20.366		19.259		23.278		19.901		24.052	
		90.0%	19.013		19.462		17.369		15.860		14.997		18.127		15.498		18.730	
	16	99.5%	39.496		34.782		37.747		35.430		32.291		38.402		37.443		34.758	
		99.0%	35.692		31.432		34.112		32.018		29.181		34.703		33.836		31.411	
		97.5%	30.063	0.000467	26.475	0.001353	28.732	0.002571	26.968	0.003942	24.578	0.005076	29.230	0.006651	28.500	0.006912	26.457	0.009095
		95.0%	25.231		22.220		24.114		22.634		20.628		24.532		23.920		22.205	
		90.0%	19.648		17.303		18.778		17.626		16.064		19.104		18.627		17.291	
	18	99.5%	34.052		33.617		35.875		36.205		34.926		38.473		33.330		32.843	
		99.0%	30.773		30.379		32.420		32.718		31.563		34.768		30.120		29.680	
		97.5%	25.919	0.000487	25.588	0.001468	27.307	0.002240	27.558	0.003613	26.585	0.004682	29.284	0.006158	25.370	0.007804	24.999	0.008436
		95.0%	21.754		21.476		22.918		23.129		22.312		24.578		21.293		20.981	
		90.0%	16.940		16.724		17.847		18.011		17.375		19.140		16.581		16.339	
	20	99.5%	36.682		40.076		38.812		38.443		33.590		31.939		35.858		36.945	
		99.0%	33.149		36.217		35.074		34.740		30.355		28.863		32.405		33.386	
		97.5%	27.921	0.000430	30.505	0.001271	29.542	0.002384	29.261	0.003438	25.568	0.004580	24.311	0.006028	27.294	0.006849	28.121	0.007802
		95.0%	23.434		25.602		24.794		24.559		21.459		20.404		22.907		23.601	
		90.0%	18.248		19.937		19.308		19.124		16.710		15.889		17.839		18.379	

Table 4.22. Table for Production Smoothing Analysis with Standard Deviation = 10% and Time = 100 Periods.

Production Smoothing
Standard Deviation = 10%, Time Frame = 100 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	72.506		68.747		53.511		52.943		45.258		41.364		36.431		41.796	
		99.0%	65.523		62.126		48.357		47.844		40.900		37.380		32.922		37.771	
		97.5%	55.189	0.002398	52.328	0.005910	40.731	0.011549	40.298	0.016812	34.449	0.025575	31.485	0.031295	27.730	0.036657	31.814	0.041007
		95.0%	46.319		43.918		34.185		33.822		28.913		26.425		23.273		26.701	
		90.0%	36.070		34.200		26.620		26.338		22.515		20.578		18.123		20.792	
	4	99.5%	71.130		63.053		61.290		61.381		57.046		51.324		60.527		44.795	
		99.0%	64.279		56.980		55.387		55.469		51.552		46.381		54.697		40.481	
		97.5%	54.142	0.001668	47.994	0.003891	46.651	0.008388	46.721	0.012492	43.422	0.016529	39.066	0.024020	46.071	0.025118	34.096	0.032498
		95.0%	45.440		40.280		39.154		39.212		36.443		32.787		38.666		28.616	
		90.0%	35.385		31.367		30.490		30.535		28.379		25.532		30.110		22.284	
	6	99.5%	61.571		65.690		76.741		64.658		51.674		54.459		68.460		55.968	
		99.0%	55.641		59.363		69.350		58.431		46.698		49.214		61.866		50.578	
		97.5%	46.866	0.001420	50.001	0.003635	58.412	0.006997	49.215	0.011328	39.333	0.015839	41.452	0.020189	52.109	0.023679	42.601	0.026581
		95.0%	39.334		41.965		49.025		41.306		33.011		34.790		43.734		35.755	
		90.0%	30.630		32.679		38.177		32.166		25.707		27.092		34.057		27.843	
	8	99.5%	65.938		62.060		62.701		67.614		72.165		55.872		64.969		56.283	
		99.0%	59.588		56.083		56.662		61.102		65.215		50.491		58.712		50.862	
		97.5%	50.190	0.001215	47.238	0.003245	47.726	0.006238	51.465	0.009585	54.930	0.013009	42.528	0.017737	49.452	0.019475	42.840	0.022129
		95.0%	42.124		39.646		40.056		43.194		46.102		35.693		41.505		35.955	
		90.0%	32.803		30.874		31.192		33.636		35.900		27.795		32.321		27.999	
	10	99.5%	64.489		63.429		72.284		63.802		72.992		66.071		62.763		65.680	
		99.0%	58.278		57.320		65.322		57.657		65.962		59.707		56.718		59.354	
		97.5%	49.087	0.001148	48.280	0.003017	55.020	0.005744	48.564	0.008622	55.559	0.011807	50.291	0.014509	47.773	0.017971	49.993	0.021665
		95.0%	41.198		40.521		46.178		40.759		46.630		42.208		40.095		41.959	
		90.0%	32.082		31.554		35.960		31.740		36.312		32.868		31.223		32.674	
	12	99.5%	59.170		67.529		62.202		66.247		68.619		62.761		67.659		64.803	
		99.0%	53.471		61.025		56.211		59.867		62.011		56.716		61.143		58.561	
		97.5%	45.038	0.000994	51.401	0.002725	47.346	0.005540	50.425	0.007987	52.231	0.010665	47.771	0.012984	51.500	0.015409	49.325	0.018550
		95.0%	37.800		43.140		39.737		42.321		43.836		40.094		43.223		41.398	
		90.0%	29.436		33.594		30.944		32.956		34.136		31.222		33.659		32.238	
	14	99.5%	69.802		67.154		66.304		59.757		58.574		65.015		59.666		70.535	
		99.0%	63.079		60.686		59.918		54.002		52.933		58.754		53.920		63.742	
		97.5%	53.131	0.001045	51.115	0.002427	50.468	0.005215	45.485	0.007266	44.585	0.010818	49.487	0.013773	45.416	0.015317	53.689	0.017630
		95.0%	44.592		42.900		42.357		38.175		37.419		41.534		38.117		45.060	
		90.0%	34.725		33.407		32.985		29.728		29.139		32.344		29.682		35.090	
	16	99.5%	71.809		62.105		69.222		66.880		61.451		64.494		63.119		62.558	
		99.0%	64.893		56.124		62.555		60.439		55.533		58.283		57.040		56.533	
		97.5%	54.659	0.000930	47.272	0.002565	52.689	0.004843	50.907	0.007965	46.774	0.009893	49.091	0.013165	48.044	0.014570	47.617	0.016770
		95.0%	45.874		39.675		44.221		42.725		39.257		41.201		40.323		39.964	
		90.0%	35.723		30.896		34.436		33.271		30.570		32.084		31.400		31.121	
	18	99.5%	71.111		65.753		67.765		73.496		60.653		63.994		66.946		60.178	
		99.0%	64.263		59.421		61.238		66.417		54.811		57.831		60.499		54.382	
		97.5%	54.127	0.000876	50.049	0.002515	51.580	0.004597	55.942	0.006458	46.167	0.009521	48.710	0.011885	50.957	0.013039	45.805	0.016352
		95.0%	45.428		42.006		43.290		46.952		38.747		40.882		42.768		38.444	
		90.0%	35.376		32.711		33.711		36.562		30.173		31.836		33.304		29.937	
	20	99.5%	67.628		68.232		70.294		74.275		66.540		61.487		52.941		64.358	
		99.0%	61.114		61.661		63.524		67.121		60.131		55.565		47.842		58.160	
		97.5%	51.476	0.000902	51.936	0.002119	53.505	0.004222	56.535	0.006124	50.648	0.008607	46.802	0.011567	40.297	0.013785	48.987	0.016695
		95.0%	43.203		43.589		44.906		47.449		42.508		39.280		33.821		41.114	
		90.0%	33.643		33.944		34.970		36.950		33.102		30.588		26.337		32.017	

Table 4.23. Table for Production Smoothing Analysis with Standard Deviation = 15% and Time = 100 Periods.

Production Smoothing
Standard Deviation = 15%, Time Frame = 100 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
	99.5%	85.996		91.784		76.354		67.465		60.428		53.347		60.429		54.802	
	99.0%	77.714		82.945		69.000		60.967		54.608		48.209		54.609		49.524	
2	97.5%	65.457	0.003288	69.863	0.008729	58.118	0.017729	51.352	0.027625	45.996	0.035960	40.606	0.047217	45.996	0.050028	41.713	0.063305
	95.0%	54.937		58.635		48.777		43.099		38.604		34.080		38.604		35.009	
	90.0%	42.781		45.661		37.984		33.562		30.062		26.539		30.062		27.263	
	99.5%	85.109		95.985		86.028		77.366		71.107		78.338		66.470		66.589	
	99.0%	76.912		86.740		77.743		69.914		64.259		70.793		60.068		60.175	
4	97.5%	64.782	0.002820	73.060	0.006939	65.481	0.013367	58.888	0.021601	54.124	0.026286	59.628	0.032355	50.595	0.040799	50.685	0.050708
	95.0%	54.370		61.318		54.958		49.424		45.426		50.045		42.463		42.539	
	90.0%	42.339		47.750		42.797		38.487		35.374		38.971		33.067		33.126	
	99.5%	95.776		94.168		98.752		88.333		71.236		80.710		78.964		75.490	
	99.0%	86.552		85.099		89.241		79.826		64.375		72.936		71.359		68.220	
6	97.5%	72.901	0.002204	71.678	0.005847	75.167	0.009450	67.236	0.016388	54.222	0.024363	61.433	0.028200	60.105	0.035061	57.461	0.042110
	95.0%	61.185		60.158		63.086		56.430		45.508		51.560		50.445		48.226	
	90.0%	47.646		46.846		49.127		43.944		35.438		40.151		39.283		37.555	
	99.5%	92.312		90.297		90.210		90.494		72.330		77.148		73.456		75.020	
	99.0%	83.422		81.600		81.522		81.779		65.364		69.718		66.381		67.795	
8	97.5%	70.265	0.002000	68.731	0.005349	68.665	0.009091	68.881	0.014778	55.055	0.019981	58.722	0.024874	55.912	0.032189	57.103	0.036848
	95.0%	58.972		57.685		57.629		57.811		46.207		49.285		46.926		47.926	
	90.0%	45.923		44.921		44.877		45.019		35.983		38.379		36.543		37.321	
	99.5%	79.832		88.818		85.146		104.634		87.740		86.764		80.008		73.047	
	99.0%	72.143		80.263		76.946		94.557		79.289		78.408		72.302		66.012	
10	97.5%	60.765	0.001793	67.605	0.004827	64.810	0.009206	79.644	0.013220	66.784	0.018764	66.042	0.025097	60.899	0.025593	55.601	0.033917
	95.0%	50.999		56.740		54.394		66.844		56.051		55.428		51.112		46.665	
	90.0%	39.714		44.185		42.358		52.053		43.648		43.163		39.802		36.339	
	99.5%	87.000		94.915		90.865		79.720		92.992		87.974		82.699		95.485	
	99.0%	78.621		85.774		82.113		72.042		84.036		79.501		74.735		86.289	
12	97.5%	66.221	0.001628	72.246	0.004628	69.163	0.008057	60.680	0.013473	70.782	0.016894	66.963	0.019328	62.948	0.025704	72.680	0.029107
	95.0%	55.578		60.635		58.048		50.928		59.407		56.201		52.831		60.999	
	90.0%	43.280		47.218		45.203		39.659		46.261		43.765		41.141		47.501	
	99.5%	83.050		98.508		81.522		90.578		98.163		89.841		81.936		81.529	
	99.0%	75.052		89.020		73.671		81.854		88.709		81.188		74.045		73.677	
14	97.5%	63.215	0.001561	74.981	0.004049	62.052	0.007559	68.945	0.012867	74.718	0.015231	68.384	0.020630	62.367	0.024747	62.057	0.028945
	95.0%	53.055		62.930		52.079		57.864		62.710		57.393		52.344		52.084	
	90.0%	41.315		49.005		40.555		45.060		48.834		44.694		40.761		40.559	
	99.5%	83.125		96.774		83.407		80.293		81.220		91.743		94.190		82.066	
	99.0%	75.119		87.454		75.374		72.560		73.398		82.907		85.119		74.162	
16	97.5%	63.272	0.001503	73.661	0.003542	63.486	0.007830	61.116	0.010773	61.822	0.013784	69.831	0.018892	71.694	0.022111	62.466	0.025973
	95.0%	53.103		61.823		53.283		51.294		51.886		58.608		60.172		52.426	
	90.0%	41.353		48.143		41.493		39.944		40.405		45.640		46.857		40.826	
	99.5%	96.475		98.627		77.385		83.779		85.901		91.498		91.642		105.978	
	99.0%	87.184		89.128		69.932		75.711		77.627		82.686		82.816		95.771	
18	97.5%	73.434	0.001391	75.072	0.003695	58.903	0.007087	63.770	0.010510	65.385	0.014899	69.645	0.016975	69.754	0.019227	80.667	0.025249
	95.0%	61.632		63.007		49.436		53.521		54.876		58.452		58.544		67.703	
	90.0%	47.994		49.065		38.497		41.678		42.733		45.518		45.590		52.722	
	99.5%	85.148		81.089		85.347		80.303		78.888		83.004		87.130		92.608	
	99.0%	76.948		73.279		77.128		72.569		71.290		75.010		78.739		83.689	
20	97.5%	64.812	0.001348	61.722	0.003556	64.964	0.006457	61.124	0.010519	60.047	0.012665	63.180	0.017633	66.321	0.017671	70.490	0.022721
	95.0%	54.396		51.802		54.523		51.300		50.396		53.026		55.662		59.161	
	90.0%	42.359		40.340		42.458		39.949		39.245		41.292		43.345		46.070	

Table 4.24. Table for Production Smoothing Analysis with Standard Deviation = 20% and Time = 100 Periods.

Production Smoothing
Standard Deviation = 20%, Time Frame = 100 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	113.951		102.877		89.904		77.299		76.798		61.830		81.486		51.630	
	99.0%	102.976		92.969		81.245		69.854		69.402		55.875		73.638		46.657	
	97.5%	86.735	0.004400	78.306	0.012971	68.432	0.024297	58.837	0.036326	58.456	0.055152	47.063	0.057602	62.024	0.074196	39.299	0.087696
	95.0%	72.796		65.721		57.434		49.381		49.061		39.499		52.056		32.983	
	90.0%	56.688		51.179		44.725		38.454		38.205		30.759		40.537		25.684	
4	99.5%	106.790		123.852		101.668		109.239		100.805		109.683		90.539		91.434	
	99.0%	96.505		111.923		91.876		98.718		91.096		99.119		81.819		82.628	
	97.5%	81.285	0.003429	94.272	0.008736	77.386	0.017550	83.149	0.025288	76.729	0.033843	83.487	0.043046	68.915	0.056398	69.597	0.063920
	95.0%	68.221		79.121		64.949		69.786		64.398		70.069		57.839		58.411	
	90.0%	53.126		61.613		50.577		54.344		50.148		54.564		45.041		45.486	
6	99.5%	124.746		109.990		106.403		118.013		110.475		116.918		100.262		98.094	
	99.0%	112.731		99.396		96.155		106.647		99.835		105.658		90.606		88.647	
	97.5%	94.952	0.002895	83.720	0.007418	80.990	0.014622	89.827	0.021404	84.090	0.031845	88.994	0.038126	76.316	0.048556	74.666	0.049219
	95.0%	79.692		70.265		67.974		75.391		70.575		74.692		64.051		62.666	
	90.0%	62.058		54.717		52.933		58.708		54.959		58.164		49.878		48.799	
8	99.5%	86.888		112.727		111.249		101.292		107.208		96.508		116.040		110.596	
	99.0%	78.520		101.870		100.534		91.537		96.882		87.213		104.864		99.945	
	97.5%	66.136	0.002795	85.804	0.006369	84.679	0.012484	77.100	0.018986	81.603	0.027373	73.459	0.033375	88.326	0.040965	84.182	0.048407
	95.0%	55.507		72.014		71.069		64.709		68.488		61.653		74.131		70.653	
	90.0%	43.225		56.079		55.343		50.390		53.333		48.010		57.727		55.019	
10	99.5%	115.509		110.744		104.610		116.748		105.575		104.463		112.769		90.450	
	99.0%	104.385		100.078		94.535		105.503		95.407		94.402		101.908		81.739	
	97.5%	87.922	0.002292	84.294	0.005600	79.625	0.012577	88.864	0.018664	80.360	0.024811	79.513	0.030504	85.836	0.036116	68.848	0.041806
	95.0%	73.791		70.747		66.828		74.582		67.445		66.734		72.041		57.783	
	90.0%	57.463		55.092		52.041		58.079		52.521		51.968		56.100		44.997	
12	99.5%	125.306		105.398		117.604		92.625		111.492		106.486		97.243		104.766	
	99.0%	113.238		95.247		106.278		83.705		100.754		96.230		87.878		94.676	
	97.5%	95.379	0.002157	80.225	0.005642	89.516	0.011930	70.503	0.016834	84.864	0.021827	81.053	0.025529	74.018	0.032053	79.745	0.039138
	95.0%	80.050		67.332		75.130		59.172		71.225		68.027		62.122		66.928	
	90.0%	62.337		52.433		58.505		46.079		55.465		52.974		48.376		52.119	
14	99.5%	106.235		100.067		114.901		83.305		92.754		111.860		106.777		110.471	
	99.0%	96.004		90.430		103.835		75.282		83.821		101.087		96.494		99.831	
	97.5%	80.863	0.002160	76.168	0.005389	87.459	0.010149	63.409	0.016909	70.601	0.021392	85.144	0.027233	81.275	0.032544	84.086	0.035830
	95.0%	67.867		63.926		73.403		53.218		59.255		71.460		68.213		70.572	
	90.0%	52.850		49.781		57.161		41.442		46.143		55.648		53.119		54.956	
16	99.5%	124.955		103.140		107.087		110.929		120.189		105.356		88.287		105.730	
	99.0%	112.920		93.206		96.773		100.246		108.613		95.209		79.784		95.547	
	97.5%	95.111	0.001936	78.506	0.005198	81.511	0.010324	84.435	0.015054	91.483	0.019354	80.193	0.025567	67.201	0.032987	80.478	0.034519
	95.0%	79.826		65.889		68.411		70.865		76.781		67.305		56.401		67.544	
	90.0%	62.162		51.310		53.273		55.185		59.791		52.412		43.920		52.598	
18	99.5%	119.114		104.990		107.179		103.364		104.210		109.672		115.056		109.042	
	99.0%	107.642		94.878		96.857		93.409		94.173		99.110		103.975		98.541	
	97.5%	90.665	0.001852	79.915	0.004916	81.581	0.009232	78.677	0.013339	79.321	0.019446	83.479	0.024878	87.576	0.030553	82.999	0.034226
	95.0%	76.094		67.071		68.470		66.033		66.573		70.062		73.502		69.660	
	90.0%	59.256		52.230		53.319		51.421		51.842		54.559		57.237		54.246	
20	99.5%	110.783		112.728		107.637		99.891		99.084		91.573		100.373		108.871	
	99.0%	100.113		101.871		97.270		90.270		89.541		82.753		90.706		98.385	
	97.5%	84.324	0.001886	85.805	0.004943	81.929	0.008743	76.033	0.014683	75.419	0.017950	69.702	0.022213	76.400	0.029242	82.869	0.031796
	95.0%	70.772		72.015		68.762		63.814		63.298		58.500		64.122		69.550	
	90.0%	55.112		56.079		53.547		49.693		49.292		45.555		49.933		54.161	

Table 4.25. Table for Production Smoothing Analysis with Standard Deviation = 25% and Time = 100 Periods.

Production Smoothing
Standard Deviation = 25%, Time Frame = 100 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	143.181		142.543		111.449		103.475		105.495		77.099		90.147		77.766	
	99.0%	129.391		128.814		100.715		93.509		95.335		69.674		81.465		70.276	
	97.5%	108.985	0.006099	108.499	0.015387	84.831	0.031887	78.762	0.042342	80.299	0.060379	58.685	0.081472	68.617	0.088077	59.193	0.102256
	95.0%	91.469		91.061		71.197		66.103		67.394		49.254		57.589		49.680	
	90.0%	71.229		70.912		55.443		51.476		52.481		38.355		44.846		38.687	
4	99.5%	135.669		151.220		113.043		108.879		109.571		130.338		119.383		86.307	
	99.0%	122.603		136.656		102.156		98.393		99.018		117.785		107.885		77.994	
	97.5%	103.267	0.004194	115.104	0.010637	86.044	0.023172	82.875	0.037260	83.401	0.046050	99.208	0.055619	90.870	0.072547	65.694	0.078838
	95.0%	86.670		96.605		72.216		69.556		69.998		83.264		76.266		55.136	
	90.0%	67.492		75.229		56.236		54.165		54.509		64.840		59.390		42.935	
6	99.5%	143.886		127.738		144.908		118.029		114.302		120.703		108.811		106.386	
	99.0%	130.028		115.435		130.951		106.662		103.293		109.078		98.331		96.140	
	97.5%	109.521	0.003681	97.230	0.009510	110.299	0.018967	89.840	0.030111	87.003	0.040496	91.875	0.046628	82.823	0.059810	80.977	0.071857
	95.0%	91.920		81.604		92.572		75.401		73.020		77.109		69.512		67.963	
	90.0%	71.580		63.547		72.088		58.717		56.862		60.047		54.131		52.924	
8	99.5%	134.432		130.627		151.082		139.062		116.359		101.539		122.272		117.612	
	99.0%	121.485		118.046		136.531		125.669		105.152		91.760		110.496		106.285	
	97.5%	102.325	0.003045	99.429	0.008910	114.998	0.016678	105.849	0.024186	88.568	0.033158	77.288	0.043501	93.069	0.051725	89.522	0.056717
	95.0%	85.880		83.449		96.516		88.838		74.334		64.867		78.112		75.135	
	90.0%	66.877		64.984		75.159		69.180		57.886		50.513		60.827		58.509	
10	99.5%	147.577		103.351		116.074		102.191		130.152		143.322		123.204		128.643	
	99.0%	133.364		93.397		104.895		92.349		117.617		129.518		111.338		116.254	
	97.5%	112.330	0.003220	78.667	0.007791	88.352	0.015453	77.784	0.024553	99.067	0.032190	109.091	0.037991	93.779	0.044192	97.919	0.052033
	95.0%	94.277		66.024		74.152		65.283		83.146		91.559		78.707		82.182	
	90.0%	73.416		51.415		57.744		50.838		64.748		71.299		61.291		63.997	
12	99.5%	122.209		131.409		146.195		131.548		123.435		131.704		116.835		123.888	
	99.0%	110.439		118.753		132.115		118.879		111.547		119.019		105.583		111.956	
	97.5%	93.022	0.002731	100.024	0.007332	111.279	0.013513	100.130	0.021435	93.954	0.028053	100.248	0.036530	88.931	0.044774	94.299	0.056722
	95.0%	78.072		83.949		93.395		84.038		78.855		84.137		74.638		79.144	
	90.0%	60.796		65.373		72.729		65.442		61.406		65.520		58.123		61.631	
14	99.5%	119.233		128.472		122.108		117.484		132.467		124.662		138.901		120.811	
	99.0%	107.750		116.098		110.347		106.169		119.709		112.656		125.524		109.175	
	97.5%	90.756	0.002623	97.788	0.006593	92.944	0.012976	89.425	0.020267	100.829	0.025768	94.888	0.035040	105.727	0.038063	91.957	0.048273
	95.0%	76.170		82.072		78.007		75.053		84.624		79.638		88.735		77.178	
	90.0%	59.316		63.912		60.746		58.446		65.899		62.016		69.100		60.100	
16	99.5%	136.264		123.630		123.208		137.438		145.124		126.156		140.261		125.723	
	99.0%	123.140		111.723		111.342		124.201		131.147		114.006		126.752		113.615	
	97.5%	103.719	0.002300	94.103	0.006245	93.782	0.012354	104.613	0.018415	110.464	0.025757	96.025	0.030898	106.762	0.036047	95.696	0.043077
	95.0%	87.050		78.979		78.710		87.800		92.710		80.593		89.603		80.316	
	90.0%	67.788		61.503		61.293		68.372		72.196		62.759		69.776		62.544	
18	99.5%	134.413		132.318		134.985		125.766		138.154		133.659		136.139		131.303	
	99.0%	121.468		119.574		121.984		113.653		124.848		120.787		123.027		118.657	
	97.5%	102.311	0.002520	100.716	0.006006	102.746	0.012169	95.728	0.017824	105.158	0.023034	101.737	0.029543	103.624	0.036377	99.943	0.041187
	95.0%	85.868		84.529		86.233		80.343		88.257		85.386		86.970		83.881	
	90.0%	66.867		65.825		67.152		62.565		68.728		66.492		67.726		65.320	
20	99.5%	112.058		137.779		130.701		134.540		118.968		132.264		130.651		113.500	
	99.0%	101.266		124.509		118.113		121.582		107.510		119.526		118.068		102.568	
	97.5%	85.295	0.002338	104.873	0.005641	99.485	0.011456	102.407	0.016712	90.554	0.021452	100.675	0.026684	99.447	0.034626	86.392	0.040080
	95.0%	71.586		88.018		83.496		85.949		76.001		84.495		83.465		72.507	
	90.0%	55.746		68.542		65.020		66.930		59.184		65.798		64.996		56.463	

Table 4.26. Table for Production Smoothing Analysis with Standard Deviation = 30% and Time = 100 Periods.

Production Smoothing
Standard Deviation = 30%, Time Frame = 100 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	141.917		156.680		129.992		110.779		134.109		117.109		95.080		97.381	
		99.0%	128.249		141.590		117.473		100.110		121.193		105.830		85.923		88.002	
		97.5%	108.022	0.007266	119.260	0.018093	98.946	0.036402	84.321	0.049247	102.079	0.071170	89.139	0.093923	72.371	0.106034	74.123	0.124663
		95.0%	90.661		100.093		83.044		70.769		85.673		74.813		60.740		62.210	
		90.0%	70.600		77.945		64.668		55.110		66.716		58.259		47.300		48.445	
	4	99.5%	127.759		142.675		129.381		140.308		153.500		105.439		132.992		123.139	
		99.0%	115.454		128.933		116.920		126.795		138.716		95.284		120.184		111.279	
		97.5%	97.246	0.005400	108.599	0.014106	98.480	0.028110	106.797	0.041418	116.839	0.056264	80.257	0.071838	101.229	0.086253	93.729	0.104091
		95.0%	81.617		91.145		82.653		89.634		98.061		67.358		84.960		78.665	
		90.0%	63.557		70.977		64.364		69.800		76.363		52.453		66.160		61.259	
	6	99.5%	158.472		149.058		108.006		153.138		155.062		116.268		131.353		154.419	
		99.0%	143.209		134.702		97.604		138.389		140.128		105.070		118.703		139.546	
		97.5%	120.623	0.004635	113.458	0.010898	82.211	0.020623	116.563	0.032875	118.028	0.046829	88.499	0.059979	99.981	0.072860	117.538	0.086605
		95.0%	101.237		95.223		68.998		97.830		99.059		74.276		83.913		98.648	
		90.0%	78.836		74.153		53.731		76.182		77.140		57.841		65.345		76.820	
	8	99.5%	153.181		168.655		165.681		144.912		142.955		113.578		155.592		148.233	
		99.0%	138.428		152.412		149.724		130.956		129.186		102.639		140.607		133.957	
		97.5%	116.596	0.003819	128.374	0.009420	126.110	0.020729	110.302	0.031603	108.812	0.041242	86.452	0.048414	118.431	0.069108	112.830	0.076117
		95.0%	97.857		107.743		105.843		92.575		91.324		72.558		99.398		94.697	
		90.0%	76.204		83.902		82.422		72.090		71.116		56.502		77.403		73.742	
	10	99.5%	162.765		151.969		151.297		160.520		142.964		155.744		137.738		131.824	
		99.0%	147.089		137.332		136.725		145.060		129.195		140.744		124.472		119.128	
		97.5%	123.891	0.003535	115.673	0.009575	115.162	0.017852	122.182	0.027561	108.819	0.035481	118.547	0.045296	104.841	0.058973	100.340	0.067456
		95.0%	103.980		97.083		96.654		102.546		91.330		99.495		87.992		84.214	
		90.0%	80.972		75.601		75.266		79.855		71.121		77.479		68.521		65.579	
	12	99.5%	122.940		154.302		160.493		158.963		129.615		157.137		141.005		146.326	
		99.0%	111.099		139.441		145.036		143.653		117.132		142.003		127.425		132.233	
		97.5%	93.578	0.003468	117.450	0.009067	122.162	0.016371	120.997	0.025479	98.659	0.033820	119.608	0.040603	107.328	0.053874	111.378	0.059116
		95.0%	78.538		98.574		102.529		101.551		82.803		100.385		90.079		93.478	
		90.0%	61.160		76.762		79.842		79.080		64.481		78.172		70.147		72.794	
	14	99.5%	162.483		142.804		185.461		137.222		163.938		157.296		135.082		147.944	
		99.0%	146.834		129.050		167.599		124.006		148.149		142.147		122.072		133.696	
		97.5%	123.676	0.003158	108.697	0.008496	141.166	0.015721	104.448	0.023557	124.784	0.031595	119.729	0.040046	102.820	0.050069	112.610	0.059435
		95.0%	103.800		91.228		118.479		87.662		104.729		100.486		86.295		94.512	
		90.0%	80.831		71.041		92.262		68.264		81.555		78.251		67.200		73.599	
	16	99.5%	127.262		126.930		150.958		143.163		158.051		150.829		151.054		138.223	
		99.0%	115.006		114.705		136.419		129.375		142.829		136.303		136.506		124.911	
		97.5%	96.868	0.003094	96.615	0.007666	114.904	0.013800	108.971	0.020472	120.303	0.029472	114.806	0.039122	114.977	0.043789	105.211	0.058131
		95.0%	81.300		81.087		96.437		91.458		100.969		96.355		96.498		88.302	
		90.0%	63.310		63.145		75.098		71.220		78.627		75.034		75.146		68.763	
	18	99.5%	171.961		142.144		168.094		174.476		139.563		143.253		171.039		137.086	
		99.0%	155.399		128.454		151.905		157.672		126.122		129.456		154.566		123.883	
		97.5%	130.891	0.003088	108.195	0.008275	127.947	0.015254	132.805	0.023376	106.231	0.030940	109.039	0.039426	130.189	0.043886	104.345	0.052838
		95.0%	109.855		90.807		107.384		111.461		89.158		91.515		109.266		87.575	
		90.0%	85.546		70.713		83.623		86.797		69.429		71.265		85.088		68.197	
	20	99.5%	156.834		152.647		158.481		157.621		165.009		161.144		122.893		147.995	
		99.0%	141.729		137.946		143.217		142.441		149.117		145.624		111.057		133.742	
		97.5%	119.377	0.003029	116.190	0.007172	120.630	0.014351	119.976	0.021496	125.599	0.026903	122.657	0.036205	93.542	0.045044	112.649	0.051590
		95.0%	100.191		97.516		101.243		100.694		105.414		102.944		78.508		94.545	
		90.0%	78.021		75.938		78.840		78.413		82.088		80.165		61.136		73.624	

Table 4.27. Table for Production Smoothing Analysis with Standard Deviation = 35% and Time = 100 Periods.

Production Smoothing
Standard Deviation = 35%, Time Frame = 100 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	165.746		157.918		135.810		139.839		140.377		119.351		140.517		100.667	
		99.0%	149.783		142.709		122.730		126.371		126.857		107.856		126.984		90.972	
		97.5%	126.160	0.008073	120.202	0.023107	103.374	0.045518	106.441	0.063473	106.850	0.080650	90.845	0.104527	106.957	0.124950	76.624	0.148274
		95.0%	105.885		100.884		86.760		89.334		89.678		76.245		89.767		64.309	
		90.0%	82.455		78.560		67.562		69.567		69.834		59.374		69.904		50.079	
	4	99.5%	164.839		184.637		189.422		164.060		153.105		140.935		169.451		128.857	
		99.0%	148.963		166.854		171.179		148.259		138.359		127.361		153.131		116.447	
		97.5%	125.469	0.007101	140.539	0.017112	144.182	0.030712	124.876	0.050317	116.538	0.071870	107.275	0.087816	128.980	0.103504	98.082	0.115412
		95.0%	105.305		117.952		121.009		104.807		97.809		90.034		108.251		82.318	
		90.0%	82.003		91.852		94.233		81.616		76.166		70.112		84.298		64.103	
	6	99.5%	189.022		166.405		176.271		144.326		175.743		159.567		159.185		153.691	
		99.0%	170.817		150.378		159.295		130.426		158.817		144.199		143.854		138.889	
		97.5%	143.877	0.005691	126.662	0.013473	134.172	0.027974	109.856	0.044287	133.769	0.057818	121.457	0.070823	121.166	0.080661	116.984	0.101400
		95.0%	120.754		106.305		112.608		92.200		112.271		101.937		101.693		98.183	
		90.0%	94.034		82.782		87.691		71.799		87.428		79.381		79.191		76.457	
	8	99.5%	183.496		169.949		152.015		153.747		201.252		175.945		152.179		156.747	
		99.0%	165.823		153.581		137.375		138.940		181.870		159.000		137.523		141.651	
		97.5%	139.671	0.004688	129.359	0.011650	115.709	0.025993	117.027	0.035101	153.186	0.051075	133.923	0.064318	115.834	0.076524	119.310	0.093003
		95.0%	117.224		108.570		97.113		98.219		128.567		112.400		97.217		100.135	
		90.0%	91.285		84.546		75.624		76.485		100.118		87.528		75.706		77.978	
	10	99.5%	175.804		213.571		195.164		161.682		171.719		169.623		159.948		172.127	
		99.0%	158.872		193.002		176.368		146.110		155.180		153.287		144.543		155.550	
		97.5%	133.816	0.004482	162.563	0.011508	148.552	0.020981	123.067	0.033887	130.706	0.041045	129.111	0.057455	121.747	0.065116	131.017	0.074654
		95.0%	112.310		136.437		124.678		103.288		109.700		108.361		102.180		109.961	
		90.0%	87.458		106.246		97.089		80.433		85.426		84.383		79.570		85.629	
	12	99.5%	192.866		192.190		151.645		164.379		163.930		162.564		150.037		198.495	
		99.0%	174.291		173.680		137.040		148.547		148.142		146.908		135.586		179.378	
		97.5%	146.803	0.003935	146.288	0.010281	115.427	0.019893	125.119	0.032055	124.778	0.039687	123.738	0.052180	114.203	0.061428	151.088	0.070082
		95.0%	123.210		122.778		96.876		105.011		104.724		103.852		95.849		126.806	
		90.0%	95.946		95.610		75.440		81.775		81.551		80.872		74.640		98.747	
	14	99.5%	174.302		183.286		171.446		208.269		134.620		135.602		182.635		194.786	
		99.0%	157.514		165.633		154.934		188.210		121.655		122.542		165.045		176.026	
		97.5%	132.672	0.003802	139.511	0.009777	130.499	0.019878	158.527	0.028114	102.468	0.040620	103.216	0.049161	139.015	0.061549	148.264	0.070727
		95.0%	111.350		117.089		109.526		133.050		86.000		86.627		116.674		124.436	
		90.0%	86.711		91.180		85.290		103.609		66.970		67.459		90.856		96.901	
	16	99.5%	168.694		182.385		220.876		155.848		171.544		159.390		187.871		184.090	
		99.0%	152.447		164.819		199.603		140.838		155.023		144.039		169.777		166.360	
		97.5%	128.404	0.003798	138.825	0.009535	168.123	0.016003	118.626	0.027264	130.573	0.036981	121.322	0.047276	143.001	0.053905	140.123	0.062903
		95.0%	107.768		116.514		141.103		99.561		109.588		101.824		120.018		117.603	
		90.0%	83.921		90.732		109.880		77.530		85.339		79.293		93.461		91.580	
	18	99.5%	186.703		168.896		171.272		148.763		182.775		182.295		170.968		175.431	
		99.0%	168.721		152.630		154.777		134.436		165.172		164.738		154.502		158.535	
		97.5%	142.112	0.003463	128.558	0.009584	130.366	0.016733	113.233	0.027745	139.122	0.038473	138.757	0.046248	130.135	0.051527	133.532	0.062501
		95.0%	119.272		107.897		109.414		95.035		116.763		116.457		109.220		112.071	
		90.0%	92.880		84.022		85.204		74.006		90.926		90.688		85.052		87.273	
	20	99.5%	174.286		144.713		184.284		176.167		187.419		163.104		154.976		216.345	
		99.0%	157.500		130.775		166.536		159.201		169.369		147.395		140.050		195.509	
		97.5%	132.660	0.003507	110.150	0.009233	140.271	0.016239	134.093	0.025411	142.657	0.035593	124.149	0.043123	117.962	0.049164	164.674	0.058550
		95.0%	111.340		92.448		117.727		112.542		119.730		104.196		99.004		138.209	
		90.0%	86.703		71.991		91.677		87.639		93.236		81.140		77.097		107.626	

Table 4.28. Table for Production Smoothing Analysis with Standard Deviation = 2% and Time = 50 Periods.

Production Smoothing
Standard Deviation = 2%, Time Frame = 50 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	5.533		5.507		4.411		4.960		3.837		4.015		4.398		3.372	
		99.0%	5.001		4.977		3.986		4.482		3.467		3.628		3.975		3.047	
		97.5%	4.212	0.000000	4.192	0.001098	3.358	0.002175	3.775	0.003484	2.920	0.004325	3.056	0.005744	3.348	0.006258	2.566	0.008023
		95.0%	3.535		3.518		2.818		3.169		2.451		2.565		2.810		2.154	
		90.0%	2.753		2.740		2.195		2.468		1.909		1.997		2.188		1.677	
	4	99.5%	5.609		5.316		4.856		4.976		5.276		4.951		4.410		4.320	
		99.0%	5.068		4.804		4.388		4.497		4.768		4.474		3.985		3.904	
		97.5%	4.269	0.000000	4.047	0.000767	3.696	0.001690	3.788	0.002454	4.016	0.003046	3.769	0.004230	3.357	0.005020	3.288	0.005808
		95.0%	3.583		3.396		3.102		3.179		3.370		3.163		2.817		2.760	
		90.0%	2.790		2.645		2.416		2.475		2.625		2.463		2.194		2.149	
	6	99.5%	5.502		5.627		5.297		5.078		5.114		5.040		4.932		5.363	
		99.0%	4.972		5.085		4.787		4.589		4.622		4.555		4.457		4.847	
		97.5%	4.188	0.000000	4.283	0.000669	4.032	0.001361	3.865	0.002037	3.893	0.002699	3.836	0.003316	3.754	0.004076	4.082	0.004707
		95.0%	3.515		3.595		3.384		3.244		3.267		3.220		3.150		3.426	
		90.0%	2.737		2.799		2.635		2.526		2.544		2.507		2.453		2.668	
	8	99.5%	5.167		4.843		5.515		4.927		4.828		5.395		4.508		5.459	
		99.0%	4.670		4.376		4.984		4.453		4.363		4.875		4.074		4.934	
		97.5%	3.933	0.000000	3.686	0.000582	4.198	0.001089	3.750	0.001775	3.675	0.002569	4.107	0.002824	3.432	0.003543	4.155	0.004233
		95.0%	3.301		3.094		3.523		3.148		3.084		3.447		2.880		3.488	
		90.0%	2.571		2.409		2.744		2.451		2.402		2.684		2.243		2.716	
	10	99.5%	5.390		5.245		5.952		5.250		5.577		4.562		4.676		5.073	
		99.0%	4.871		4.740		5.379		4.744		5.040		4.123		4.225		4.585	
		97.5%	4.102	0.000000	3.993	0.000564	4.531	0.000996	3.996	0.001600	4.245	0.002126	3.472	0.002946	3.559	0.003112	3.862	0.003663
		95.0%	3.443		3.351		3.803		3.354		3.563		2.914		2.987		3.241	
		90.0%	2.681		2.609		2.961		2.612		2.775		2.269		2.326		2.524	
	12	99.5%	5.178		5.878		5.633		5.013		5.585		5.896		5.393		4.791	
		99.0%	4.679		5.312		5.091		4.530		5.047		5.328		4.874		4.330	
		97.5%	3.941	0.000000	4.474	0.000517	4.288	0.000919	3.816	0.001395	4.251	0.001953	4.488	0.002318	4.105	0.002874	3.647	0.003427
		95.0%	3.308		3.755		3.599		3.203		3.568		3.767		3.446		3.061	
		90.0%	2.576		2.924		2.802		2.494		2.778		2.933		2.683		2.383	
	14	99.5%	5.534		5.945		5.237		5.099		5.498		4.543		5.345		5.110	
		99.0%	5.001		5.372		4.733		4.608		4.968		4.106		4.830		4.618	
		97.5%	4.213	0.000000	4.525	0.000484	3.987	0.000955	3.881	0.001375	4.185	0.001948	3.458	0.002204	4.068	0.002893	3.889	0.003303
		95.0%	3.536		3.798		3.346		3.258		3.512		2.902		3.415		3.264	
		90.0%	2.753		2.957		2.606		2.537		2.735		2.260		2.659		2.542	
	16	99.5%	5.622		5.635		5.124		5.281		5.234		4.543		5.459		5.848	
		99.0%	5.080		5.092		4.630		4.773		4.730		4.106		4.934		5.285	
		97.5%	4.279	0.000000	4.289	0.000432	3.900	0.000909	4.020	0.001324	3.984	0.001671	3.458	0.002264	4.156	0.002451	4.452	0.002938
		95.0%	3.591		3.600		3.273		3.374		3.344		2.902		3.488		3.736	
		90.0%	2.797		2.803		2.549		2.627		2.604		2.260		2.716		2.909	
	18	99.5%	5.838		5.029		5.000		5.784		4.837		5.277		5.421		5.892	
		99.0%	5.276		4.544		4.518		5.227		4.371		4.768		4.899		5.324	
		97.5%	4.444	0.000000	3.828	0.000392	3.806	0.000758	4.403	0.001096	3.682	0.001480	4.016	0.001814	4.127	0.002201	4.485	0.002644
		95.0%	3.730		3.212		3.194		3.695		3.090		3.371		3.463		3.764	
		90.0%	2.904		2.502		2.487		2.878		2.406		2.625		2.697		2.931	
	20	99.5%	5.179		4.911		5.481		4.999		5.061		5.476		5.922		5.031	
		99.0%	4.680		4.438		4.953		4.518		4.574		4.948		5.352		4.546	
		97.5%	3.942	0.000000	3.738	0.000393	4.172	0.000678	3.805	0.001067	3.852	0.001414	4.168	0.001945	4.508	0.002313	3.829	0.002590
		95.0%	3.308		3.137		3.502		3.194		3.233		3.498		3.783		3.214	
		90.0%	2.576		2.443		2.727		2.487		2.518		2.724		2.946		2.503	

Table 4.29. Table for Production Smoothing Analysis with Standard Deviation = 5% and Time = 50 Periods.

Production Smoothing
Standard Deviation = 5%, Time Frame = 50 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	10.862		12.856		12.004		11.147		11.619		11.224		9.210		7.612	
	99.0%	9.816		11.618		10.848		10.074		10.500		10.143		8.323		6.879	
	97.5%	8.268	0.001100	9.786	0.003152	9.137	0.005255	8.485	0.007856	8.844	0.010977	8.543	0.013569	7.010	0.017515	5.794	0.020381
	95.0%	6.939		8.213		7.668		7.121		7.423		7.170		5.884		4.863	
	90.0%	5.404		6.396		5.972		5.546		5.780		5.584		4.582		3.787	
4	99.5%	12.604		13.824		12.244		12.405		12.963		10.035		11.195		10.796	
	99.0%	11.390		12.493		11.065		11.211		11.715		9.068		10.117		9.756	
	97.5%	9.594	0.000833	10.523	0.002476	9.320	0.003895	9.443	0.005911	9.867	0.008483	7.638	0.011454	8.521	0.012365	8.218	0.015054
	95.0%	8.052		8.831		7.822		7.925		8.281		6.411		7.152		6.897	
	90.0%	6.270		6.877		6.091		6.171		6.449		4.992		5.569		5.371	
6	99.5%	13.943		13.297		13.302		13.024		11.671		13.073		11.463		10.321	
	99.0%	12.600		12.016		12.021		11.770		10.547		11.814		10.359		9.327	
	97.5%	10.613	0.000678	10.121	0.002168	10.125	0.003177	9.914	0.005544	8.884	0.006969	9.951	0.009123	8.725	0.010541	7.856	0.012676
	95.0%	8.907		8.495		8.498		8.320		7.456		8.351		7.323		6.594	
	90.0%	6.936		6.615		6.617		6.479		5.806		6.503		5.702		5.135	
8	99.5%	13.745		13.071		12.932		12.817		12.921		12.929		11.631		11.461	
	99.0%	12.421		11.813		11.687		11.583		11.677		11.684		10.511		10.357	
	97.5%	10.462	0.000557	9.950	0.001877	9.844	0.002922	9.756	0.004403	9.835	0.005728	9.841	0.007554	8.853	0.008623	8.723	0.010187
	95.0%	8.781		8.351		8.262		8.188		8.255		8.260		7.430		7.321	
	90.0%	6.838		6.503		6.434		6.376		6.428		6.432		5.786		5.701	
10	99.5%	14.068		14.066		13.101		13.990		13.641		13.059		12.871		12.506	
	99.0%	12.713		12.712		11.840		12.643		12.327		11.801		11.631		11.301	
	97.5%	10.708	0.000554	10.707	0.001601	9.972	0.002765	10.649	0.004315	10.383	0.005023	9.940	0.006553	9.797	0.007890	9.519	0.010119
	95.0%	8.987		8.986		8.370		8.938		8.714		8.342		8.222		7.989	
	90.0%	6.998		6.998		6.518		6.960		6.786		6.496		6.403		6.221	
12	99.5%	12.584		13.412		15.086		13.434		12.710		13.583		13.958		13.313	
	99.0%	11.372		12.120		13.633		12.140		11.486		12.275		12.614		12.031	
	97.5%	9.578	0.000472	10.209	0.001566	11.483	0.002281	10.225	0.003842	9.674	0.005076	10.339	0.006582	10.624	0.007148	10.133	0.009281
	95.0%	8.039		8.568		9.637		8.582		8.120		8.677		8.917		8.505	
	90.0%	6.260		6.672		7.505		6.683		6.323		6.757		6.944		6.623	
14	99.5%	14.035		14.481		13.565		11.612		11.903		13.318		11.984		13.229	
	99.0%	12.684		13.086		12.259		10.494		10.757		12.036		10.830		11.955	
	97.5%	10.683	0.000457	11.022	0.001388	10.326	0.002292	8.839	0.003803	9.060	0.004445	10.138	0.006336	9.122	0.007461	10.069	0.008651
	95.0%	8.966		9.251		8.666		7.418		7.604		8.508		7.656		8.451	
	90.0%	6.982		7.204		6.748		5.777		5.922		6.626		5.962		6.581	
16	99.5%	15.074		12.471		13.315		12.726		11.941		13.386		13.703		12.939	
	99.0%	13.623		11.270		12.033		11.501		10.791		12.097		12.383		11.693	
	97.5%	11.474	0.000432	9.493	0.001269	10.135	0.002341	9.687	0.003500	9.089	0.004518	10.189	0.006062	10.430	0.006282	9.849	0.008161
	95.0%	9.630		7.967		8.506		8.130		7.628		8.552		8.754		8.266	
	90.0%	7.499		6.204		6.624		6.331		5.940		6.659		6.817		6.437	
18	99.5%	12.419		12.420		14.198		13.748		12.366		14.181		12.428		12.757	
	99.0%	11.223		11.224		12.831		12.424		11.175		12.815		11.231		11.529	
	97.5%	9.453	0.000386	9.454	0.001144	10.807	0.001817	10.465	0.002875	9.413	0.003795	10.794	0.004916	9.460	0.006292	9.710	0.006859
	95.0%	7.934		7.935		9.070		8.783		7.900		9.059		7.939		8.150	
	90.0%	6.178		6.179		7.063		6.839		6.152		7.055		6.183		6.346	
20	99.5%	12.513		14.712		13.718		14.323		13.020		11.569		13.340		12.712	
	99.0%	11.308		13.295		12.397		12.944		11.766		10.455		12.055		11.487	
	97.5%	9.525	0.000376	11.198	0.001114	10.442	0.001969	10.902	0.002982	9.910	0.003915	8.806	0.005189	10.154	0.005783	9.676	0.006639
	95.0%	7.994		9.399		8.764		9.150		8.318		7.391		8.522		8.121	
	90.0%	6.225		7.319		6.824		7.126		6.477		5.755		6.636		6.324	

Table 4.30. Table for Production Smoothing Analysis with Standard Deviation = 10% and Time = 50 Periods.

Production Smoothing
Standard Deviation = 10%, Time Frame = 50 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	27.474		27.072		22.442		24.322		18.933		20.188		17.725		17.814	
	99.0%	24.828		24.465		20.280		21.980		17.109		18.244		16.018		16.098	
	97.5%	20.912	0.002173	20.606	0.005620	17.082	0.010518	18.513	0.015508	14.411	0.023591	15.366	0.028768	13.492	0.032947	13.559	0.037134
	95.0%	17.551		17.294		14.336		15.538		12.095		12.897		11.324		11.380	
	90.0%	13.668		13.468		11.164		12.100		9.419		10.043		8.818		8.862	
4	99.5%	28.603		26.464		24.698		24.628		24.109		22.016		24.921		19.649	
	99.0%	25.848		23.915		22.319		22.256		21.787		19.896		22.521		17.756	
	97.5%	21.772	0.001566	20.143	0.003556	18.799	0.007613	18.746	0.011384	18.351	0.015125	16.758	0.021738	18.969	0.023359	14.956	0.029329
	95.0%	18.273		16.906		15.778		15.733		15.402		14.065		15.920		12.552	
	90.0%	14.229		13.165		12.287		12.252		11.994		10.953		12.398		9.775	
6	99.5%	24.029		26.280		29.962		25.858		22.576		22.464		26.572		23.558	
	99.0%	21.715		23.749		27.076		23.367		20.401		20.301		24.013		21.289	
	97.5%	18.290	0.001288	20.003	0.003352	22.806	0.006626	19.682	0.010403	17.184	0.014500	17.099	0.018250	20.226	0.021194	17.931	0.023664
	95.0%	15.351		16.788		19.141		16.519		14.422		14.351		16.975		15.050	
	90.0%	11.954		13.073		14.905		12.864		11.231		11.176		13.219		11.719	
8	99.5%	25.920		24.762		26.527		25.833		27.556		22.375		26.492		23.540	
	99.0%	23.423		22.377		23.972		23.345		24.902		20.220		23.941		21.273	
	97.5%	19.729	0.001092	18.848	0.002901	20.192	0.005507	19.663	0.008492	20.974	0.011347	17.031	0.015280	20.165	0.017557	17.918	0.019817
	95.0%	16.558		15.819		16.947		16.503		17.603		14.294		16.924		15.038	
	90.0%	12.894		12.318		13.197		12.851		13.708		11.131		13.179		11.710	
10	99.5%	25.170		25.118		27.506		24.443		28.642		25.710		24.554		24.374	
	99.0%	22.746		22.699		24.857		22.089		25.884		23.234		22.189		22.027	
	97.5%	19.159	0.001050	19.119	0.002793	20.937	0.005415	18.605	0.007868	21.801	0.010781	19.570	0.012922	18.690	0.016567	18.553	0.019648
	95.0%	16.080		16.047		17.572		15.615		18.298		16.425		15.686		15.571	
	90.0%	12.522		12.496		13.684		12.160		14.249		12.790		12.215		12.126	
12	99.5%	24.287		26.926		24.772		25.207		27.063		25.018		27.804		26.873	
	99.0%	21.948		24.333		22.386		22.779		24.456		22.609		25.126		24.285	
	97.5%	18.486	0.000888	20.495	0.002422	18.855	0.005050	19.186	0.007290	20.599	0.009704	19.043	0.011724	21.163	0.014099	20.455	0.017277
	95.0%	15.515		17.201		15.825		16.103		17.289		15.982		17.762		17.167	
	90.0%	12.082		13.395		12.323		12.540		13.463		12.446		13.832		13.369	
14	99.5%	26.148		26.211		25.735		24.732		23.799		24.370		24.475		26.101	
	99.0%	23.629		23.687		23.256		22.350		21.507		22.023		22.118		23.587	
	97.5%	19.903	0.000960	19.951	0.002162	19.588	0.004747	18.825	0.006528	18.115	0.009963	18.550	0.012532	18.630	0.013946	19.867	0.015987
	95.0%	16.704		16.745		16.440		15.800		15.204		15.568		15.636		16.674	
	90.0%	13.008		13.039		12.802		12.303		11.839		12.124		12.176		12.985	
16	99.5%	27.241		24.528		27.408		25.293		24.874		25.197		25.649		24.006	
	99.0%	24.618		22.166		24.768		22.857		22.478		22.770		23.179		21.694	
	97.5%	20.735	0.000853	18.670	0.002212	20.862	0.004352	19.252	0.007153	18.933	0.009087	19.179	0.011639	19.523	0.013468	18.273	0.015218
	95.0%	17.403		15.669		17.509		16.158		15.890		16.097		16.385		15.336	
	90.0%	13.552		12.202		13.635		12.583		12.374		12.535		12.760		11.942	
18	99.5%	27.710		24.044		25.168		28.541		23.918		26.843		26.885		23.906	
	99.0%	25.041		21.728		22.744		25.792		21.615		24.257		24.296		21.604	
	97.5%	21.092	0.000700	18.302	0.002057	19.157	0.003681	21.724	0.005166	18.206	0.007544	20.432	0.009409	20.464	0.010279	18.197	0.013335
	95.0%	17.702		15.360		16.078		18.233		15.280		17.148		17.175		15.272	
	90.0%	13.785		11.961		12.520		14.198		11.899		13.354		13.375		11.893	
20	99.5%	25.459		26.025		28.243		30.218		26.211		24.260		22.018		25.549	
	99.0%	23.007		23.519		25.522		27.307		23.687		21.924		19.897		23.089	
	97.5%	19.379	0.000764	19.809	0.001808	21.497	0.003609	23.001	0.005347	19.951	0.007301	18.466	0.009770	16.759	0.011960	19.447	0.014150
	95.0%	16.264		16.626		18.042		19.304		16.745		15.498		14.066		16.322	
	90.0%	12.665		12.947		14.050		15.033		13.040		12.069		10.953		12.710	

Table 4.31. Table for Production Smoothing Analysis with Standard Deviation = 15% and Time = 50 Periods.

Production Smoothing
Standard Deviation = 15%, Time Frame = 50 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	36.659		36.881		30.746		30.982		29.144		23.768		28.657		23.037	
		99.0%	33.129		33.329		27.785		27.998		26.337		21.479		25.897		20.819	
		97.5%	27.904	0.003081	28.072	0.007940	23.403	0.016717	23.582	0.024722	22.184	0.032264	18.091	0.042774	21.813	0.046565	17.535	0.058276
		95.0%	23.419		23.561		19.642		19.792		18.618		15.184		18.307		14.717	
		90.0%	18.237		18.347		15.295		15.413		14.499		11.824		14.256		11.461	
	4	99.5%	34.438		36.173		33.498		31.381		29.126		33.672		28.975		25.597	
		99.0%	31.121		32.689		30.271		28.359		26.321		30.429		26.184		23.132	
		97.5%	26.213	0.002585	27.533	0.006281	25.497	0.012298	23.886	0.019974	22.169	0.023851	25.630	0.029928	22.054	0.036920	19.484	0.045356
		95.0%	22.000		23.108		21.399		20.048		18.607		21.511		18.510		16.352	
		90.0%	17.132		17.995		16.664		15.611		14.489		16.751		14.414		12.734	
	6	99.5%	34.770		37.110		38.928		36.149		28.937		33.587		34.342		31.020	
		99.0%	31.421		33.536		35.179		32.668		26.150		30.352		31.035		28.033	
		97.5%	26.466	0.002041	28.247	0.005451	29.630	0.008680	27.516	0.014985	22.025	0.021739	25.565	0.025277	26.140	0.031378	23.612	0.037232
		95.0%	22.212		23.707		24.868		23.094		18.486		21.456		21.939		19.817	
		90.0%	17.297		18.461		19.366		17.983		14.395		16.708		17.084		15.432	
	8	99.5%	38.477		36.781		36.343		35.383		30.266		32.972		31.320		32.792	
		99.0%	34.771		33.238		32.843		31.975		27.351		29.796		28.303		29.633	
		97.5%	29.287	0.001785	27.996	0.004933	27.663	0.008186	26.932	0.013562	23.037	0.018162	25.097	0.022175	23.839	0.028644	24.960	0.033157
		95.0%	24.580		23.497		23.217		22.604		19.335		21.064		20.008		20.948	
		90.0%	19.141		18.298		18.080		17.602		15.057		16.403		15.581		16.313	
	10	99.5%	32.827		37.052		34.268		39.951		34.798		33.272		34.258		31.300	
		99.0%	29.666		33.483		30.968		36.103		31.447		30.067		30.959		28.285	
		97.5%	24.987	0.001664	28.203	0.004369	26.084	0.008292	30.409	0.012075	26.487	0.017146	25.325	0.022303	26.076	0.023355	23.824	0.030163
		95.0%	20.971		23.670		21.892		25.522		22.230		21.255		21.885		19.995	
		90.0%	16.331		18.432		17.048		19.875		17.311		16.552		17.043		15.571	
	12	99.5%	32.879		37.958		36.980		31.535		37.828		39.038		34.009		34.254	
		99.0%	29.713		34.302		33.419		28.498		34.185		35.279		30.734		30.955	
		97.5%	25.027	0.001493	28.892	0.004100	28.148	0.007311	24.004	0.012178	28.793	0.015611	29.715	0.017728	25.887	0.023822	26.073	0.026435
		95.0%	21.004		24.249		23.624		20.146		24.166		24.939		21.726		21.883	
		90.0%	16.357		18.883		18.397		15.688		18.818		19.421		16.919		17.041	
	14	99.5%	34.503		40.401		35.867		37.273		39.088		33.324		34.025		33.960	
		99.0%	31.180		36.510		32.413		33.683		35.323		30.114		30.748		30.690	
		97.5%	26.262	0.001450	30.752	0.003867	27.301	0.007036	28.371	0.011692	29.752	0.013711	25.365	0.018598	25.899	0.022915	25.850	0.026303
		95.0%	22.042		25.810		22.913		23.811		24.971		21.288		21.736		21.695	
		90.0%	17.164		20.099		17.843		18.542		19.445		16.578		16.927		16.895	
	16	99.5%	31.064		37.835		31.716		33.441		35.705		35.219		36.620		34.122	
		99.0%	28.072		34.191		28.661		30.221		32.266		31.827		33.093		30.836	
		97.5%	23.645	0.001376	28.799	0.003295	24.141	0.006978	25.454	0.010068	27.177	0.012797	26.808	0.017411	27.874	0.020148	25.973	0.024268
		95.0%	19.845		24.170		20.261		21.363		22.809		22.499		23.394		21.799	
		90.0%	15.454		18.822		15.778		16.636		17.762		17.521		18.218		16.975	
	18	99.5%	36.329		37.087		32.184		33.241		34.977		35.388		38.377		40.425	
		99.0%	32.830		33.515		29.084		30.040		31.608		31.980		34.681		36.532	
		97.5%	27.652	0.001107	28.230	0.002968	24.497	0.005807	25.302	0.008422	26.623	0.011702	26.936	0.013902	29.211	0.015426	30.770	0.020677
		95.0%	23.208		23.693		20.560		21.236		22.345		22.607		24.517		25.825	
		90.0%	18.073		18.450		16.011		16.537		17.400		17.605		19.092		20.111	
	20	99.5%	34.037		33.837		35.844		33.493		34.448		34.605		37.225		39.178	
		99.0%	30.759		30.578		32.392		30.267		31.130		31.272		33.640		35.405	
		97.5%	25.908	0.001135	25.756	0.003041	27.283	0.005412	25.493	0.008876	26.221	0.010689	26.340	0.014588	28.334	0.015080	29.821	0.019642
		95.0%	21.744		21.616		22.898		21.396		22.007		22.107		23.781		25.028	
		90.0%	16.933		16.833		17.832		16.662		17.137		17.215		18.519		19.490	

Table 4.32. Table for Production Smoothing Analysis with Standard Deviation = 20% and Time = 50 Periods.

Production Smoothing
Standard Deviation = 20%, Time Frame = 50 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
	99.5%	46.082		44.065		38.613		35.751		34.582		29.161		35.690		23.894	
	99.0%	41.644		39.821		34.894		32.308		31.252		26.352		32.253		21.593	
2	97.5%	35.076	0.004172	33.541	0.012168	29.391	0.022058	27.212	0.033692	26.323	0.048840	22.196	0.054237	27.166	0.067872	18.187	0.077751
	95.0%	29.439		28.150		24.667		22.839		22.092		18.629		22.800		15.264	
	90.0%	22.925		21.921		19.209		17.785		17.204		14.507		17.755		11.887	
	99.5%	41.600		46.032		42.194		42.277		40.278		41.536		38.811		39.006	
	99.0%	37.593		41.598		38.131		38.205		36.399		37.535		35.073		35.249	
4	97.5%	31.664	0.003100	35.038	0.008057	32.117	0.016040	32.180	0.023494	30.658	0.030965	31.616	0.038333	29.542	0.050753	29.690	0.056915
	95.0%	26.575		29.407		26.955		27.008		25.731		26.535		24.794		24.918	
	90.0%	20.695		22.900		20.991		21.032		20.037		20.663		19.308		19.404	
	99.5%	46.260		46.146		45.150		44.890		41.047		45.171		37.940		43.734	
	99.0%	41.805		41.701		40.802		40.567		37.094		40.821		34.286		39.522	
6	97.5%	35.211	0.002627	35.124	0.006878	34.367	0.013043	34.169	0.020146	31.244	0.028717	34.383	0.034284	28.879	0.042947	33.289	0.044514
	95.0%	29.552		29.479		28.844		28.677		26.222		28.857		24.237		27.939	
	90.0%	23.013		22.956		22.461		22.332		20.420		22.472		18.874		21.757	
	99.5%	37.519		45.026		44.141		40.339		45.329		41.026		49.093		44.101	
	99.0%	33.906		40.689		39.890		36.454		40.963		37.075		44.365		39.853	
8	97.5%	28.558	0.002499	34.272	0.005632	33.599	0.011241	30.705	0.016892	34.503	0.023830	31.228	0.028923	37.368	0.036090	33.568	0.041203
	95.0%	23.969		28.764		28.199		25.770		28.958		26.209		31.362		28.173	
	90.0%	18.665		22.399		21.959		20.068		22.550		20.410		24.423		21.939	
	99.5%	44.881		45.623		40.416		46.804		39.407		41.595		44.855		38.303	
	99.0%	40.558		41.229		36.524		42.296		35.612		37.589		40.535		34.614	
10	97.5%	34.161	0.002151	34.727	0.005085	30.763	0.011438	35.626	0.017070	29.995	0.022596	31.661	0.027991	34.142	0.032412	29.155	0.037678
	95.0%	28.671		29.146		25.819		29.900		25.175		26.572		28.655		24.469	
	90.0%	22.327		22.697		20.106		23.284		19.604		20.692		22.314		19.055	
	99.5%	46.060		42.045		44.822		40.896		41.901		44.099		40.374		40.533	
	99.0%	41.624		37.996		40.505		36.958		37.866		39.852		36.486		36.630	
12	97.5%	35.060	0.002011	32.003	0.005030	34.117	0.010716	31.129	0.015216	31.894	0.019149	33.567	0.022632	30.731	0.028548	30.853	0.035228
	95.0%	29.425		26.860		28.634		26.126		26.768		28.172		25.792		25.894	
	90.0%	22.914		20.917		22.298		20.345		20.845		21.938		20.085		20.164	
	99.5%	38.896		41.401		45.928		34.160		38.329		43.840		44.514		46.917	
	99.0%	35.150		37.414		41.505		30.870		34.638		39.618		40.227		42.399	
14	97.5%	29.606	0.001953	31.513	0.004869	34.959	0.009252	26.002	0.015014	29.175	0.019094	33.369	0.024801	33.882	0.030119	35.712	0.031478
	95.0%	24.848		26.449		29.340		21.823		24.486		28.006		28.437		29.973	
	90.0%	19.350		20.596		22.848		16.994		19.068		21.809		22.145		23.340	
	99.5%	49.145		41.106		42.470		42.829		47.585		40.974		33.993		43.933	
	99.0%	44.412		37.147		38.379		38.704		43.002		37.028		30.719		39.702	
16	97.5%	37.407	0.001735	31.289	0.004658	32.326	0.009534	32.600	0.013769	36.220	0.017710	31.188	0.021997	25.874	0.028818	33.440	0.031906
	95.0%	31.396		26.260		27.131		27.361		30.399		26.176		21.716		28.066	
	90.0%	24.448		20.449		21.128		21.306		23.672		20.384		16.911		21.856	
	99.5%	47.017		42.979		42.080		41.884		41.725		42.915		43.928		45.545	
	99.0%	42.489		38.840		38.027		37.850		37.707		38.782		39.697		41.158	
18	97.5%	35.788	0.001460	32.714	0.003706	32.030	0.006924	31.880	0.010423	31.760	0.015113	32.665	0.019804	33.436	0.023782	34.667	0.026348
	95.0%	30.036		27.456		26.882		26.757		26.655		27.416		28.063		29.095	
	90.0%	23.390		21.381		20.934		20.836		20.757		21.349		21.853		22.657	
	99.5%	45.634		41.241		42.141		38.412		40.916		40.442		39.536		45.936	
	99.0%	41.239		37.269		38.083		34.712		36.975		36.547		35.728		41.512	
20	97.5%	34.735	0.001599	31.391	0.004234	32.076	0.007380	29.238	0.012283	31.144	0.015309	30.783	0.018451	30.093	0.023344	34.965	0.027522
	95.0%	29.153		26.346		26.921		24.539		26.139		25.836		25.257		29.346	
	90.0%	22.702		20.516		20.964		19.109		20.355		20.119		19.668		22.852	

Table 4.33. Table for Production Smoothing Analysis with Standard Deviation = 25% and Time = 50 Periods.

Production Smoothing
Standard Deviation = 25%, Time Frame = 50 periods

Flex Bound Length		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	57.260		54.567		42.620		43.822		41.855		32.087		29.748		34.111	
	99.0%	51.745		49.312		38.515		39.602		37.824		28.997		26.883		30.826	
	97.5%	43.584	0.005557	41.534	0.014477	32.441	0.029338	33.356	0.038377	31.858	0.053188	24.424	0.075368	22.643	0.080467	25.964	0.098053
	95.0%	36.579		34.859		27.227		27.995		26.738		20.498		19.004		21.791	
	90.0%	28.485		27.146		21.202		21.800		20.822		15.963		14.799		16.969	
4	99.5%	54.492		56.494		44.946		44.957		41.671		53.139		47.802		35.042	
	99.0%	49.243		51.053		40.617		40.627		37.657		48.021		43.198		31.667	
	97.5%	41.477	0.003845	43.001	0.009559	34.211	0.020538	34.220	0.033805	31.718	0.041020	40.447	0.049207	36.385	0.065431	26.673	0.071282
	95.0%	34.811		36.090		28.713		28.720		26.621		33.947		30.538		22.386	
	90.0%	27.108		28.104		22.359		22.365		20.730		26.435		23.780		17.433	
6	99.5%	54.136		52.936		55.725		45.305		48.379		44.491		43.467		43.544	
	99.0%	48.922		47.838		50.358		40.941		43.720		40.206		39.281		39.351	
	97.5%	41.206	0.003209	40.293	0.008566	42.416	0.017073	34.484	0.026754	36.825	0.036637	33.865	0.041249	33.086	0.053282	33.144	0.062896
	95.0%	34.584		33.817		35.599		28.942		30.907		28.423		27.768		27.818	
	90.0%	26.931		26.334		27.722		22.538		24.068		22.133		21.624		21.662	
8	99.5%	51.903		51.671		54.347		56.361		52.296		41.128		46.354		47.105	
	99.0%	46.904		46.695		49.113		50.932		47.259		37.167		41.889		42.568	
	97.5%	39.507	0.002673	39.330	0.007511	41.367	0.014196	42.900	0.020888	39.806	0.029629	31.306	0.037339	35.283	0.044085	35.855	0.049367
	95.0%	33.157		33.009		34.719		36.005		33.408		26.274		29.612		30.092	
	90.0%	25.820		25.705		27.036		28.038		26.016		20.460		23.060		23.434	
10	99.5%	57.007		47.119		45.623		41.624		53.793		56.100		49.818		51.930	
	99.0%	51.517		42.581		41.229		37.615		48.612		50.697		45.020		46.929	
	97.5%	43.392	0.002982	35.865	0.006875	34.726	0.013783	31.683	0.022172	40.945	0.028710	42.702	0.033628	37.920	0.038597	39.527	0.047131
	95.0%	36.418		30.101		29.145		26.591		34.365		35.839		31.826		33.175	
	90.0%	28.360		23.440		22.696		20.707		26.761		27.909		24.783		25.834	
12	99.5%	50.254		52.279		57.527		51.727		48.568		50.676		46.961		50.652	
	99.0%	45.414		47.244		51.987		46.745		43.891		45.795		42.438		45.774	
	97.5%	38.251	0.002425	39.793	0.006501	43.788	0.012172	39.373	0.019467	36.968	0.024496	38.573	0.032938	35.745	0.038993	38.555	0.049771
	95.0%	32.104		33.398		36.750		33.045		31.027		32.374		30.000		32.359	
	90.0%	25.000		26.007		28.618		25.733		24.161		25.210		23.362		25.198	
14	99.5%	47.182		52.554		50.596		47.622		50.145		52.291		57.077		46.344	
	99.0%	42.638		47.492		45.723		43.035		45.316		47.255		51.580		41.881	
	97.5%	35.914	0.002227	40.002	0.005975	38.512	0.011779	36.248	0.017991	38.169	0.023390	39.802	0.030907	43.445	0.034377	35.276	0.043331
	95.0%	30.142		33.573		32.322		30.422		32.035		33.405		36.463		29.606	
	90.0%	23.472		26.144		25.170		23.691		24.946		26.013		28.395		23.055	
16	99.5%	48.944		50.728		47.370		54.826		53.972		52.865		56.567		53.003	
	99.0%	44.230		45.842		42.808		49.546		48.774		47.774		51.119		47.898	
	97.5%	37.255	0.002064	38.612	0.005608	36.056	0.010990	41.732	0.016268	41.082	0.022946	40.239	0.027965	43.057	0.032998	40.344	0.039421
	95.0%	31.267		32.407		30.262		35.025		34.479		33.772		36.137		33.860	
	90.0%	24.349		25.236		23.565		27.275		26.850		26.299		28.141		26.367	
18	99.5%	55.075		51.063		52.171		55.241		57.953		53.232		55.678		54.112	
	99.0%	49.771		46.145		47.146		49.921		52.371		48.105		50.316		48.900	
	97.5%	41.921	0.001965	38.867	0.004527	39.711	0.009124	42.047	0.013548	44.111	0.017990	40.518	0.023503	42.380	0.027901	41.188	0.032790
	95.0%	35.184		32.621		33.329		35.290		37.022		34.006		35.569		34.569	
	90.0%	27.399		25.402		25.954		27.481		28.830		26.481		27.698		26.919	
20	99.5%	49.280		59.767		51.528		55.150		49.841		51.765		52.207		48.556	
	99.0%	44.534		54.011		46.565		49.838		45.041		46.780		47.179		43.879	
	97.5%	37.510	0.001898	45.492	0.004646	39.221	0.009658	41.978	0.013532	37.937	0.017940	39.402	0.021051	39.738	0.027326	36.959	0.032884
	95.0%	31.482		38.181		32.918		35.231		31.840		33.069		33.352		31.019	
	90.0%	24.516		29.732		25.634		27.436		24.795		25.752		25.972		24.155	

Table 4.34. Table for Production Smoothing Analysis with Standard Deviation = 30% and Time = 50 Periods.

Production Smoothing
Standard Deviation = 30%, Time Frame = 50 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	56.476		59.602		52.976		45.012		54.165		41.407		40.149		47.024	
		99.0%	51.036		53.862		47.874		40.677		48.949		37.419		36.283		42.495	
		97.5%	42.987	0.006816	45.367	0.016355	40.324	0.033032	34.261	0.044308	41.229	0.067230	31.518	0.082024	30.560	0.099035	35.793	0.118197
		95.0%	36.079		38.076		33.843		28.755		34.603		26.452		25.649		30.040	
		90.0%	28.095		29.651		26.354		22.392		26.946		20.599		19.973		23.393	
	4	99.5%	55.152		54.319		48.047		52.127		56.690		47.468		56.738		49.401	
		99.0%	49.840		49.088		43.420		47.107		51.230		42.896		51.274		44.643	
		97.5%	41.979	0.004837	41.346	0.012713	36.572	0.024994	39.678	0.036643	43.151	0.050439	36.131	0.063614	43.187	0.077070	37.602	0.088851
		95.0%	35.233		34.701		30.694		33.301		36.216		30.324		36.246		31.559	
		90.0%	27.437		27.023		23.902		25.932		28.202		23.614		28.226		24.576	
	6	99.5%	59.697		59.818		49.766		57.194		57.725		44.198		49.298		57.733	
		99.0%	53.948		54.057		44.973		51.685		52.166		39.941		44.550		52.173	
		97.5%	45.439	0.004148	45.532	0.009518	37.880	0.017595	43.534	0.028121	43.938	0.041570	33.642	0.052163	37.524	0.062399	43.945	0.074935
		95.0%	38.137		38.214		31.792		36.537		36.877		28.235		31.493		36.882	
		90.0%	29.698		29.758		24.757		28.453		28.717		21.987		24.524		28.721	
	8	99.5%	61.946		65.236		59.991		59.443		58.928		53.858		59.650		50.935	
		99.0%	55.980		58.954		54.213		53.718		53.252		48.671		53.905		46.029	
		97.5%	47.151	0.003376	49.656	0.008366	45.663	0.018023	45.246	0.027688	44.854	0.035215	40.995	0.041610	45.403	0.058509	38.770	0.067869
		95.0%	39.573		41.675		38.324		37.975		37.645		34.407		38.106		32.539	
		90.0%	30.817		32.454		29.844		29.572		29.315		26.793		29.674		25.339	
	10	99.5%	65.584		59.478		61.062		61.422		55.476		60.869		53.757		53.225	
		99.0%	59.268		53.750		55.181		55.506		50.133		55.007		48.579		48.099	
		97.5%	49.920	0.003199	45.272	0.008612	46.478	0.015578	46.752	0.025226	42.226	0.031820	46.332	0.040307	40.918	0.052042	40.513	0.059494
		95.0%	41.897		37.997		39.008		39.238		35.440		38.886		34.342		34.002	
		90.0%	32.626		29.589		30.377		30.556		27.598		30.281		26.743		26.478	
	12	99.5%	53.300		62.908		62.020		60.774		48.804		60.993		55.743		57.140	
		99.0%	48.167		56.849		56.047		54.921		44.104		55.119		50.374		51.637	
		97.5%	40.570	0.003011	47.883	0.007928	47.208	0.014390	46.259	0.022243	37.148	0.028943	46.426	0.036669	42.429	0.045770	43.493	0.051020
		95.0%	34.050		40.188		39.621		38.825		31.178		38.965		35.610		36.503	
		90.0%	26.515		31.295		30.854		30.234		24.279		30.343		27.731		28.426	
	14	99.5%	63.420		52.891		67.755		52.378		64.425		58.592		51.276		57.981	
		99.0%	57.312		47.797		61.229		47.333		58.220		52.949		46.337		52.397	
		97.5%	48.273	0.002793	40.259	0.007376	51.573	0.013832	39.868	0.020291	49.038	0.027581	44.598	0.035006	39.029	0.043513	44.133	0.052715
		95.0%	40.515		33.789		43.284		33.461		41.157		37.431		32.757		37.040	
		90.0%	31.550		26.312		33.706		26.057		32.050		29.148		25.508		28.844	
	16	99.5%	46.644		53.712		57.987		58.011		58.283		59.365		63.789		49.863	
		99.0%	42.151		48.539		52.402		52.424		52.670		53.647		57.646		45.060	
		97.5%	35.504	0.002705	40.884	0.006623	44.138	0.012594	44.156	0.018559	44.363	0.025195	45.186	0.033363	48.554	0.038783	37.954	0.050753
		95.0%	29.798		34.313		37.044		37.060		37.233		37.924		40.751		31.854	
		90.0%	23.204		26.720		28.847		28.859		28.995		29.533		31.734		24.805	
	18	99.5%	68.037		52.295		62.104		65.545		56.275		55.686		64.027		53.459	
		99.0%	61.485		47.259		56.122		59.232		50.855		50.323		57.861		48.310	
		97.5%	51.788	0.002393	39.805	0.006212	47.271	0.012126	49.891	0.018052	42.835	0.024487	42.386	0.030192	48.735	0.033511	40.691	0.041739
		95.0%	43.465		33.408		39.674		41.872		35.950		35.574		40.903		34.151	
		90.0%	33.847		26.016		30.895		32.607		27.995		27.702		31.852		26.595	
	20	99.5%	60.965		63.979		57.247		60.157		65.572		61.357		47.238		53.022	
		99.0%	55.093		57.817		51.734		54.363		59.257		55.448		42.688		47.915	
		97.5%	46.404	0.002436	48.699	0.005760	43.575	0.011725	45.789	0.017150	49.911	0.022291	46.703	0.028469	35.956	0.035381	40.358	0.041386
		95.0%	38.947		40.872		36.571		38.430		41.890		39.197		30.177		33.872	
		90.0%	30.329		31.828		28.479		29.926		32.621		30.524		23.500		26.377	

Table 4.35. Table for Production Smoothing Analysis with Standard Deviation = 35% and Time = 50 Periods.

Production Smoothing
Standard Deviation = 35%, Time Frame = 50 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length		99.5%	68.390		55.838		56.280		54.556		55.135		46.118		55.452		46.036	
		99.0%	61.803		50.460		50.860		49.302		49.825		41.676		50.111		41.602	
	2	97.5%	52.056	0.007104	42.502	0.021086	42.838	0.040891	41.526	0.058349	41.967	0.076199	35.103	0.095980	42.208	0.114963	35.041	0.140453
		95.0%	43.690		35.671		35.954		34.852		35.222		29.462		35.425		29.409	
		90.0%	34.022		27.778		27.998		27.140		27.429		22.943		27.586		22.902	
		99.5%	56.461		70.133		71.376		58.122		50.608		50.449		71.670		50.783	
		99.0%	51.023		63.379		64.502		52.524		45.734		45.591		64.768		45.892	
	4	97.5%	42.976	0.006376	53.383	0.015555	54.329	0.026863	44.240	0.043113	38.521	0.061760	38.400	0.079572	54.553	0.092596	38.654	0.103346
		95.0%	36.069		44.804		45.598		37.130		32.330		32.229		45.785		32.442	
		90.0%	28.088		34.890		35.508		28.914		25.176		25.097		35.654		25.263	
		99.5%	67.111		61.619		62.975		59.508		65.806		65.748		62.279		63.044	
		99.0%	60.647		55.685		56.909		53.777		59.468		59.416		56.281		56.972	
	6	97.5%	51.082	0.005190	46.902	0.011827	47.934	0.024482	45.295	0.037494	50.089	0.052111	50.045	0.061700	47.405	0.068656	47.987	0.087460
		95.0%	42.873		39.365		40.230		38.016		42.039		42.002		39.786		40.275	
		90.0%	33.386		30.654		31.328		29.604		32.737		32.708		30.982		31.363	
		99.5%	70.117		63.813		53.724		55.904		76.841		69.447		60.804		55.726	
		99.0%	63.364		57.667		48.550		50.520		69.441		62.759		54.948		50.359	
	8	97.5%	53.371	0.004003	48.572	0.009967	40.893	0.021952	42.552	0.030216	58.489	0.044150	52.861	0.054685	46.282	0.066188	42.417	0.078900
		95.0%	44.793		40.766		34.321		35.714		49.089		44.365		38.844		35.600	
		90.0%	34.882		31.745		26.726		27.811		38.227		34.548		30.248		27.722	
		99.5%	61.844		79.138		74.871		59.684		69.412		60.480		58.020		66.329	
		99.0%	55.888		71.516		67.660		53.936		62.727		54.655		52.432		59.941	
	10	97.5%	47.074	0.003896	60.237	0.010403	56.989	0.018520	45.430	0.029927	52.834	0.035364	46.035	0.050911	44.163	0.057417	50.487	0.064879
		95.0%	39.508		50.556		47.830		38.128		44.343		38.637		37.065		42.373	
		90.0%	30.766		39.369		37.247		29.691		34.531		30.087		28.864		32.997	
		99.5%	69.786		73.911		60.535		68.419		63.481		60.983		57.843		78.366	
		99.0%	63.065		66.793		54.705		61.830		57.367		55.110		52.272		70.819	
	12	97.5%	53.119	0.003482	56.258	0.009184	46.077	0.017455	52.078	0.027417	48.319	0.034035	46.418	0.044175	44.028	0.052071	59.650	0.059391
		95.0%	44.582		47.217		38.672		43.708		40.554		38.958		36.952		50.063	
		90.0%	34.717		36.769		30.115		34.037		31.580		30.338		28.775		38.985	
		99.5%	68.293		65.359		67.150		81.599		53.961		55.472		71.540		78.528	
		99.0%	61.716		59.065		60.683		73.740		48.764		50.129		64.650		70.965	
	14	97.5%	51.982	0.003366	49.749	0.008805	51.112	0.017066	62.110	0.023899	41.073	0.036104	42.223	0.042269	54.454	0.054834	59.773	0.062598
		95.0%	43.628		41.754		42.898		52.128		34.472		35.437		45.702		50.167	
		90.0%	33.974		32.515		33.406		40.593		26.844		27.596		35.589		39.066	
		99.5%	64.739		68.011		84.098		63.932		68.725		67.198		65.104		70.610	
		99.0%	58.504		61.461		75.999		57.775		62.106		60.726		58.834		63.809	
	16	97.5%	49.277	0.003383	51.767	0.008453	64.013	0.014448	48.663	0.024312	52.311	0.032807	51.149	0.039022	49.555	0.047426	53.746	0.055819
		95.0%	41.358		43.448		53.725		40.842		43.904		42.928		41.591		45.108	
		90.0%	32.206		33.834		41.837		31.805		34.189		33.429		32.388		35.127	
		99.5%	69.660		71.472		63.958		64.394		66.460		68.547		71.442		68.791	
		99.0%	62.951		64.589		57.798		58.192		60.059		61.945		64.562		62.166	
	18	97.5%	53.023	0.002744	54.402	0.007305	48.683	0.012743	49.015	0.021412	50.587	0.029234	52.176	0.036739	54.379	0.039876	52.362	0.049747
		95.0%	44.501		45.659		40.859		41.137		42.457		43.790		45.640		43.946	
		90.0%	34.654		35.556		31.818		32.034		33.062		34.101		35.541		34.222	
		99.5%	65.104		55.198		74.749		67.377		69.484		61.120		66.205		76.549	
		99.0%	58.834		49.881		67.550		60.888		62.792		55.234		59.829		69.176	
	20	97.5%	49.555	0.002896	42.014	0.007200	56.897	0.013140	51.285	0.020175	52.888	0.028837	46.523	0.036103	50.393	0.040116	58.266	0.047138
		95.0%	41.591		35.262		47.752		43.043		44.389		39.046		42.294		48.902	
		90.0%	32.388		27.459		37.186		33.518		34.566		30.406		32.936		38.081	

Table 4.36. Table for Production Smoothing Analysis with Standard Deviation = 2% and Time = 25 Periods.

Production Smoothing
Standard Deviation = 2%, Time Frame = 25 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
	99.5%	1.869		1.914		1.702		1.998		1.442		1.665		1.606		1.394	
	99.0%	1.689		1.730		1.538		1.806		1.303		1.504		1.451		1.260	
2	97.5%	1.423	0.000000	1.457	0.001016	1.296	0.001979	1.521	0.003120	1.098	0.003905	1.267	0.005331	1.223	0.005720	1.061	0.007454
	95.0%	1.194		1.223		1.087		1.276		0.921		1.063		1.026		0.890	
	90.0%	0.930		0.952		0.847		0.994		0.717		0.828		0.799		0.693	
	99.5%	2.116		1.832		1.659		1.766		1.979		1.838		1.771		1.718	
	99.0%	1.913		1.655		1.499		1.596		1.788		1.661		1.600		1.553	
4	97.5%	1.611	0.000000	1.394	0.000683	1.263	0.001536	1.344	0.002161	1.506	0.002784	1.399	0.003746	1.348	0.004522	1.308	0.005226
	95.0%	1.352		1.170		1.060		1.128		1.264		1.174		1.131		1.098	
	90.0%	1.053		0.911		0.825		0.879		0.985		0.914		0.881		0.855	
	99.5%	1.981		2.066		1.982		1.877		1.863		1.790		1.925		1.947	
	99.0%	1.790		1.867		1.791		1.696		1.683		1.617		1.740		1.759	
6	97.5%	1.508	0.000000	1.572	0.000597	1.509	0.001187	1.429	0.001803	1.418	0.002390	1.362	0.003006	1.465	0.003591	1.482	0.004171
	95.0%	1.265		1.320		1.266		1.199		1.190		1.143		1.230		1.244	
	90.0%	0.985		1.028		0.986		0.934		0.927		0.890		0.958		0.968	
	99.5%	1.979		1.776		2.178		1.755		1.898		2.060		1.810		2.026	
	99.0%	1.788		1.605		1.969		1.586		1.715		1.862		1.636		1.831	
8	97.5%	1.506	0.000000	1.352	0.000528	1.658	0.001021	1.336	0.001642	1.444	0.002345	1.568	0.002582	1.378	0.003299	1.542	0.003922
	95.0%	1.264		1.134		1.392		1.121		1.212		1.316		1.157		1.294	
	90.0%	0.984		0.883		1.084		0.873		0.944		1.025		0.901		1.008	
	99.5%	1.938		1.901		2.266		1.869		2.005		1.746		1.888		1.903	
	99.0%	1.751		1.718		2.048		1.689		1.812		1.577		1.706		1.720	
10	97.5%	1.475	0.000000	1.447	0.000478	1.725	0.000838	1.423	0.001285	1.526	0.001691	1.329	0.002382	1.437	0.002544	1.449	0.003029
	95.0%	1.238		1.215		1.448		1.194		1.281		1.115		1.206		1.216	
	90.0%	0.964		0.946		1.127		0.930		0.997		0.868		0.939		0.947	
	99.5%	2.028		2.204		2.120		1.992		2.009		2.129		1.981		1.811	
	99.0%	1.833		1.992		1.915		1.800		1.816		1.924		1.790		1.637	
12	97.5%	1.544	0.000000	1.678	0.000454	1.613	0.000840	1.516	0.001243	1.529	0.001730	1.621	0.002097	1.508	0.002577	1.379	0.002976
	95.0%	1.296		1.408		1.354		1.273		1.284		1.360		1.266		1.157	
	90.0%	1.009		1.097		1.054		0.991		1.000		1.059		0.986		0.901	
	99.5%	1.867		2.076		1.883		1.860		1.967		1.922		2.045		1.961	
	99.0%	1.687		1.876		1.702		1.681		1.777		1.737		1.848		1.772	
14	97.5%	1.421	0.000000	1.580	0.000447	1.433	0.000891	1.416	0.001225	1.497	0.001734	1.463	0.001924	1.556	0.002675	1.492	0.002964
	95.0%	1.193		1.326		1.203		1.189		1.256		1.228		1.306		1.253	
	90.0%	0.929		1.033		0.937		0.926		0.978		0.956		1.017		0.975	
	99.5%	2.156		2.100		1.838		1.916		1.855		1.760		2.004		2.181	
	99.0%	1.949		1.898		1.661		1.732		1.676		1.591		1.811		1.971	
16	97.5%	1.641	0.000000	1.598	0.000418	1.399	0.000863	1.459	0.001276	1.412	0.001572	1.340	0.002144	1.526	0.002251	1.660	0.002762
	95.0%	1.378		1.341		1.174		1.224		1.185		1.124		1.280		1.393	
	90.0%	1.073		1.045		0.914		0.953		0.923		0.876		0.997		1.085	
	99.5%	2.059		1.869		1.801		2.237		1.893		1.936		1.967		2.110	
	99.0%	1.860		1.689		1.628		2.021		1.710		1.750		1.778		1.906	
18	97.5%	1.567	0.000000	1.423	0.000411	1.371	0.000767	1.702	0.001127	1.441	0.001663	1.474	0.001987	1.497	0.002405	1.606	0.002782
	95.0%	1.315		1.194		1.151		1.429		1.209		1.237		1.257		1.348	
	90.0%	1.024		0.930		0.896		1.113		0.942		0.963		0.979		1.049	
	99.5%	1.955		1.840		2.125		1.968		1.921		2.175		2.061		1.952	
	99.0%	1.766		1.663		1.920		1.778		1.736		1.966		1.863		1.764	
20	97.5%	1.488	0.000000	1.401	0.000378	1.617	0.000677	1.498	0.000977	1.462	0.001413	1.656	0.001792	1.569	0.002255	1.486	0.002592
	95.0%	1.249		1.176		1.357		1.257		1.227		1.390		1.317		1.247	
	90.0%	0.972		0.916		1.057		0.979		0.956		1.082		1.026		0.971	

Table 4.37. Table for Production Smoothing Analysis with Standard Deviation = 5% and Time = 25 Periods.

Production Smoothing
Standard Deviation = 5%, Time Frame = 25 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	3.799		4.892		4.387		4.524		4.457		4.524		3.942		3.302	
		99.0%	3.433		4.421		3.965		4.088		4.028		4.088		3.563		2.984	
		97.5%	2.892	0.001018	3.724	0.003001	3.339	0.004813	3.443	0.007183	3.393	0.009818	3.443	0.012102	3.001	0.015456	2.513	0.018062
		95.0%	2.427		3.125		2.803		2.890		2.847		2.890		2.518		2.109	
		90.0%	1.890		2.434		2.182		2.251		2.217		2.250		1.961		1.643	
	4	99.5%	4.577		5.404		4.356		4.761		4.803		3.802		4.324		3.850	
		99.0%	4.136		4.883		3.936		4.302		4.340		3.436		3.908		3.479	
		97.5%	3.484	0.000761	4.113	0.002228	3.316	0.003531	3.624	0.005378	3.656	0.007539	2.894	0.010156	3.291	0.010944	2.930	0.013340
		95.0%	2.924		3.452		2.783		3.041		3.068		2.429		2.762		2.459	
		90.0%	2.277		2.688		2.167		2.368		2.389		1.891		2.151		1.915	
	6	99.5%	4.991		5.016		4.868		5.021		4.157		5.163		4.174		3.996	
		99.0%	4.510		4.533		4.399		4.537		3.757		4.666		3.772		3.611	
		97.5%	3.799	0.000603	3.818	0.001932	3.705	0.002822	3.822	0.004839	3.164	0.006269	3.930	0.008042	3.177	0.009112	3.042	0.010903
		95.0%	3.188		3.204		3.110		3.208		2.656		3.298		2.666		2.553	
		90.0%	2.483		2.495		2.422		2.498		2.068		2.568		2.076		1.988	
	8	99.5%	4.936		4.920		4.692		4.882		4.710		4.839		4.644		5.012	
		99.0%	4.461		4.446		4.240		4.412		4.257		4.373		4.196		4.529	
		97.5%	3.757	0.000515	3.745	0.001711	3.571	0.002712	3.716	0.004062	3.585	0.005388	3.683	0.006896	3.535	0.008057	3.815	0.009180
		95.0%	3.154		3.143		2.997		3.119		3.009		3.091		2.967		3.202	
		90.0%	2.456		2.448		2.334		2.429		2.343		2.407		2.310		2.493	
	10	99.5%	5.257		5.324		4.772		5.389		5.320		4.761		4.701		4.772	
		99.0%	4.751		4.811		4.313		4.870		4.807		4.303		4.248		4.312	
		97.5%	4.001	0.000449	4.052	0.001286	3.632	0.002201	4.102	0.003612	4.049	0.004122	3.624	0.005462	3.578	0.006622	3.632	0.008513
		95.0%	3.358		3.401		3.049		3.443		3.398		3.042		3.003		3.048	
		90.0%	2.615		2.648		2.374		2.681		2.646		2.369		2.339		2.374	
	12	99.5%	4.874		4.525		5.602		5.310		4.648		4.982		5.014		5.183	
		99.0%	4.404		4.089		5.063		4.798		4.200		4.503		4.531		4.683	
		97.5%	3.710	0.000408	3.444	0.001426	4.264	0.002021	4.042	0.003432	3.538	0.004475	3.792	0.005941	3.816	0.006464	3.945	0.008179
		95.0%	3.114		2.891		3.579		3.392		2.969		3.183		3.203		3.311	
		90.0%	2.425		2.251		2.787		2.641		2.312		2.479		2.494		2.578	
	14	99.5%	5.213		5.304		4.861		4.634		4.740		4.657		4.872		4.386	
		99.0%	4.711		4.793		4.393		4.188		4.284		4.208		4.403		3.964	
		97.5%	3.968	0.000425	4.037	0.001270	3.700	0.002054	3.527	0.003433	3.608	0.004092	3.545	0.005881	3.708	0.006672	3.339	0.007698
		95.0%	3.330		3.388		3.106		2.960		3.028		2.975		3.112		2.802	
		90.0%	2.594		2.639		2.418		2.305		2.358		2.317		2.424		2.182	
	16	99.5%	5.467		4.740		4.698		4.952		4.466		4.703		5.289		4.710	
		99.0%	4.941		4.283		4.245		4.475		4.036		4.250		4.779		4.256	
		97.5%	4.161	0.000425	3.608	0.001181	3.576	0.002161	3.769	0.003178	3.400	0.004126	3.580	0.005738	4.026	0.005960	3.585	0.007706
		95.0%	3.493		3.028		3.001		3.163		2.853		3.005		3.379		3.009	
		90.0%	2.720		2.358		2.337		2.463		2.222		2.340		2.631		2.343	
	18	99.5%	4.726		4.532		5.455		5.393		4.525		5.076		4.422		5.065	
		99.0%	4.271		4.096		4.929		4.873		4.089		4.587		3.996		4.577	
		97.5%	3.597	0.000404	3.450	0.001223	4.152	0.001876	4.105	0.002981	3.444	0.004119	3.863	0.005243	3.366	0.006034	3.855	0.006984
		95.0%	3.019		2.895		3.485		3.445		2.891		3.242		2.825		3.236	
		90.0%	2.351		2.255		2.714		2.683		2.251		2.525		2.200		2.520	
	20	99.5%	4.463		5.100		4.965		5.760		4.836		4.404		4.783		5.032	
		99.0%	4.033		4.609		4.487		5.205		4.370		3.980		4.322		4.547	
		97.5%	3.397	0.000371	3.882	0.001070	3.779	0.002008	4.384	0.002865	3.681	0.003840	3.352	0.004511	3.640	0.005754	3.830	0.006423
		95.0%	2.851		3.258		3.172		3.680		3.089		2.813		3.055		3.215	
		90.0%	2.220		2.537		2.470		2.865		2.406		2.191		2.379		2.503	

Table 4.38. Table for Production Smoothing Analysis with Standard Deviation = 10% and Time = 25 Periods.

Production Smoothing
Standard Deviation = 10%, Time Frame = 25 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	10.452		10.324		9.053		9.344		7.889		8.306		7.737		6.540	
		99.0%	9.445		9.330		8.181		8.444		7.130		7.506		6.992		5.910	
		97.5%	7.955	0.002012	7.858	0.005200	6.891	0.009383	7.113	0.014035	6.005	0.020999	6.322	0.026281	5.889	0.030234	4.978	0.032481
		95.0%	6.677		6.595		5.783		5.970		5.040		5.306		4.943		4.178	
		90.0%	5.199		5.136		4.504		4.649		3.925		4.132		3.849		3.253	
	4	99.5%	11.085		10.655		9.667		9.702		9.399		9.176		9.023		8.461	
		99.0%	10.018		9.629		8.736		8.767		8.494		8.292		8.154		7.646	
		97.5%	8.438	0.001441	8.110	0.003287	7.358	0.006923	7.385	0.010188	7.154	0.013339	6.984	0.019361	6.868	0.021711	6.440	0.026336
		95.0%	7.082		6.807		6.175		6.198		6.005		5.862		5.764		5.405	
		90.0%	5.515		5.301		4.809		4.826		4.676		4.565		4.489		4.209	
	6	99.5%	9.651		9.608		10.935		9.196		9.414		8.963		9.663		9.418	
		99.0%	8.722		8.683		9.882		8.310		8.507		8.100		8.732		8.511	
		97.5%	7.346	0.001152	7.313	0.002989	8.323	0.006030	6.999	0.009317	7.166	0.012749	6.822	0.016304	7.355	0.017891	7.169	0.020588
		95.0%	6.165		6.138		6.985		5.874		6.014		5.726		6.173		6.017	
		90.0%	4.801		4.780		5.440		4.575		4.683		4.459		4.807		4.685	
	8	99.5%	9.809		9.494		10.569		9.732		10.038		8.974		9.892		9.273	
		99.0%	8.864		8.580		9.551		8.795		9.071		8.110		8.940		8.380	
		97.5%	7.466	0.001015	7.227	0.002687	8.045	0.005128	7.408	0.007946	7.640	0.010475	6.831	0.013360	7.530	0.016976	7.058	0.018176
		95.0%	6.266		6.065		6.752		6.217		6.413		5.733		6.320		5.924	
		90.0%	4.880		4.723		5.258		4.841		4.994		4.465		4.921		4.613	
	10	99.5%	10.241		9.513		9.817		9.293		10.292		9.950		9.450		9.154	
		99.0%	9.255		8.597		8.872		8.398		9.301		8.992		8.540		8.273	
		97.5%	7.795	0.000847	7.241	0.002337	7.472	0.004468	7.073	0.006391	7.834	0.008920	7.573	0.010732	7.193	0.013884	6.968	0.016071
		95.0%	6.542		6.077		6.271		5.936		6.575		6.356		6.037		5.848	
		90.0%	5.095		4.732		4.884		4.623		5.120		4.950		4.701		4.554	
	12	99.5%	9.882		10.180		9.125		9.663		9.851		9.994		10.753		10.974	
		99.0%	8.931		9.200		8.246		8.732		8.902		9.032		9.718		9.917	
		97.5%	7.522	0.000777	7.749	0.002112	6.946	0.004435	7.355	0.006596	7.498	0.009042	7.607	0.010661	8.185	0.012794	8.353	0.015490
		95.0%	6.313		6.503		5.830		6.173		6.293		6.385		6.870		7.010	
		90.0%	4.916		5.064		4.540		4.807		4.901		4.972		5.349		5.459	
	14	99.5%	10.312		10.181		9.699		9.922		9.551		9.052		9.406		10.040	
		99.0%	9.319		9.200		8.764		8.967		8.631		8.180		8.500		9.073	
		97.5%	7.849	0.000869	7.749	0.001860	7.382	0.004409	7.553	0.005771	7.270	0.008887	6.890	0.011134	7.160	0.012530	7.642	0.014295
		95.0%	6.588		6.504		6.196		6.339		6.102		5.783		6.009		6.414	
		90.0%	5.130		5.065		4.825		4.936		4.752		4.503		4.679		4.995	
	16	99.5%	11.163		8.917		10.448		9.755		9.698		9.482		10.187		9.602	
		99.0%	10.088		8.058		9.442		8.816		8.764		8.568		9.206		8.677	
		97.5%	8.497	0.000876	6.788	0.002162	7.953	0.004194	7.425	0.006740	7.382	0.008721	7.217	0.010662	7.754	0.012231	7.309	0.015157
		95.0%	7.131		5.697		6.675		6.232		6.195		6.057		6.508		6.134	
		90.0%	5.553		4.436		5.198		4.853		4.824		4.717		5.068		4.777	
	18	99.5%	10.518		9.069		9.471		11.270		9.057		11.019		10.962		9.940	
		99.0%	9.505		8.195		8.559		10.184		8.185		9.958		9.906		8.983	
		97.5%	8.006	0.000751	6.903	0.002145	7.209	0.003785	8.578	0.005255	6.894	0.008245	8.387	0.009370	8.344	0.010539	7.566	0.013330
		95.0%	6.719		5.793		6.051		7.200		5.786		7.039		7.003		6.350	
		90.0%	5.233		4.511		4.712		5.606		4.506		5.482		5.453		4.945	
	20	99.5%	9.309		9.823		10.593		11.109		9.681		9.559		8.914		9.602	
		99.0%	8.412		8.877		9.573		10.039		8.749		8.639		8.056		8.677	
		97.5%	7.085	0.000765	7.477	0.001790	8.063	0.003645	8.456	0.005351	7.369	0.007603	7.276	0.009085	6.785	0.011388	7.309	0.013782
		95.0%	5.947		6.276		6.767		7.097		6.185		6.107		5.695		6.134	
		90.0%	4.631		4.887		5.270		5.527		4.816		4.756		4.435		4.777	

Table 4.39. Table for Production Smoothing Analysis with Standard Deviation = 15% and Time = 25 Periods.

Production Smoothing
Standard Deviation = 15%, Time Frame = 25 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	14.926		14.760		12.766		13.603		11.781		11.320		13.236		10.836	
		99.0%	13.488		13.339		11.536		12.293		10.647		10.229		11.961		9.792	
		97.5%	11.361	0.002843	11.235	0.007301	9.717	0.015348	10.354	0.022280	8.968	0.028715	8.616	0.038228	10.075	0.042767	8.248	0.050960
		95.0%	9.535		9.429		8.155		8.690		7.526		7.231		8.455		6.922	
		90.0%	7.425		7.343		6.351		6.767		5.861		5.631		6.584		5.390	
	4	99.5%	13.305		12.550		12.550		12.475		12.565		13.775		12.536		10.584	
		99.0%	12.023		11.341		11.341		11.273		11.355		12.448		11.329		9.565	
		97.5%	10.127	0.002277	9.552	0.005595	9.553	0.011136	9.495	0.017945	9.564	0.021417	10.485	0.027144	9.542	0.033371	8.056	0.038820
		95.0%	8.499		8.017		8.017		7.969		8.027		8.800		8.009		6.762	
		90.0%	6.619		6.243		6.243		6.206		6.251		6.853		6.237		5.265	
	6	99.5%	13.311		13.762		15.512		15.063		12.110		14.020		13.182		12.838	
		99.0%	12.029		12.436		14.018		13.612		10.943		12.670		11.913		11.602	
		97.5%	10.132	0.001827	10.475	0.004812	11.807	0.007753	11.465	0.013574	9.217	0.018403	10.672	0.022226	10.034	0.028471	9.772	0.032562
		95.0%	8.504		8.791		9.910		9.623		7.736		8.957		8.421		8.202	
		90.0%	6.622		6.846		7.717		7.493		6.024		6.975		6.558		6.387	
	8	99.5%	14.335		13.891		14.813		13.755		12.479		13.641		12.410		12.917	
		99.0%	12.954		12.553		13.386		12.430		11.277		12.327		11.215		11.673	
		97.5%	10.911	0.001643	10.574	0.004565	11.275	0.007933	10.470	0.012869	9.498	0.016776	10.383	0.020341	9.446	0.026565	9.832	0.030386
		95.0%	9.158		8.874		9.463		8.787		7.972		8.714		7.928		8.252	
		90.0%	7.131		6.911		7.369		6.843		6.208		6.786		6.174		6.426	
	10	99.5%	13.692		14.592		13.877		15.836		14.230		12.150		13.376		12.928	
		99.0%	12.374		13.186		12.540		14.311		12.859		10.980		12.088		11.683	
		97.5%	10.422	0.001358	11.107	0.003518	10.562	0.007022	12.054	0.009821	10.831	0.014311	9.248	0.017880	10.181	0.018854	9.840	0.024490
		95.0%	8.747		9.322		8.865		10.116		9.090		7.762		8.545		8.259	
		90.0%	6.812		7.259		6.903		7.878		7.079		6.044		6.654		6.431	
	12	99.5%	12.964		15.025		13.569		12.433		14.708		15.818		13.647		12.667	
		99.0%	11.715		13.578		12.262		11.235		13.291		14.295		12.332		11.447	
		97.5%	9.868	0.001321	11.436	0.003566	10.328	0.006492	9.463	0.010854	11.195	0.013956	12.040	0.016603	10.387	0.021564	9.642	0.023891
		95.0%	8.282		9.598		8.669		7.942		9.396		10.105		8.718		8.092	
		90.0%	6.449		7.474		6.750		6.185		7.317		7.869		6.789		6.301	
	14	99.5%	14.665		15.493		13.955		14.278		14.932		12.829		13.589		14.162	
		99.0%	13.252		14.001		12.611		12.903		13.494		11.594		12.280		12.798	
		97.5%	11.162	0.001337	11.793	0.003478	10.622	0.006379	10.868	0.010397	11.366	0.012383	9.765	0.016151	10.344	0.020775	10.780	0.022936
		95.0%	9.368		9.897		8.915		9.121		9.539		8.196		8.681		9.047	
		90.0%	7.295		7.707		6.942		7.103		7.429		6.382		6.760		7.045	
	16	99.5%	11.677		14.792		13.348		13.301		14.409		13.546		14.345		13.967	
		99.0%	10.552		13.368		12.063		12.020		13.021		12.242		12.964		12.622	
		97.5%	8.888	0.001242	11.259	0.003256	10.160	0.006069	10.124	0.008908	10.967	0.012324	10.311	0.016207	10.919	0.018632	10.631	0.023321
		95.0%	7.460		9.450		8.527		8.497		9.205		8.654		9.164		8.923	
		90.0%	5.809		7.359		6.641		6.617		7.168		6.739		7.136		6.948	
	18	99.5%	14.626		14.485		13.227		13.570		12.989		13.420		15.166		14.381	
		99.0%	13.218		13.090		11.953		12.263		11.738		12.127		13.705		12.996	
		97.5%	11.133	0.001121	11.025	0.003086	10.068	0.005934	10.329	0.008571	9.887	0.011677	10.215	0.013970	11.544	0.017448	10.946	0.021079
		95.0%	9.344		9.253		8.450		8.669		8.298		8.573		9.689		9.187	
		90.0%	7.276		7.206		6.580		6.751		6.462		6.676		7.545		7.154	
	20	99.5%	14.055		14.458		15.197		13.951		14.428		13.959		15.342		16.492	
		99.0%	12.701		13.065		13.733		12.607		13.039		12.615		13.864		14.904	
		97.5%	10.698	0.001125	11.005	0.003054	11.567	0.005358	10.619	0.008797	10.982	0.010434	10.625	0.013508	11.678	0.016700	12.553	0.019049
		95.0%	8.979		9.236		9.708		8.912		9.217		8.917		9.801		10.536	
		90.0%	6.992		7.192		7.560		6.940		7.178		6.944		7.632		8.204	

Table 4.40. Table for Production Smoothing Analysis with Standard Deviation = 20% and Time = 25 Periods.

Production Smoothing
Standard Deviation = 20%, Time Frame = 25 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	17.706		18.174		17.828		16.383		15.485		12.821		14.665		11.618	
		99.0%	16.001		16.424		16.111		14.805		13.994		11.587		13.253		10.499	
		97.5%	13.477	0.003923	13.833	0.011278	13.570	0.019929	12.470	0.031010	11.787	0.042772	9.759	0.049140	11.163	0.061823	8.843	0.068827
		95.0%	11.311		11.610		11.389		10.466		9.893		8.191		9.369		7.422	
		90.0%	8.808		9.041		8.869		8.150		7.704		6.378		7.295		5.780	
	4	99.5%	16.958		18.399		18.894		17.751		16.274		16.178		16.594		16.857	
		99.0%	15.325		16.627		17.074		16.042		14.706		14.620		14.996		15.233	
		97.5%	12.908	0.002834	14.005	0.007253	14.381	0.014640	13.512	0.021652	12.387	0.028126	12.314	0.034767	12.631	0.045446	12.831	0.050361
		95.0%	10.833		11.754		12.070		11.340		10.396		10.335		10.601		10.769	
		90.0%	8.436		9.153		9.399		8.831		8.096		8.048		8.255		8.386	
	6	99.5%	18.094		18.589		17.667		17.999		15.772		18.265		15.065		18.999	
		99.0%	16.351		16.799		15.965		16.265		14.253		16.506		13.614		17.169	
		97.5%	13.772	0.002346	14.150	0.006154	13.447	0.011762	13.700	0.018483	12.005	0.025308	13.903	0.030491	11.467	0.036890	14.461	0.039635
		95.0%	11.559		11.875		11.286		11.498		10.076		11.668		9.624		12.137	
		90.0%	9.001		9.248		8.789		8.954		7.846		9.086		7.494		9.451	
	8	99.5%	15.150		18.307		18.911		17.677		18.245		17.476		18.687		18.017	
		99.0%	13.691		16.544		17.090		15.975		16.488		15.793		16.887		16.282	
		97.5%	11.531	0.002225	13.935	0.005293	14.394	0.010705	13.455	0.015335	13.887	0.021324	13.302	0.026821	14.224	0.033549	13.714	0.037505
		95.0%	9.678		11.695		12.081		11.293		11.655		11.164		11.938		11.510	
		90.0%	7.537		9.107		9.408		8.794		9.076		8.694		9.296		8.963	
	10	99.5%	16.723		18.480		16.270		18.389		16.348		17.988		18.310		16.822	
		99.0%	15.112		16.700		14.703		16.618		14.773		16.256		16.547		15.202	
		97.5%	12.729	0.001770	14.066	0.004272	12.384	0.009361	13.997	0.014006	12.443	0.018805	13.692	0.022314	13.937	0.027301	12.804	0.031496
		95.0%	10.683		11.806		10.394		11.747		10.444		11.491		11.697		10.746	
		90.0%	8.319		9.193		8.094		9.148		8.133		8.949		9.109		8.368	
	12	99.5%	18.572		17.053		16.874		16.967		16.022		18.387		17.364		16.203	
		99.0%	16.784		15.411		15.249		15.333		14.479		16.616		15.691		14.643	
		97.5%	14.137	0.001839	12.980	0.004430	12.844	0.009934	12.914	0.013391	12.196	0.016651	13.995	0.020225	13.217	0.024690	12.333	0.031364
		95.0%	11.865		10.894		10.780		10.839		10.236		11.746		11.093		10.351	
		90.0%	9.239		8.484		8.395		8.440		7.971		9.147		8.638		8.061	
	14	99.5%	17.564		18.258		18.726		14.812		16.246		17.541		18.129		19.131	
		99.0%	15.873		16.500		16.922		13.386		14.682		15.852		16.383		17.288	
		97.5%	13.369	0.001768	13.897	0.004219	14.253	0.008457	11.274	0.013446	12.366	0.017616	13.352	0.022361	13.799	0.027657	14.562	0.028387
		95.0%	11.221		11.664		11.963		9.462		10.379		11.206		11.582		12.221	
		90.0%	8.738		9.083		9.316		7.369		8.082		8.726		9.019		9.517	
	16	99.5%	19.038		17.955		17.933		17.751		17.617		17.935		14.101		18.676	
		99.0%	17.204		16.226		16.206		16.041		15.921		16.208		12.743		16.877	
		97.5%	14.491	0.001616	13.667	0.004364	13.650	0.008687	13.511	0.012902	13.410	0.017261	13.652	0.019769	10.733	0.025652	14.215	0.028073
		95.0%	12.162		11.471		11.456		11.340		11.255		11.458		9.008		11.931	
		90.0%	9.471		8.932		8.921		8.831		8.764		8.922		7.015		9.291	
	18	99.5%	18.903		17.486		17.652		18.007		17.334		17.489		18.292		19.009	
		99.0%	17.082		15.802		15.952		16.273		15.665		15.804		16.531		17.178	
		97.5%	14.388	0.001576	13.310	0.003922	13.436	0.007662	13.706	0.011596	13.194	0.016299	13.312	0.020592	13.924	0.024598	14.469	0.027937
		95.0%	12.076		11.171		11.277		11.503		11.074		11.172		11.686		12.144	
		90.0%	9.404		8.699		8.782		8.958		8.623		8.700		9.100		9.457	
	20	99.5%	18.330		16.076		16.986		15.950		17.006		18.345		16.469		19.446	
		99.0%	16.565		14.527		15.350		14.414		15.368		16.578		14.883		17.573	
		97.5%	13.952	0.001535	12.236	0.004100	12.929	0.007310	12.141	0.011017	12.944	0.014359	13.964	0.016395	12.536	0.022224	14.802	0.026670
		95.0%	11.710		10.270		10.851		10.190		10.864		11.719		10.521		12.423	
		90.0%	9.119		7.997		8.450		7.935		8.460		9.126		8.193		9.674	

Table 4.41. Table for Production Smoothing Analysis with Standard Deviation = 25% and Time = 25 Periods.

Production Smoothing
Standard Deviation = 25%, Time Frame = 25 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	22.466		21.857		18.583		18.623		18.110		14.897		12.771		15.792	
	99.0%	20.302		19.752		16.794		16.830		16.366		13.462		11.541		14.271	
	97.5%	17.100	0.005066	16.637	0.013182	14.145	0.026118	14.175	0.035330	13.784	0.046622	11.339	0.066500	9.721	0.071943	12.020	0.088921
	95.0%	14.352		13.963		11.872		11.897		11.569		9.516		8.159		10.089	
	90.0%	11.176		10.873		9.245		9.265		9.009		7.411		6.353		7.856	
4	99.5%	20.783		21.075		20.329		19.146		17.093		20.146		19.138		16.703	
	99.0%	18.781		19.046		18.371		17.302		15.447		18.206		17.295		15.095	
	97.5%	15.819	0.003550	16.042	0.008603	15.473	0.018184	14.574	0.030102	13.011	0.036942	15.335	0.043750	14.568	0.058652	12.714	0.062548
	95.0%	13.277		13.464		12.987		12.231		10.920		12.870		12.226		10.671	
	90.0%	10.339		10.484		10.113		9.525		8.503		10.022		9.521		8.310	
6	99.5%	21.837		22.320		21.986		18.959		19.856		19.527		17.496		17.425	
	99.0%	19.734		20.170		19.869		17.133		17.943		17.646		15.811		15.747	
	97.5%	16.622	0.002791	16.989	0.007607	16.735	0.014892	14.431	0.023057	15.113	0.031971	14.863	0.035858	13.318	0.045160	13.263	0.054182
	95.0%	13.950		14.259		14.046		12.112		12.685		12.475		11.177		11.132	
	90.0%	10.863		11.104		10.938		9.432		9.878		9.714		8.704		8.669	
8	99.5%	21.657		20.349		21.588		22.677		22.007		17.585		21.088		20.098	
	99.0%	19.571		18.389		19.509		20.493		19.888		15.891		19.057		18.162	
	97.5%	16.484	0.002461	15.489	0.007106	16.432	0.012770	17.261	0.018979	16.751	0.027555	13.385	0.033529	16.052	0.039952	15.298	0.045664
	95.0%	13.835		13.000		13.791		14.487		14.059		11.234		13.472		12.839	
	90.0%	10.774		10.123		10.740		11.281		10.948		8.748		10.491		9.998	
10	99.5%	22.543		21.035		20.464		18.614		21.767		21.595		19.889		21.449	
	99.0%	20.372		19.009		18.493		16.821		19.671		19.515		17.974		19.383	
	97.5%	17.159	0.002409	16.011	0.005632	15.577	0.011293	14.168	0.018608	16.568	0.023053	16.437	0.028701	15.139	0.032643	16.326	0.038904
	95.0%	14.401		13.438		13.073		11.891		13.906		13.795		12.706		13.702	
	90.0%	11.214		10.464		10.180		9.260		10.829		10.743		9.894		10.670	
12	99.5%	20.787		21.518		21.624		20.691		19.938		19.342		19.438		19.568	
	99.0%	18.785		19.446		19.541		18.698		18.018		17.479		17.565		17.684	
	97.5%	15.822	0.002154	16.379	0.005936	16.459	0.010769	15.749	0.017664	15.176	0.021915	14.722	0.029745	14.795	0.034433	14.895	0.043865
	95.0%	13.280		13.746		13.814		13.218		12.737		12.356		12.417		12.501	
	90.0%	10.341		10.705		10.757		10.293		9.919		9.622		9.670		9.735	
14	99.5%	20.631		22.397		20.297		20.919		20.963		21.143		22.980		20.521	
	99.0%	18.644		20.240		18.342		18.904		18.944		19.106		20.767		18.544	
	97.5%	15.704	0.001980	17.048	0.005455	15.449	0.010700	15.923	0.016302	15.956	0.021594	16.093	0.027930	17.492	0.031773	15.620	0.037953
	95.0%	13.180		14.308		12.966		13.364		13.392		13.507		14.681		13.109	
	90.0%	10.264		11.142		10.097		10.407		10.429		10.518		11.432		10.209	
16	99.5%	19.982		21.296		20.579		22.825		21.227		23.686		23.318		21.512	
	99.0%	18.057		19.245		18.597		20.626		19.183		21.405		21.073		19.441	
	97.5%	15.209	0.001899	16.210	0.005273	15.664	0.010375	17.373	0.014894	16.158	0.021826	18.029	0.024898	17.749	0.031178	16.375	0.038500
	95.0%	12.765		13.605		13.146		14.581		13.561		15.131		14.897		13.743	
	90.0%	9.940		10.594		10.237		11.355		10.560		11.783		11.600		10.702	
18	99.5%	21.651		22.055		22.575		23.501		23.427		22.219		23.009		21.808	
	99.0%	19.566		19.931		20.401		21.238		21.171		20.079		20.793		19.708	
	97.5%	16.480	0.001980	16.788	0.004755	17.184	0.009786	17.888	0.013717	17.832	0.019055	16.912	0.024653	17.514	0.028134	16.600	0.036087
	95.0%	13.831		14.090		14.422		15.013		14.966		14.194		14.699		13.932	
	90.0%	10.771		10.972		11.231		11.691		11.654		11.053		11.446		10.849	
20	99.5%	19.791		23.538		21.291		23.098		20.454		22.693		21.145		21.328	
	99.0%	17.885		21.271		19.240		20.874		18.484		20.507		19.108		19.274	
	97.5%	15.065	0.001840	17.916	0.004593	16.206	0.010063	17.582	0.013256	15.569	0.016672	17.273	0.021834	16.095	0.026306	16.234	0.031926
	95.0%	12.643		15.037		13.601		14.756		13.067		14.497		13.508		13.625	
	90.0%	9.846		11.710		10.592		11.491		10.175		11.289		10.519		10.610	

Table 4.42. Table for Production Smoothing Analysis with Standard Deviation = 30% and Time = 25 Periods.

Production Smoothing
Standard Deviation = 30%, Time Frame = 25 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	23.419		23.578		22.883		19.256		21.252		18.811		18.248		20.221	
		99.0%	21.163		21.308		20.679		17.401		19.205		16.999		16.491		18.273	
		97.5%	17.826	0.006355	17.947	0.014741	17.418	0.030226	14.657	0.040071	16.176	0.060704	14.318	0.069670	13.890	0.090387	15.391	0.105629
		95.0%	14.961		15.063		14.618		12.301		13.576		12.017		11.658		12.918	
		90.0%	11.650		11.730		11.384		9.579		10.572		9.358		9.078		10.059	
	4	99.5%	23.663		22.268		20.342		19.907		23.497		22.007		23.359		20.931	
		99.0%	21.384		20.124		18.382		17.990		21.234		19.887		21.109		18.915	
		97.5%	18.011	0.004387	16.950	0.011402	15.483	0.021915	15.153	0.032186	17.885	0.044743	16.751	0.055531	17.780	0.066992	15.932	0.076199
		95.0%	15.116		14.226		12.995		12.718		15.011		14.059		14.923		13.372	
		90.0%	11.772		11.078		10.119		9.903		11.689		10.948		11.621		10.413	
	6	99.5%	24.079		25.446		24.549		25.218		24.238		19.682		20.668		23.486	
		99.0%	21.760		22.995		22.185		22.789		21.903		17.786		18.678		21.224	
		97.5%	18.328	0.003632	19.368	0.008233	18.686	0.015594	19.195	0.024668	18.449	0.036878	14.981	0.043475	15.732	0.054369	17.877	0.064780
		95.0%	15.383		16.256		15.683		16.110		15.484		12.574		13.204		15.004	
		90.0%	11.979		12.659		12.213		12.545		12.058		9.791		10.282		11.684	
	8	99.5%	25.458		26.501		22.493		23.189		23.600		25.636		23.863		20.550	
		99.0%	23.006		23.949		20.326		20.956		21.327		23.167		21.565		18.571	
		97.5%	19.378	0.003204	20.172	0.007683	17.121	0.016765	17.651	0.026024	17.964	0.032183	19.514	0.039341	18.164	0.051119	15.642	0.061136
		95.0%	16.264		16.930		14.369		14.814		15.077		16.377		15.245		13.128	
		90.0%	12.665		13.184		11.190		11.536		11.741		12.753		11.871		10.223	
	10	99.5%	26.120		24.564		24.342		24.093		23.312		24.255		22.557		23.324	
		99.0%	23.604		22.198		21.998		21.772		21.066		21.919		20.385		21.078	
		97.5%	19.882	0.002676	18.697	0.007053	18.528	0.012776	18.338	0.020620	17.744	0.025511	18.462	0.032827	17.170	0.042028	17.753	0.048206
		95.0%	16.686		15.692		15.551		15.391		14.892		15.495		14.410		14.900	
		90.0%	12.994		12.220		12.110		11.985		11.597		12.066		11.222		11.603	
	12	99.5%	23.553		26.303		24.398		25.574		21.433		24.949		24.084		23.142	
		99.0%	21.285		23.770		22.048		23.111		19.369		22.546		21.764		20.913	
		97.5%	17.928	0.002596	20.021	0.006932	18.571	0.013031	19.466	0.020028	16.314	0.025548	18.991	0.032986	18.332	0.039933	17.615	0.045218
		95.0%	15.046		16.803		15.586		16.338		13.692		15.938		15.386		14.784	
		90.0%	11.717		13.085		12.137		12.723		10.663		12.412		11.981		11.513	
	14	99.5%	26.537		21.798		26.644		22.485		25.778		24.139		21.968		22.449	
		99.0%	23.982		19.699		24.078		20.320		23.296		21.814		19.853		20.287	
		97.5%	20.199	0.002470	16.592	0.006371	20.281	0.012301	17.115	0.017384	19.621	0.024009	18.374	0.029655	16.722	0.038235	17.088	0.046911
		95.0%	16.953		13.925		17.021		14.364		16.468		15.421		14.034		14.342	
		90.0%	13.202		10.844		13.255		11.186		12.824		12.009		10.929		11.168	
	16	99.5%	21.358		23.520		24.302		25.457		25.396		23.555		26.275		19.904	
		99.0%	19.301		21.255		21.961		23.005		22.950		21.286		23.744		17.987	
		97.5%	16.257	0.002448	17.902	0.006150	18.498	0.012265	19.377	0.017232	19.331	0.023725	17.929	0.030049	19.999	0.033964	15.150	0.045148
		95.0%	13.644		15.025		15.525		16.263		16.224		15.048		16.785		12.715	
		90.0%	10.625		11.701		12.090		12.664		12.634		11.718		13.071		9.902	
	18	99.5%	25.553		21.860		22.961		26.619		23.964		25.766		26.925		22.471	
		99.0%	23.092		19.755		20.750		24.056		21.656		23.285		24.331		20.306	
		97.5%	19.450	0.002423	16.639	0.006337	17.477	0.012212	20.262	0.018917	18.240	0.022428	19.612	0.029958	20.494	0.037127	17.104	0.039331
		95.0%	16.324		13.965		14.668		17.005		15.309		16.460		17.200		14.355	
		90.0%	12.712		10.875		11.423		13.242		11.921		12.818		13.394		11.179	
	20	99.5%	24.066		25.778		22.194		23.874		24.885		25.204		21.583		22.644	
		99.0%	21.748		23.296		20.057		21.574		22.488		22.776		19.504		20.463	
		97.5%	18.318	0.002187	19.622	0.005265	16.893	0.010999	18.172	0.016980	18.942	0.021350	19.184	0.026675	16.428	0.034973	17.236	0.039087
		95.0%	15.374		16.468		14.178		15.251		15.898		16.101		13.788		14.466	
		90.0%	11.972		12.824		11.041		11.877		12.380		12.538		10.737		11.265	

Table 4.43. Table for Production Smoothing Analysis with Standard Deviation = 35% and Time = 25 Periods.

Production Smoothing
Standard Deviation = 35%, Time Frame = 25 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
Flex Bound Length	2	99.5%	27.633		21.363		24.507		21.504		22.970		20.515		23.696		20.177	
		99.0%	24.971		19.305		22.147		19.433		20.758		18.539		21.414		18.234	
		97.5%	21.033	0.006235	16.261	0.018790	18.654	0.036869	16.368	0.053103	17.484	0.068663	15.615	0.085076	18.037	0.104440	15.358	0.129522
		95.0%	17.653		13.647		15.656		13.738		14.674		13.106		15.138		12.890	
		90.0%	13.747		10.627		12.192		10.698		11.427		10.206		11.788		10.038	
	4	99.5%	24.589		27.535		28.868		23.153		21.488		21.264		27.668		21.349	
		99.0%	22.221		24.883		26.088		20.923		19.418		19.216		25.003		19.293	
		97.5%	18.716	0.005654	20.959	0.013816	21.973	0.023588	17.623	0.037743	16.356	0.053424	16.185	0.069422	21.060	0.082467	16.250	0.089578
		95.0%	15.708		17.590		18.442		14.791		13.727		13.584		17.675		13.639	
		90.0%	12.232		13.698		14.361		11.518		10.690		10.578		13.764		10.621	
	6	99.5%	26.299		23.156		26.008		24.028		25.521		27.734		24.251		25.558	
		99.0%	23.766		20.926		23.503		21.714		23.063		25.063		21.915		23.097	
		97.5%	20.018	0.004525	17.626	0.010397	19.796	0.020412	18.289	0.032338	19.426	0.045098	21.110	0.054776	18.459	0.060815	19.454	0.076046
		95.0%	16.801		14.793		16.615		15.350		16.304		17.718		15.492		16.327	
		90.0%	13.083		11.520		12.938		11.953		12.696		13.797		12.064		12.715	
	8	99.5%	28.030		26.831		22.536		21.951		27.577		25.400		24.426		24.246	
		99.0%	25.331		24.247		20.366		19.837		24.921		22.954		22.073		21.911	
		97.5%	21.336	0.003486	20.423	0.009277	17.154	0.020588	16.708	0.028012	20.991	0.039564	19.334	0.046588	18.592	0.058317	18.455	0.067527
		95.0%	17.907		17.140		14.397		14.023		17.617		16.227		15.604		15.489	
		90.0%	13.944		13.348		11.211		10.920		13.719		12.636		12.151		12.062	
	10	99.5%	26.132		30.422		30.925		25.491		29.572		23.090		24.657		29.354	
		99.0%	23.615		27.492		27.946		23.036		26.724		20.866		22.282		26.526	
		97.5%	19.890	0.003126	23.156	0.008532	23.539	0.015091	19.403	0.024090	22.509	0.029003	17.576	0.041169	18.768	0.046847	22.343	0.051828
		95.0%	16.694		19.435		19.756		16.284		18.892		14.751		15.752		18.752	
		90.0%	13.000		15.134		15.384		12.681		14.711		11.487		12.266		14.603	
	12	99.5%	27.791		29.478		24.498		27.406		27.944		24.344		25.682		29.661	
		99.0%	25.114		26.639		22.139		24.766		25.253		21.999		23.208		26.804	
		97.5%	21.153	0.002979	22.438	0.008248	18.647	0.015269	20.860	0.022904	21.270	0.029982	18.530	0.038463	19.548	0.043736	22.577	0.052054
		95.0%	17.754		18.832		15.650		17.508		17.852		15.552		16.406		18.948	
		90.0%	13.825		14.665		12.187		13.634		13.902		12.111		12.776		14.755	
	14	99.5%	27.602		26.360		28.539		32.911		22.483		24.195		29.288		30.731	
		99.0%	24.944		23.821		25.790		29.741		20.318		21.865		26.467		27.771	
		97.5%	21.010	0.003029	20.064	0.007808	21.723	0.015133	25.051	0.021851	17.113	0.031602	18.417	0.036741	22.293	0.046969	23.391	0.054934
		95.0%	17.633		16.840		18.232		21.025		14.363		15.457		18.710		19.632	
		90.0%	13.731		13.113		14.197		16.372		11.185		12.037		14.570		15.288	
	16	99.5%	27.367		26.152		31.185		26.631		27.795		28.330		26.183		28.114	
		99.0%	24.731		23.634		28.182		24.066		25.118		25.602		23.662		25.406	
		97.5%	20.831	0.003068	19.906	0.007230	23.737	0.013789	20.271	0.022651	21.157	0.029614	21.564	0.034366	19.930	0.042787	21.399	0.052863
		95.0%	17.483		16.707		19.922		17.013		17.757		18.098		16.727		17.960	
		90.0%	13.615		13.010		15.514		13.248		13.828		14.094		13.026		13.986	
	18	99.5%	27.866		29.587		26.531		27.082		25.759		27.089		28.439		27.917	
		99.0%	25.182		26.737		23.976		24.474		23.278		24.480		25.700		25.229	
		97.5%	21.211	0.002772	22.520	0.007512	20.195	0.012363	20.614	0.021709	19.607	0.030166	20.619	0.034850	21.647	0.039834	21.250	0.047828
		95.0%	17.802		18.901		16.949		17.301		16.456		17.305		18.168		17.835	
		90.0%	13.863		14.719		13.199		13.473		12.815		13.476		14.148		13.888	
	20	99.5%	26.324		23.400		30.808		26.549		27.016		25.041		28.911		29.750	
		99.0%	23.789		21.147		27.841		23.992		24.414		22.629		26.126		26.885	
		97.5%	20.037	0.002597	17.811	0.007054	23.450	0.012526	20.208	0.019533	20.564	0.028501	19.060	0.033257	22.006	0.038307	22.645	0.045114
		95.0%	16.817		14.949		19.681		16.960		17.259		15.997		18.469		19.005	
		90.0%	13.095		11.641		15.326		13.207		13.440		12.457		14.382		14.800	

Table 4.44. Table for Production Smoothing Analysis with Standard Deviation = 2% and Time = 12 Periods.

Production Smoothing
Standard Deviation = 2%, Time Frame = 12 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
	2	99.5%	0.647		0.725		0.689		0.699		0.552		0.613		0.583		0.567	
		99.0%	0.585		0.655		0.623		0.632		0.499		0.554		0.527		0.512	
		97.5%	0.493	0.000000	0.552	0.000960	0.524	0.001811	0.532	0.002814	0.420	0.003523	0.467	0.004680	0.444	0.005264	0.431	0.006685
		95.0%	0.414		0.463		0.440		0.446		0.353		0.392		0.372		0.362	
		90.0%	0.322		0.361		0.343		0.348		0.275		0.305		0.290		0.282	
	4	99.5%	0.719		0.634		0.588		0.627		0.705		0.645		0.631		0.678	
		99.0%	0.649		0.573		0.531		0.566		0.637		0.583		0.570		0.612	
		97.5%	0.547	0.000000	0.482	0.000612	0.448	0.001335	0.477	0.001901	0.536	0.002554	0.491	0.003257	0.480	0.004041	0.516	0.004526
		95.0%	0.459		0.405		0.376		0.400		0.450		0.412		0.403		0.433	
		90.0%	0.357		0.315		0.292		0.312		0.351		0.321		0.314		0.337	
	6	99.5%	0.679		0.723		0.745		0.659		0.695		0.658		0.733		0.701	
		99.0%	0.614		0.653		0.673		0.595		0.628		0.595		0.662		0.633	
		97.5%	0.517	0.000000	0.550	0.000528	0.567	0.001059	0.501	0.001574	0.529	0.002136	0.501	0.002680	0.558	0.003135	0.533	0.003709
		95.0%	0.434		0.462		0.476		0.421		0.444		0.420		0.468		0.448	
		90.0%	0.338		0.359		0.370		0.328		0.346		0.327		0.365		0.349	
	8	99.5%	0.708		0.627		0.810		0.630		0.683		0.766		0.672		0.718	
		99.0%	0.639		0.566		0.732		0.569		0.618		0.692		0.607		0.648	
		97.5%	0.539	0.000000	0.477	0.000471	0.617	0.000973	0.480	0.001455	0.520	0.002023	0.583	0.002391	0.512	0.002900	0.546	0.003417
		95.0%	0.452		0.400		0.518		0.402		0.437		0.489		0.429		0.458	
		90.0%	0.352		0.312		0.403		0.313		0.340		0.381		0.334		0.357	
	10	99.5%	0.689		0.703		0.815		0.705		0.681		0.613		0.728		0.706	
		99.0%	0.623		0.635		0.736		0.637		0.615		0.554		0.658		0.638	
		97.5%	0.525	0.000000	0.535	0.000473	0.620	0.000824	0.536	0.001274	0.518	0.001727	0.466	0.002349	0.554	0.002550	0.537	0.002863
		95.0%	0.440		0.449		0.521		0.450		0.435		0.391		0.465		0.451	
		90.0%	0.343		0.350		0.405		0.351		0.339		0.305		0.362		0.351	
	12	99.5%	0.708		0.777		0.752		0.750		0.746		0.742		0.730		0.702	
		99.0%	0.640		0.702		0.679		0.678		0.674		0.671		0.660		0.635	
		97.5%	0.539	0.000000	0.591	0.000286	0.572	0.000555	0.571	0.000862	0.568	0.001107	0.565	0.001393	0.556	0.001713	0.535	0.001981
		95.0%	0.452		0.496		0.480		0.479		0.477		0.474		0.466		0.449	
		90.0%	0.352		0.387		0.374		0.373		0.371		0.369		0.363		0.349	
	14	99.5%	0.701		0.700		0.666		0.690		0.697		0.752		0.703		0.722	
		99.0%	0.633		0.632		0.601		0.623		0.630		0.679		0.636		0.653	
		97.5%	0.533	0.000000	0.533	0.000000	0.507	0.000000	0.525	0.000000	0.530	0.000000	0.572	0.000000	0.535	0.000000	0.550	0.000000
		95.0%	0.448		0.447		0.425		0.441		0.445		0.480		0.449		0.461	
		90.0%	0.349		0.348		0.331		0.343		0.347		0.374		0.350		0.359	
	16	99.5%	0.786		0.724		0.705		0.688		0.708		0.692		0.735		0.798	
		99.0%	0.710		0.654		0.637		0.622		0.640		0.625		0.664		0.721	
		97.5%	0.598	0.000000	0.551	0.000000	0.537	0.000000	0.524	0.000000	0.539	0.000000	0.527	0.000000	0.560	0.000000	0.607	0.000000
		95.0%	0.502		0.462		0.451		0.440		0.452		0.442		0.470		0.510	
		90.0%	0.391		0.360		0.351		0.342		0.352		0.344		0.366		0.397	
	18	99.5%	0.664		0.665		0.675		0.774		0.707		0.684		0.702		0.693	
		99.0%	0.600		0.601		0.610		0.699		0.639		0.618		0.634		0.626	
		97.5%	0.505	0.000000	0.506	0.000000	0.514	0.000000	0.589	0.000000	0.538	0.000000	0.521	0.000000	0.534	0.000000	0.527	0.000000
		95.0%	0.424		0.425		0.431		0.494		0.452		0.437		0.448		0.443	
		90.0%	0.330		0.331		0.336		0.385		0.352		0.340		0.349		0.345	
	20	99.5%	0.729		0.735		0.782		0.717		0.730		0.808		0.685		0.707	
		99.0%	0.659		0.664		0.707		0.648		0.659		0.730		0.619		0.639	
		97.5%	0.555	0.000000	0.560	0.000000	0.595	0.000000	0.546	0.000000	0.555	0.000000	0.615	0.000000	0.521	0.000000	0.538	0.000000
		95.0%	0.466		0.470		0.500		0.458		0.466		0.516		0.438		0.452	
		90.0%	0.363		0.366		0.389		0.357		0.363		0.402		0.341		0.352	

Table 4.45. Table for Production Smoothing Analysis with Standard Deviation = 5% and Time = 12 Periods.

Production Smoothing
Standard Deviation = 5%, Time Frame = 12 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	1.403		1.806		1.543		1.764		1.595		1.702		1.584		1.476	
	99.0%	1.268		1.632		1.394		1.594		1.441		1.538		1.431		1.334	
	97.5%	1.068	0.000938	1.374	0.002815	1.175	0.004303	1.342	0.006749	1.214	0.008887	1.295	0.010847	1.205	0.013876	1.123	0.016071
	95.0%	0.896		1.154		0.986		1.127		1.019		1.087		1.012		0.943	
	90.0%	0.698		0.898		0.768		0.877		0.793		0.847		0.788		0.734	
4	99.5%	1.696		1.836		1.584		1.797		1.728		1.575		1.687		1.429	
	99.0%	1.533		1.660		1.431		1.624		1.562		1.424		1.525		1.291	
	97.5%	1.291	0.000681	1.398	0.001998	1.206	0.003150	1.368	0.004801	1.315	0.006777	1.199	0.008892	1.284	0.010062	1.088	0.011818
	95.0%	1.084		1.173		1.012		1.148		1.104		1.006		1.078		0.913	
	90.0%	0.844		0.914		0.788		0.894		0.860		0.784		0.839		0.711	
6	99.5%	1.871		1.850		1.724		1.907		1.533		1.894		1.578		1.632	
	99.0%	1.691		1.672		1.558		1.723		1.385		1.711		1.426		1.475	
	97.5%	1.424	0.000536	1.408	0.001640	1.312	0.002579	1.451	0.004200	1.167	0.005845	1.441	0.006898	1.201	0.008114	1.242	0.009380
	95.0%	1.195		1.182		1.101		1.218		0.979		1.210		1.008		1.043	
	90.0%	0.931		0.920		0.858		0.948		0.762		0.942		0.785		0.812	
8	99.5%	1.794		1.656		1.807		1.686		1.700		1.687		1.731		1.917	
	99.0%	1.622		1.497		1.633		1.524		1.536		1.525		1.564		1.733	
	97.5%	1.366	0.000440	1.261	0.001629	1.376	0.002393	1.284	0.003791	1.294	0.005057	1.284	0.006224	1.318	0.007532	1.459	0.008487
	95.0%	1.146		1.058		1.155		1.077		1.086		1.078		1.106		1.225	
	90.0%	0.893		0.824		0.899		0.839		0.845		0.839		0.861		0.954	
10	99.5%	1.969		1.997		1.791		1.915		1.948		1.830		1.589		1.690	
	99.0%	1.779		1.804		1.618		1.731		1.760		1.654		1.436		1.527	
	97.5%	1.499	0.000443	1.520	0.001298	1.363	0.002186	1.458	0.003562	1.483	0.004130	1.393	0.005179	1.210	0.006658	1.286	0.007548
	95.0%	1.258		1.275		1.144		1.224		1.244		1.169		1.015		1.080	
	90.0%	0.979		0.993		0.891		0.953		0.969		0.911		0.791		0.841	
12	99.5%	1.751		1.531		1.998		1.934		1.704		1.854		1.771		1.997	
	99.0%	1.582		1.384		1.805		1.748		1.540		1.675		1.601		1.804	
	97.5%	1.333	0.000287	1.166	0.000862	1.521	0.001437	1.472	0.002299	1.297	0.002872	1.411	0.003726	1.348	0.004246	1.520	0.005063
	95.0%	1.119		0.978		1.276		1.235		1.089		1.184		1.132		1.276	
	90.0%	0.871		0.762		0.994		0.962		0.848		0.922		0.881		0.993	
14	99.5%	1.825		1.893		1.726		1.756		1.758		1.661		1.813		1.590	
	99.0%	1.649		1.711		1.560		1.587		1.588		1.501		1.639		1.437	
	97.5%	1.389	0.000000	1.441	0.000000	1.314	0.000000	1.336	0.000000	1.338	0.000000	1.264	0.000000	1.380	0.000000	1.210	0.000000
	95.0%	1.166		1.209		1.103		1.122		1.123		1.061		1.158		1.016	
	90.0%	0.908		0.942		0.859		0.873		0.874		0.826		0.902		0.791	
16	99.5%	1.871		1.755		1.655		1.803		1.658		1.658		1.917		1.725	
	99.0%	1.690		1.586		1.496		1.629		1.499		1.498		1.733		1.559	
	97.5%	1.424	0.000000	1.336	0.000000	1.260	0.000000	1.372	0.000000	1.262	0.000000	1.262	0.000000	1.459	0.000000	1.313	0.000000
	95.0%	1.195		1.121		1.057		1.152		1.059		1.059		1.225		1.102	
	90.0%	0.931		0.873		0.823		0.897		0.825		0.825		0.954		0.858	
18	99.5%	1.820		1.573		1.869		2.034		1.580		1.727		1.662		1.903	
	99.0%	1.645		1.421		1.689		1.838		1.428		1.561		1.502		1.719	
	97.5%	1.385	0.000000	1.197	0.000000	1.422	0.000000	1.548	0.000000	1.202	0.000000	1.314	0.000000	1.265	0.000000	1.448	0.000000
	95.0%	1.163		1.005		1.194		1.299		1.009		1.103		1.062		1.215	
	90.0%	0.905		0.782		0.930		1.012		0.786		0.859		0.827		0.947	
20	99.5%	1.699		1.760		1.798		2.084		1.740		1.602		1.719		1.944	
	99.0%	1.536		1.590		1.625		1.884		1.572		1.448		1.554		1.757	
	97.5%	1.293	0.000000	1.339	0.000000	1.369	0.000000	1.586	0.000000	1.324	0.000000	1.220	0.000000	1.309	0.000000	1.480	0.000000
	95.0%	1.086		1.124		1.149		1.331		1.112		1.024		1.098		1.242	
	90.0%	0.845		0.875		0.894		1.037		0.866		0.797		0.855		0.967	

Table 4.46. Table for Production Smoothing Analysis with Standard Deviation = 10% and Time = 12 Periods.

Production Smoothing
Standard Deviation = 10%, Time Frame = 12 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
	99.5%	3.535		3.628		3.302		3.267		3.300		3.359		2.974		2.614	
	99.0%	3.194		3.279		2.984		2.952		2.982		3.035		2.688		2.362	
2	97.5%	2.690	0.001838	2.762	0.004759	2.514	0.008421	2.487	0.012725	2.512	0.018900	2.556	0.023574	2.264	0.026357	1.989	0.028828
	95.0%	2.258		2.318		2.110		2.087		2.108		2.146		1.900		1.670	
	90.0%	1.758		1.805		1.643		1.625		1.642		1.671		1.480		1.300	
	99.5%	3.906		3.928		3.818		3.629		3.477		3.256		3.193		3.149	
	99.0%	3.530		3.549		3.451		3.279		3.142		2.942		2.885		2.846	
4	97.5%	2.973	0.001326	2.990	0.003028	2.906	0.006130	2.762	0.009225	2.647	0.011729	2.478	0.017454	2.430	0.018868	2.397	0.023385
	95.0%	2.495		2.509		2.439		2.318		2.221		2.080		2.040		2.012	
	90.0%	1.943		1.954		1.900		1.805		1.730		1.620		1.588		1.567	
	99.5%	3.528		3.288		3.727		3.180		3.269		3.387		3.593		3.338	
	99.0%	3.188		2.971		3.368		2.874		2.954		3.061		3.247		3.017	
6	97.5%	2.685	0.001029	2.503	0.002770	2.837	0.005458	2.421	0.008674	2.488	0.011013	2.578	0.014340	2.735	0.015467	2.541	0.017474
	95.0%	2.254		2.101		2.381		2.032		2.088		2.164		2.295		2.133	
	90.0%	1.755		1.636		1.854		1.582		1.626		1.685		1.787		1.661	
	99.5%	3.458		3.430		3.936		3.572		3.314		3.231		3.455		3.422	
	99.0%	3.125		3.099		3.557		3.228		2.995		2.920		3.122		3.092	
8	97.5%	2.632	0.000956	2.611	0.002455	2.996	0.004758	2.719	0.007576	2.523	0.009607	2.459	0.011735	2.630	0.015793	2.604	0.016455
	95.0%	2.209		2.191		2.514		2.282		2.117		2.064		2.207		2.186	
	90.0%	1.720		1.706		1.958		1.777		1.649		1.607		1.719		1.702	
	99.5%	3.940		3.521		3.455		3.272		3.730		3.983		3.508		3.448	
	99.0%	3.560		3.182		3.122		2.957		3.371		3.600		3.170		3.116	
10	97.5%	2.999	0.000864	2.680	0.002310	2.630	0.004436	2.491	0.006126	2.840	0.008525	3.032	0.010748	2.670	0.013559	2.625	0.015145
	95.0%	2.517		2.249		2.207		2.091		2.383		2.545		2.241		2.203	
	90.0%	1.960		1.751		1.719		1.628		1.856		1.982		1.745		1.715	
	99.5%	3.777		3.531		3.439		3.554		3.386		3.779		3.968		4.125	
	99.0%	3.413		3.191		3.108		3.212		3.060		3.415		3.586		3.728	
12	97.5%	2.875	0.000573	2.688	0.001437	2.618	0.002886	2.705	0.004284	2.577	0.005746	2.877	0.007194	3.020	0.008444	3.140	0.009853
	95.0%	2.413		2.256		2.197		2.270		2.163		2.414		2.535		2.635	
	90.0%	1.879		1.757		1.711		1.768		1.685		1.880		1.974		2.052	
	99.5%	3.710		3.995		3.542		3.710		3.585		3.265		3.447		3.720	
	99.0%	3.353		3.611		3.201		3.352		3.239		2.950		3.115		3.362	
14	97.5%	2.824	0.000000	3.041	0.000000	2.696	0.000000	2.824	0.000000	2.728	0.000000	2.485	0.000000	2.624	0.000000	2.832	0.000000
	95.0%	2.370		2.552		2.263		2.370		2.290		2.086		2.202		2.376	
	90.0%	1.846		1.988		1.762		1.845		1.783		1.624		1.715		1.851	
	99.5%	3.875		3.277		3.785		3.716		3.484		3.457		3.803		3.546	
	99.0%	3.501		2.961		3.420		3.358		3.148		3.124		3.437		3.205	
16	97.5%	2.949	0.000000	2.494	0.000000	2.881	0.000000	2.828	0.000000	2.652	0.000000	2.631	0.000000	2.895	0.000000	2.699	0.000000
	95.0%	2.475		2.093		2.418		2.374		2.226		2.208		2.430		2.265	
	90.0%	1.928		1.630		1.883		1.848		1.733		1.720		1.892		1.764	
	99.5%	3.971		3.393		3.613		4.310		3.263		4.071		4.139		3.759	
	99.0%	3.588		3.066		3.265		3.895		2.949		3.679		3.740		3.397	
18	97.5%	3.022	0.000000	2.583	0.000000	2.750	0.000000	3.281	0.000000	2.484	0.000000	3.099	0.000000	3.150	0.000000	2.861	0.000000
	95.0%	2.537		2.168		2.308		2.754		2.085		2.601		2.644		2.401	
	90.0%	1.975		1.688		1.797		2.144		1.623		2.025		2.059		1.870	
	99.5%	3.473		3.317		3.591		3.952		3.532		3.457		3.392		3.282	
	99.0%	3.138		2.997		3.245		3.572		3.191		3.124		3.065		2.966	
20	97.5%	2.643	0.000000	2.525	0.000000	2.733	0.000000	3.008	0.000000	2.688	0.000000	2.631	0.000000	2.582	0.000000	2.498	0.000000
	95.0%	2.219		2.119		2.294		2.525		2.256		2.208		2.167		2.096	
	90.0%	1.728		1.650		1.786		1.966		1.757		1.720		1.687		1.633	

Table 4.47. Table for Production Smoothing Analysis with Standard Deviation = 15% and Time = 12 Periods.

Production Smoothing
Standard Deviation = 15%, Time Frame = 12 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	5.536		5.529		4.810		5.575		4.450		4.456		5.112		4.561	
	99.0%	5.003		4.996		4.346		5.038		4.021		4.027		4.620		4.122	
	97.5%	4.214	0.002698	4.208	0.006757	3.661	0.013444	4.243	0.020417	3.387	0.026081	3.392	0.035020	3.891	0.038553	3.472	0.044863
	95.0%	3.537		3.532		3.072		3.561		2.843		2.847		3.266		2.914	
	90.0%	2.754		2.750		2.393		2.773		2.214		2.217		2.543		2.269	
4	99.5%	4.419		4.361		4.554		4.578		4.767		5.243		4.864		4.079	
	99.0%	3.994		3.941		4.115		4.137		4.308		4.738		4.396		3.686	
	97.5%	3.364	0.001982	3.319	0.005043	3.466	0.009791	3.484	0.015552	3.628	0.018623	3.991	0.024999	3.702	0.030212	3.105	0.034308
	95.0%	2.823		2.786		2.909		2.924		3.045		3.350		3.107		2.606	
	90.0%	2.198		2.169		2.265		2.277		2.371		2.608		2.420		2.029	
6	99.5%	5.061		4.989		5.977		5.202		4.744		5.214		4.569		4.840	
	99.0%	4.573		4.509		5.401		4.701		4.287		4.712		4.129		4.374	
	97.5%	3.852	0.001549	3.798	0.004197	4.549	0.007227	3.959	0.012335	3.611	0.015932	3.969	0.019942	3.478	0.026004	3.684	0.029195
	95.0%	3.233		3.187		3.818		3.323		3.030		3.331		2.919		3.092	
	90.0%	2.518		2.482		2.973		2.588		2.360		2.594		2.273		2.408	
8	99.5%	4.973		5.053		5.444		5.225		4.651		5.208		4.930		4.547	
	99.0%	4.494		4.566		4.920		4.721		4.203		4.706		4.455		4.109	
	97.5%	3.785	0.001522	3.846	0.004015	4.144	0.007647	3.977	0.011809	3.540	0.015305	3.964	0.017828	3.753	0.024349	3.461	0.029012
	95.0%	3.177		3.228		3.478		3.338		2.971		3.327		3.149		2.905	
	90.0%	2.474		2.514		2.708		2.599		2.314		2.591		2.453		2.262	
10	99.5%	5.330		5.412		5.170		5.893		5.442		4.758		5.148		4.796	
	99.0%	4.817		4.891		4.672		5.326		4.918		4.299		4.652		4.334	
	97.5%	4.057	0.001296	4.120	0.003201	3.935	0.006366	4.486	0.010026	4.143	0.013472	3.621	0.016484	3.919	0.017971	3.650	0.024474
	95.0%	3.405		3.458		3.302		3.765		3.477		3.039		3.289		3.064	
	90.0%	2.652		2.693		2.572		2.932		2.707		2.367		2.561		2.386	
12	99.5%	5.198		5.284		4.835		4.935		5.317		5.692		5.123		4.804	
	99.0%	4.697		4.775		4.369		4.460		4.805		5.144		4.630		4.341	
	97.5%	3.956	0.000862	4.022	0.002299	3.680	0.004283	3.757	0.006562	4.047	0.008515	4.333	0.010918	3.900	0.012988	3.656	0.015195
	95.0%	3.320		3.376		3.088		3.153		3.397		3.636		3.273		3.069	
	90.0%	2.586		2.629		2.405		2.455		2.645		2.832		2.549		2.390	
14	99.5%	5.738		5.311		5.112		5.287		5.561		5.485		5.047		5.829	
	99.0%	5.185		4.800		4.620		4.778		5.025		4.957		4.561		5.267	
	97.5%	4.367	0.000000	4.043	0.000000	3.891	0.000000	4.024	0.000000	4.233	0.000000	4.175	0.000000	3.842	0.000000	4.437	0.000000
	95.0%	3.665		3.393		3.266		3.378		3.553		3.504		3.225		3.724	
	90.0%	2.854		2.642		2.543		2.630		2.766		2.729		2.511		2.900	
16	99.5%	4.599		5.244		5.307		5.101		5.246		5.088		5.258		5.318	
	99.0%	4.156		4.739		4.796		4.610		4.741		4.598		4.752		4.806	
	97.5%	3.501	0.000000	3.991	0.000000	4.040	0.000000	3.883	0.000000	3.993	0.000000	3.873	0.000000	4.002	0.000000	4.048	0.000000
	95.0%	2.938		3.350		3.390		3.259		3.351		3.250		3.359		3.397	
	90.0%	2.288		2.609		2.640		2.538		2.610		2.531		2.616		2.645	
18	99.5%	5.654		5.408		5.178		5.283		4.759		5.534		5.563		5.000	
	99.0%	5.109		4.887		4.679		4.774		4.301		5.001		5.027		4.518	
	97.5%	4.304	0.000000	4.116	0.000000	3.941	0.000000	4.021	0.000000	3.622	0.000000	4.212	0.000000	4.234	0.000000	3.806	0.000000
	95.0%	3.612		3.455		3.308		3.375		3.040		3.535		3.554		3.194	
	90.0%	2.813		2.690		2.576		2.628		2.368		2.753		2.767		2.487	
20	99.5%	5.610		5.602		5.509		5.206		5.474		5.186		5.705		5.990	
	99.0%	5.070		5.062		4.979		4.705		4.947		4.686		5.156		5.413	
	97.5%	4.270	0.000000	4.264	0.000000	4.194	0.000000	3.963	0.000000	4.167	0.000000	3.947	0.000000	4.343	0.000000	4.559	0.000000
	95.0%	3.584		3.578		3.520		3.326		3.497		3.313		3.645		3.827	
	90.0%	2.791		2.787		2.741		2.590		2.723		2.580		2.838		2.980	

Table 4.48. Table for Production Smoothing Analysis with Standard Deviation = 20% and Time = 12 Periods.

Production Smoothing
Standard Deviation = 20%, Time Frame = 12 periods

		Flex Bound Width: 2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	6.510		7.032		6.995		6.725		6.688		5.816		6.049		5.241	
	99.0%	5.883		6.354		6.322		6.077		6.044		5.255		5.466		4.737	
	97.5%	4.955	0.003651	5.352	0.010458	5.325	0.017670	5.119	0.028135	5.091	0.038440	4.427	0.044514	4.604	0.054689	3.990	0.061965
	95.0%	4.159		4.492		4.469		4.296		4.273		3.715		3.864		3.348	
	90.0%	3.239		3.498		3.480		3.345		3.327		2.893		3.009		2.607	
4	99.5%	6.725		6.532		7.552		6.635		6.309		6.949		7.137		6.977	
	99.0%	6.078		5.903		6.824		5.996		5.701		6.280		6.450		6.305	
	97.5%	5.119	0.002573	4.972	0.006730	5.748	0.013554	5.050	0.019994	4.802	0.025257	5.290	0.030417	5.433	0.039303	5.311	0.044326
	95.0%	4.296		4.173		4.824		4.238		4.030		4.439		4.560		4.457	
	90.0%	3.346		3.249		3.757		3.301		3.139		3.457		3.551		3.471	
6	99.5%	6.638		7.076		6.246		6.443		6.088		6.858		6.127		7.156	
	99.0%	5.999		6.394		5.644		5.823		5.501		6.197		5.537		6.467	
	97.5%	5.053	0.002117	5.386	0.005242	4.754	0.010601	4.904	0.016915	4.634	0.023143	5.220	0.027015	4.663	0.033076	5.447	0.034928
	95.0%	4.241		4.520		3.990		4.116		3.889		4.381		3.914		4.572	
	90.0%	3.302		3.520		3.107		3.205		3.028		3.412		3.048		3.560	
8	99.5%	6.285		6.869		7.470		7.089		7.268		6.875		6.843		7.187	
	99.0%	5.680		6.208		6.751		6.406		6.568		6.213		6.184		6.495	
	97.5%	4.784	0.001960	5.229	0.005031	5.686	0.009862	5.396	0.014088	5.532	0.020152	5.233	0.024914	5.208	0.032021	5.471	0.034157
	95.0%	4.015		4.388		4.772		4.529		4.643		4.392		4.371		4.592	
	90.0%	3.127		3.417		3.716		3.527		3.616		3.420		3.404		3.576	
10	99.5%	6.468		7.137		5.990		6.966		6.591		7.220		6.894		6.743	
	99.0%	5.845		6.450		5.413		6.295		5.956		6.525		6.230		6.094	
	97.5%	4.923	0.001807	5.433	0.003919	4.560	0.008930	5.302	0.013735	5.017	0.016386	5.496	0.023381	5.248	0.025304	5.133	0.030411
	95.0%	4.132		4.560		3.827		4.450		4.211		4.612		4.404		4.308	
	90.0%	3.218		3.551		2.980		3.465		3.279		3.592		3.430		3.354	
12	99.5%	7.173		6.736		6.301		6.366		6.638		7.282		7.013		6.499	
	99.0%	6.482		6.087		5.694		5.753		5.999		6.581		6.338		5.873	
	97.5%	5.460	0.001155	5.127	0.002887	4.796	0.005774	4.845	0.008610	5.053	0.011455	5.543	0.014372	5.338	0.017230	4.947	0.020000
	95.0%	4.583		4.303		4.025		4.067		4.241		4.652		4.480		4.152	
	90.0%	3.569		3.351		3.135		3.167		3.302		3.623		3.489		3.233	
14	99.5%	6.699		7.274		6.941		6.221		6.752		6.619		6.943		7.367	
	99.0%	6.053		6.574		6.273		5.622		6.102		5.982		6.275		6.657	
	97.5%	5.099	0.000000	5.537	0.000000	5.284	0.000000	4.735	0.000000	5.140	0.000000	5.038	0.000000	5.285	0.000000	5.607	0.000000
	95.0%	4.279		4.647		4.434		3.974		4.314		4.229		4.436		4.706	
	90.0%	3.332		3.619		3.453		3.095		3.359		3.293		3.454		3.665	
16	99.5%	7.076		7.244		6.866		7.015		6.213		7.445		5.774		7.438	
	99.0%	6.395		6.546		6.205		6.339		5.615		6.728		5.217		6.722	
	97.5%	5.386	0.000000	5.514	0.000000	5.226	0.000000	5.339	0.000000	4.729	0.000000	5.667	0.000000	4.395	0.000000	5.662	0.000000
	95.0%	4.520		4.628		4.386		4.481		3.969		4.756		3.688		4.752	
	90.0%	3.520		3.604		3.416		3.490		3.091		3.704		2.872		3.700	
18	99.5%	7.399		6.372		6.771		7.401		6.674		7.000		7.419		7.288	
	99.0%	6.686		5.758		6.118		6.688		6.031		6.326		6.704		6.586	
	97.5%	5.632	0.000000	4.850	0.000000	5.153	0.000000	5.633	0.000000	5.080	0.000000	5.328	0.000000	5.647	0.000000	5.547	0.000000
	95.0%	4.727		4.070		4.325		4.728		4.263		4.472		4.739		4.656	
	90.0%	3.681		3.170		3.368		3.682		3.320		3.482		3.691		3.626	
20	99.5%	6.802		6.069		6.414		6.012		6.652		7.470		6.709		7.104	
	99.0%	6.147		5.484		5.797		5.433		6.011		6.751		6.063		6.420	
	97.5%	5.177	0.000000	4.619	0.000000	4.882	0.000000	4.576	0.000000	5.063	0.000000	5.686	0.000000	5.107	0.000000	5.408	0.000000
	95.0%	4.345		3.877		4.098		3.841		4.250		4.772		4.286		4.539	
	90.0%	3.384		3.019		3.191		2.991		3.309		3.716		3.338		3.534	

Table 4.49. Table for Production Smoothing Analysis with Standard Deviation = 25% and Time = 12 Periods.

Production Smoothing
Standard Deviation = 25%, Time Frame = 12 periods

			Flex Bound Width															
			2%		5%		10%		15%		20%		25%		30%		35%	
			Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
		99.5%	8.340		8.354		7.499		7.659		7.541		6.745		5.795		7.084	
		99.0%	7.537		7.550		6.777		6.921		6.815		6.095		5.237		6.402	
	2	97.5%	6.348	0.004484	6.359	0.012036	5.708	0.023141	5.829	0.031882	5.740	0.041297	5.134	0.060009	4.411	0.065933	5.392	0.080715
		95.0%	5.328		5.337		4.791		4.893		4.818		4.309		3.702		4.526	
		90.0%	4.149		4.156		3.731		3.810		3.752		3.355		2.883		3.524	
		99.5%	7.761		8.754		8.947		7.518		7.577		7.792		7.612		7.784	
		99.0%	7.013		7.911		8.085		6.794		6.847		7.042		6.879		7.034	
	4	97.5%	5.907	0.003137	6.663	0.008147	6.810	0.016032	5.722	0.026914	5.767	0.033738	5.931	0.037630	5.794	0.050939	5.925	0.054151
		95.0%	4.958		5.592		5.716		4.803		4.841		4.978		4.863		4.973	
		90.0%	3.861		4.355		4.451		3.740		3.769		3.877		3.787		3.872	
		99.5%	8.814		8.671		8.827		8.265		7.559		8.243		7.444		6.793	
		99.0%	7.966		7.836		7.977		7.469		6.831		7.449		6.727		6.139	
	6	97.5%	6.709	0.002490	6.600	0.006970	6.719	0.012790	6.291	0.020513	5.753	0.028584	6.274	0.033096	5.666	0.038588	5.171	0.044374
		95.0%	5.631		5.540		5.639		5.280		4.829		5.266		4.756		4.340	
		90.0%	4.385		4.314		4.391		4.111		3.760		4.101		3.703		3.379	
		99.5%	8.677		7.882		8.292		8.387		8.509		7.164		8.671		8.214	
		99.0%	7.841		7.122		7.493		7.580		7.689		6.474		7.836		7.423	
	8	97.5%	6.604	0.002180	5.999	0.006869	6.312	0.011357	6.384	0.017576	6.476	0.024794	5.453	0.030483	6.600	0.037492	6.252	0.044090
		95.0%	5.543		5.035		5.297		5.358		5.436		4.576		5.539		5.248	
		90.0%	4.316		3.921		4.125		4.173		4.233		3.564		4.314		4.086	
		99.5%	8.724		8.508		8.567		8.074		8.686		8.019		7.882		9.168	
		99.0%	7.884		7.689		7.741		7.296		7.850		7.247		7.123		8.285	
Flex Bound Length	10	97.5%	6.641	0.002441	6.476	0.005466	6.521	0.010452	6.145	0.016737	6.612	0.021550	6.104	0.027088	5.999	0.030487	6.978	0.037850
		95.0%	5.573		5.435		5.473		5.158		5.549		5.123		5.035		5.857	
		90.0%	4.340		4.233		4.262		4.017		4.321		3.989		3.921		4.561	
		99.5%	8.340		8.350		8.144		8.086		8.060		7.858		8.259		7.457	
		99.0%	7.537		7.546		7.360		7.308		7.284		7.101		7.464		6.739	
	12	97.5%	6.348	0.001443	6.356	0.003750	6.199	0.007151	6.155	0.010888	6.135	0.014303	5.981	0.017865	6.287	0.021493	5.676	0.025154
		95.0%	5.328		5.334		5.203		5.166		5.149		5.020		5.276		4.764	
		90.0%	4.149		4.154		4.052		4.023		4.010		3.909		4.109		3.710	
		99.5%	8.687		8.575		7.920		7.897		8.525		7.987		9.393		8.680	
		99.0%	7.850		7.749		7.157		7.136		7.704		7.218		8.488		7.844	
	14	97.5%	6.612	0.000000	6.527	0.000000	6.028	0.000000	6.011	0.000000	6.489	0.000000	6.080	0.000000	7.150	0.000000	6.607	0.000000
		95.0%	5.549		5.478		5.060		5.045		5.446		5.103		6.001		5.545	
		90.0%	4.322		4.266		3.940		3.928		4.241		3.974		4.673		4.318	
		99.5%	8.364		8.687		8.393		8.705		8.299		9.432		8.957		8.431	
		99.0%	7.559		7.850		7.585		7.866		7.500		8.523		8.094		7.619	
	16	97.5%	6.367	0.000000	6.612	0.000000	6.389	0.000000	6.626	0.000000	6.317	0.000000	7.179	0.000000	6.818	0.000000	6.418	0.000000
		95.0%	5.343		5.549		5.362		5.561		5.302		6.025		5.722		5.386	
		90.0%	4.161		4.321		4.175		4.330		4.129		4.692		4.456		4.194	
		99.5%	8.222		8.722		8.760		9.260		8.566		8.615		9.466		8.408	
		99.0%	7.430		7.882		7.917		8.369		7.741		7.785		8.555		7.598	
	18	97.5%	6.258	0.000000	6.639	0.000000	6.668	0.000000	7.049	0.000000	6.520	0.000000	6.557	0.000000	7.206	0.000000	6.400	0.000000
		95.0%	5.253		5.572		5.596		5.916		5.472		5.503		6.048		5.371	
		90.0%	4.090		4.339		4.358		4.607		4.261		4.286		4.709		4.183	
		99.5%	7.734		8.931		7.968		9.058		8.076		9.446		8.376		8.915	
		99.0%	6.989		8.071		7.201		8.186		7.298		8.536		7.569		8.057	
	20	97.5%	5.887	0.000000	6.798	0.000000	6.065	0.000000	6.895	0.000000	6.147	0.000000	7.190	0.000000	6.376	0.000000	6.786	0.000000
		95.0%	4.941		5.706		5.091		5.787		5.159		6.034		5.351		5.695	
		90.0%	3.848		4.443		3.964		4.506		4.017		4.699		4.167		4.435	

Table 4.50. Table for Production Smoothing Analysis with Standard Deviation = 30% and Time = 12 Periods.

Production Smoothing
Standard Deviation = 30%, Time Frame = 12 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
2	99.5%	8.857		9.049		9.107		8.200		9.097		8.455		8.294		8.425	
	99.0%	8.004		8.178		8.230		7.410		8.221		7.641		7.496		7.613	
	97.5%	6.741	0.005841	6.888	0.013049	6.932	0.027633	6.241	0.036163	6.924	0.054620	6.436	0.063669	6.313	0.081748	6.413	0.092496
	95.0%	5.658		5.781		5.818		5.238		5.811		5.401		5.299		5.382	
	90.0%	4.406		4.502		4.530		4.079		4.525		4.206		4.126		4.191	
4	99.5%	9.628		9.225		8.598		8.424		10.153		9.057		10.097		9.175	
	99.0%	8.701		8.337		7.770		7.613		9.175		8.185		9.124		8.291	
	97.5%	7.329	0.004128	7.022	0.010490	6.544	0.019885	6.412	0.029761	7.728	0.039851	6.894	0.050420	7.685	0.058362	6.984	0.068848
	95.0%	6.151		5.893		5.493		5.382		6.486		5.786		6.450		5.861	
	90.0%	4.790		4.589		4.277		4.191		5.051		4.506		5.023		4.564	
6	99.5%	9.677		9.741		10.499		10.022		9.714		8.686		8.444		9.722	
	99.0%	8.745		8.803		9.488		9.057		8.778		7.850		7.631		8.785	
	97.5%	7.366	0.003260	7.415	0.007470	7.992	0.014963	7.629	0.022382	7.394	0.032537	6.612	0.039394	6.427	0.048752	7.400	0.057597
	95.0%	6.182		6.223		6.707		6.403		6.206		5.549		5.394		6.211	
	90.0%	4.814		4.846		5.223		4.986		4.832		4.321		4.201		4.836	
8	99.5%	10.234		10.752		8.924		8.968		10.128		10.636		9.754		8.666	
	99.0%	9.248		9.716		8.065		8.104		9.152		9.612		8.815		7.831	
	97.5%	7.790	0.003071	8.184	0.006872	6.793	0.015294	6.826	0.023573	7.709	0.029191	8.096	0.035654	7.424	0.044625	6.596	0.055016
	95.0%	6.538		6.869		5.701		5.729		6.470		6.795		6.231		5.536	
	90.0%	5.091		5.349		4.440		4.461		5.038		5.291		4.852		4.311	
10	99.5%	10.112		10.089		10.056		9.974		9.514		9.131		9.430		9.659	
	99.0%	9.138		9.117		9.087		9.013		8.598		8.252		8.521		8.729	
	97.5%	7.697	0.002624	7.679	0.006760	7.654	0.012098	7.591	0.019741	7.242	0.025232	6.951	0.031783	7.177	0.037299	7.352	0.045622
	95.0%	6.460		6.445		6.424		6.371		6.078		5.833		6.024		6.171	
	90.0%	5.031		5.019		5.002		4.962		4.733		4.543		4.691		4.805	
12	99.5%	9.853		10.263		9.271		10.256		9.483		10.003		10.086		9.677	
	99.0%	8.904		9.274		8.378		9.268		8.570		9.039		9.114		8.745	
	97.5%	7.499	0.001733	7.811	0.004332	7.057	0.008652	7.806	0.012863	7.218	0.017048	7.614	0.021293	7.677	0.025886	7.366	0.030175
	95.0%	6.294		6.556		5.922		6.552		6.058		6.390		6.443		6.182	
	90.0%	4.901		5.105		4.612		5.102		4.718		4.976		5.017		4.814	
14	99.5%	10.890		9.257		10.122		9.821		10.562		9.997		9.172		9.227	
	99.0%	9.841		8.366		9.147		8.875		9.544		9.034		8.289		8.338	
	97.5%	8.289	0.000000	7.046	0.000000	7.704	0.000000	7.475	0.000000	8.039	0.000000	7.609	0.000000	6.981	0.000000	7.023	0.000000
	95.0%	6.957		5.914		6.466		6.274		6.747		6.386		5.859		5.895	
	90.0%	5.417		4.605		5.035		4.886		5.254		4.973		4.563		4.590	
16	99.5%	9.885		9.830		9.663		10.471		10.374		9.224		10.825		8.670	
	99.0%	8.933		8.884		8.732		9.463		9.375		8.336		9.782		7.835	
	97.5%	7.524	0.000000	7.483	0.000000	7.355	0.000000	7.971	0.000000	7.897	0.000000	7.021	0.000000	8.240	0.000000	6.599	0.000000
	95.0%	6.315		6.280		6.173		6.690		6.628		5.893		6.915		5.539	
	90.0%	4.917		4.890		4.807		5.209		5.161		4.589		5.385		4.313	
18	99.5%	9.974		8.716		8.761		10.069		9.619		10.719		10.085		8.921	
	99.0%	9.014		7.876		7.917		9.100		8.693		9.687		9.114		8.062	
	97.5%	7.592	0.000000	6.634	0.000000	6.669	0.000000	7.664	0.000000	7.322	0.000000	8.159	0.000000	7.677	0.000000	6.791	0.000000
	95.0%	6.372		5.568		5.597		6.433		6.145		6.848		6.443		5.699	
	90.0%	4.962		4.336		4.358		5.009		4.785		5.332		5.017		4.438	
20	99.5%	9.905		9.957		8.918		9.343		9.479		10.243		8.913		8.955	
	99.0%	8.951		8.998		8.059		8.443		8.566		9.256		8.055		8.092	
	97.5%	7.539	0.000000	7.579	0.000000	6.788	0.000000	7.112	0.000000	7.215	0.000000	7.796	0.000000	6.785	0.000000	6.816	0.000000
	95.0%	6.328		6.361		5.697		5.969		6.056		6.543		5.694		5.721	
	90.0%	4.928		4.953		4.437		4.648		4.716		5.095		4.434		4.455	

Table 4.51. Table for Production Smoothing Analysis with Standard Deviation = 35% and Time = 12 Periods.

Production Smoothing
Standard Deviation = 35%, Time Frame = 12 periods

		Flex Bound Width															
		2%		5%		10%		15%		20%		25%		30%		35%	
Flex Bound Length		Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift	Inventory	Prod. Shift
	99.5%	11.057		8.591		10.089		9.749		9.677		9.389		9.367		8.371	
	99.0%	9.992		7.764		9.118		8.810		8.745		8.485		8.465		7.565	
2	97.5%	8.416	0.005542	6.539	0.016374	7.680	0.031643	7.420	0.049015	7.366	0.063486	7.147	0.075466	7.130	0.092927	6.372	0.113276
	95.0%	7.064		5.488		6.445		6.228		6.182		5.998		5.984		5.348	
	90.0%	5.501		4.274		5.019		4.850		4.814		4.671		4.660		4.164	
	99.5%	10.487		11.285		11.698		9.891		8.990		9.345		10.753		9.538	
	99.0%	9.477		10.198		10.572		8.938		8.124		8.445		9.718		8.619	
4	97.5%	7.982	0.004947	8.590	0.012009	8.904	0.021660	7.528	0.034015	6.843	0.046243	7.113	0.062225	8.185	0.073063	7.260	0.079062
	95.0%	6.699		7.209		7.473		6.318		5.743		5.970		6.870		6.093	
	90.0%	5.217		5.614		5.820		4.920		4.472		4.649		5.349		4.745	
	99.5%	10.302		9.406		10.822		9.402		9.813		10.875		10.226		9.976	
	99.0%	9.310		8.500		9.780		8.496		8.868		9.827		9.241		9.015	
6	97.5%	7.842	0.003963	7.159	0.009092	8.237	0.018686	7.156	0.028985	7.469	0.038742	8.277	0.050000	7.784	0.055977	7.593	0.065642
	95.0%	6.581		6.009		6.914		6.006		6.269		6.947		6.533		6.373	
	90.0%	5.125		4.679		5.384		4.677		4.882		5.410		5.087		4.963	
	99.5%	11.111		11.043		9.799		9.600		10.497		10.256		10.067		10.421	
	99.0%	10.041		9.979		8.856		8.675		9.486		9.269		9.098		9.417	
8	97.5%	8.458	0.003334	8.405	0.008317	7.459	0.018872	7.307	0.025759	7.990	0.035323	7.807	0.041060	7.663	0.052458	7.932	0.059073
	95.0%	7.098		7.054		6.260		6.133		6.706		6.552		6.431		6.657	
	90.0%	5.528		5.493		4.875		4.776		5.222		5.102		5.008		5.184	
	99.5%	11.185		11.348		12.271		11.285		12.029		9.697		9.485		12.255	
	99.0%	10.108		10.255		11.089		10.198		10.871		8.763		8.572		11.075	
10	97.5%	8.513	0.003209	8.638	0.008605	9.340	0.013859	8.590	0.022650	9.156	0.026371	7.381	0.038175	7.220	0.047103	9.328	0.050568
	95.0%	7.145		7.250		7.839		7.209		7.685		6.195		6.059		7.829	
	90.0%	5.564		5.645		6.105		5.614		5.984		4.824		4.719		6.097	
	99.5%	10.915		11.257		10.247		11.005		11.423		10.193		11.185		11.613	
	99.0%	9.864		10.173		9.260		9.945		10.323		9.211		10.108		10.495	
12	97.5%	8.308	0.002011	8.568	0.005188	7.800	0.010012	8.377	0.015202	8.695	0.020177	7.759	0.025327	8.514	0.029966	8.840	0.035065
	95.0%	6.973		7.191		6.546		7.030		7.297		6.512		7.146		7.419	
	90.0%	5.430		5.600		5.098		5.475		5.682		5.071		5.564		5.777	
	99.5%	11.417		9.964		11.607		12.344		9.160		10.587		11.803		11.451	
	99.0%	10.318		9.004		10.490		11.155		8.278		9.568		10.666		10.348	
14	97.5%	8.691	0.000000	7.584	0.000000	8.835	0.000000	9.396	0.000000	6.972	0.000000	8.059	0.000000	8.984	0.000000	8.716	0.000000
	95.0%	7.294		6.365		7.415		7.886		5.852		6.764		7.540		7.315	
	90.0%	5.680		4.957		5.774		6.141		4.557		5.267		5.872		5.696	
	99.5%	10.540		10.250		12.082		10.567		10.716		11.337		10.566		11.606	
	99.0%	9.525		9.263		10.919		9.549		9.684		10.245		9.549		10.489	
16	97.5%	8.023	0.000000	7.802	0.000000	9.197	0.000000	8.043	0.000000	8.156	0.000000	8.629	0.000000	8.043	0.000000	8.834	0.000000
	95.0%	6.734		6.548		7.719		6.751		6.846		7.242		6.750		7.415	
	90.0%	5.244		5.099		6.011		5.257		5.331		5.640		5.256		5.774	
	99.5%	11.482		11.643		11.384		11.071		9.798		10.725		11.754		10.997	
	99.0%	10.376		10.521		10.287		10.005		8.854		9.692		10.622		9.938	
18	97.5%	8.739	0.000000	8.862	0.000000	8.665	0.000000	8.427	0.000000	7.458	0.000000	8.164	0.000000	8.947	0.000000	8.370	0.000000
	95.0%	7.335		7.438		7.272		7.073		6.259		6.852		7.509		7.025	
	90.0%	5.712		5.792		5.663		5.508		4.874		5.335		5.847		5.471	
	99.5%	10.785		9.814		12.428		10.841		10.546		10.275		12.326		11.739	
	99.0%	9.746		8.869		11.231		9.797		9.530		9.286		11.139		10.608	
20	97.5%	8.209	0.000000	7.470	0.000000	9.459	0.000000	8.252	0.000000	8.027	0.000000	7.821	0.000000	9.382	0.000000	8.935	0.000000
	95.0%	6.890		6.270		7.939		6.926		6.737		6.564		7.874		7.499	
	90.0%	5.365		4.882		6.182		5.393		5.246		5.112		6.132		5.840	

4.5 How to Use the Tables

An important product of this research is the results that are shown in Tables 4.10 through 4.51. These tables are a result of many simulations to test the Retailer and Production Smoothing scenarios in authentic demand environments. To make the research applicable to industry, companies must have information that they may use to implement these techniques. Usually, research provides a single solution that requires so many assumptions that the answer is no longer applicable. Instead, this research provides two techniques that companies may choose between. Then, for each technique, there are a set of tables that display the tradeoffs between the significant factors.

The inventory is based on the coefficient of variation of the study. Coefficient of variation is the standard deviation divided by the mean. The goal of using this metric is to enable the user to utilize the tables regardless of the variation and average production. The columns of inventory values employ the standard deviation of inventory times a multiplier from the Z statistics tables to achieve the customer service level defined by the row. The inventory level is then multiplied by the average production to understand how much inventory is necessary in this environment.

For example, a company may want to use the flex bound length of 14 with an average production of 500 units to achieve a 99% customer service level while using the Retailer Smoothing method. They also note a standard deviation of 10% with alpha of 30% to follow demand. Therefore, the user turns to Table 4.16 to follow the table for flex bound length of 14. By following the row with alpha of 30% and customer service level of 99% to the column of standard deviation of 10%, the inventory is 19.039. This number must be multiplied by the average production to realize that inventory of 9520 units are necessary to buffer this environment. However, if the company wants to reduce its inventory, they may simply reduce the flex bound length to become more flexible. By reducing this lead time to 8 periods as shown in Table 4.13, the company only has to hold 4255 units in inventory to achieve a 99% customer service level.

As shown in Tables 4.10 through 4.19, the alpha, standard deviation, and flex bound length factors are significant when using the Retailer Smoothing technique. Therefore, a person may scan across the table to understand the tradeoffs between setting alpha and standard deviation by comparing the inventory and production shift values.

Similarly, inventory levels for the Production Smoothing technique may be located in the tables. However, Production Smoothing is different in the fact that it is also dependent on time. The longer the process runs without being reset, the more likely that variation will increase in the system. Therefore, additional inventory is needed to buffer the variation. The values for Production Smoothing may be found in Tables 4.20 through 4.51 to understand the impact of standard deviation, flex bound width, flex bound length, and time.

There is also a column called Production Shift in these tables. The purpose of this column is to provide the implementer with an understanding of how much the production levels may shift on average from period to period. All data values in this column represent the standard deviation between shifts in production. With this information, the user will be able to anticipate why the provided inventory levels are necessary. As before, the average production must be multiplied by the Production Shift value to interpret the information. For instance, using the Production Smoothing technique, a company may want a flex bound length of 8, flex bound width of 10%, while having a 25% standard deviation with 200 units produced on average. If they want to run for 100 periods, then 19303 units need to be held in inventory to buffer potential shifts of 3 units per period. If the time frame is cut in half to 50 periods, the inventory is reduced to just fewer than 7000 units. Further, 2748 units are necessary for 25 periods, and 1059 units provide buffer during 12 time periods.

Oke (2003) uses the concept of volume flexibility, which states the volume of production and/or demand may vary without having an adverse impact on efficiency or quality. As shown in Figure 4.11, most companies wish to use production volume to buffer against variability. Also, most of those companies that currently use inventory as a buffer will opt to use production volume to buffer against the uncertainty. With this discussion in mind, companies would probably want to opt for changes in production rather than using inventory to safeguard against stocking out due to varying demand.

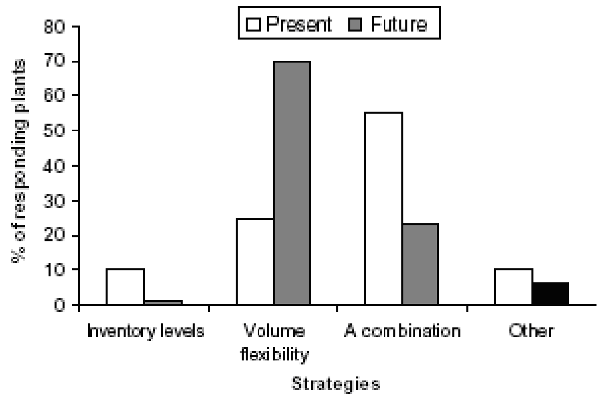

Figure 4.11. Type of Production Strategies Used (Oke 2003).

4.5.1 Using the Tables to Understand Retailer Smoothing Trends

Now that the tables have been presented and the technique to use the tables has been discussed, it is time to discuss the trends that occur. This section is devoted solely for the Retailer Smoothing technique. First, the impact of standard deviation, alpha, and customer service levels is discussed for short flex bound lengths. Then, these input variables are compared for long flex bound lengths. The results have been accumulated from the tables in section 4.4.1.

When observing Figure 4.12 for patterns at low flex bound lengths, the observed trend is that as alpha increases, the production shift increases also. However, the production shift increases more rapidly as the standard deviation increases. Figure 4.13 demonstrates the same trends, but the trends are clearer with the standard deviation on the x-axis. The pattern appears to be mostly linear as the input variables change. When the standard of deviation increases, there is more volatility in the demand. As alpha increases, the forecast, and hence the production schedule, will follow the demand information more closely. Therefore, the production amount will shift more as alpha and standard deviation both increase. Since standard deviation has a more dramatic impact, the user will want to reduce the unpredictability of demand to reduce the volatility of production.

A nonlinear trend is detected in Figure 4.14. As the alpha increases for the same level of standard deviation, the amount of inventory required to buffer against demand is decreased. This is an intuitive result because as

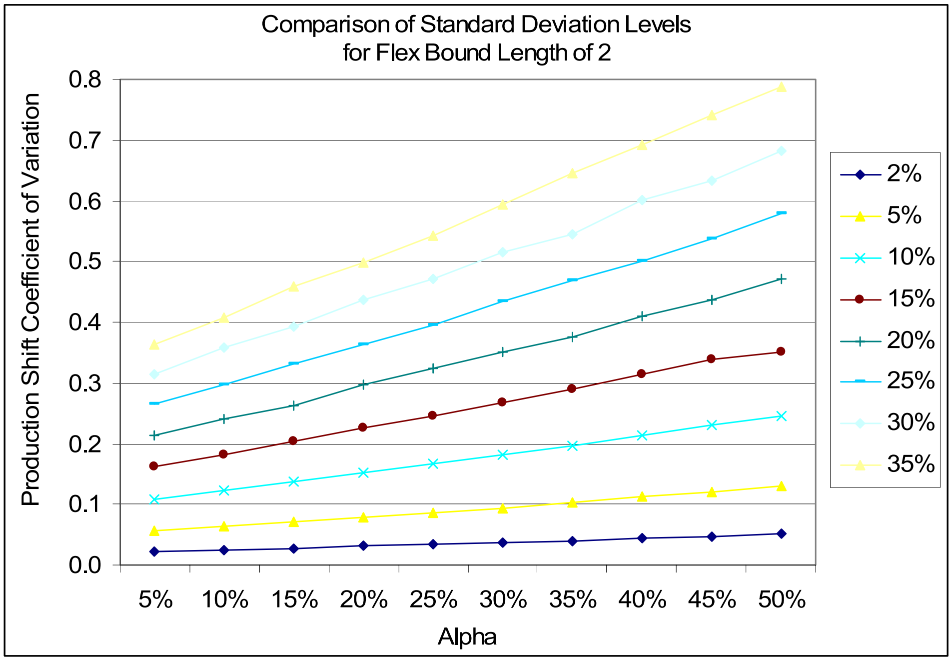

Figure 4.12. Retailer Smoothing Production Shift Comparison of Standard Deviation Levels for Flex Bound Length of 2.

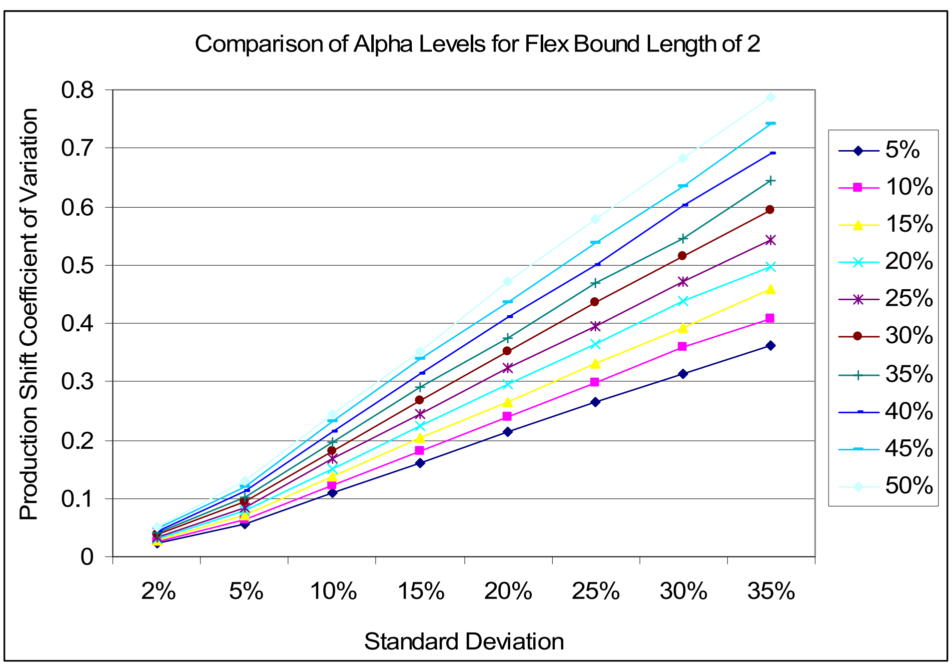

Figure 4.13. Retailer Smoothing Production Shift Comparison of Alpha Levels for Flex Bound Length of 2.

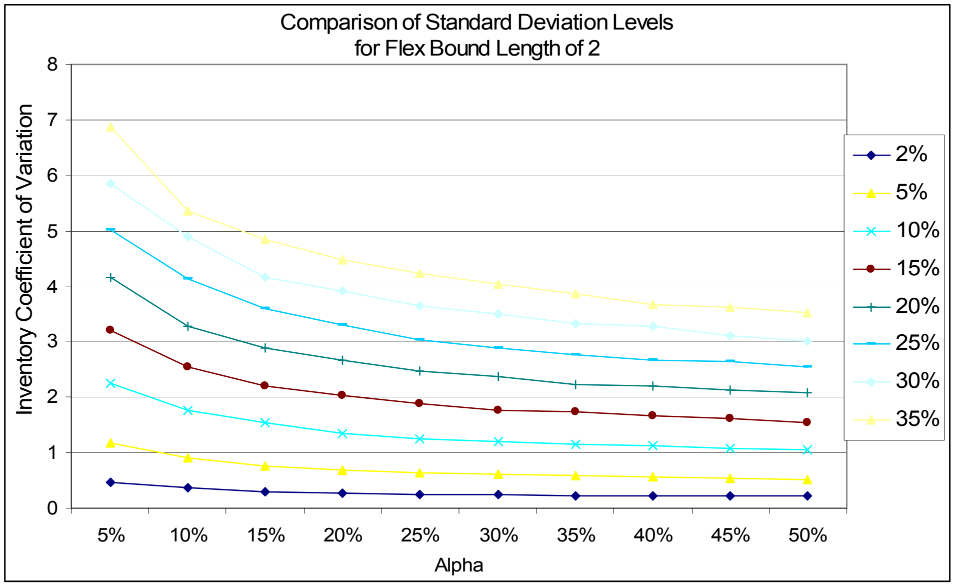

Figure 4.14. Retailer Smoothing Inventory Comparison of Standard Deviation Levels for Flex Bound Length of 2.

alpha increases, the model will more closely follow the demand and less inventory is needed. The point that is not intuitive is when alpha decreases, the inventory increases at an expanding rate, making the trend nonlinear. The logic behind this phenomenon is that more inventory will be needed at an increasing rate as production does not follow demand. Figure 4.15 further demonstrates that standard deviation has a more profound effect than alpha on inventory.

The trends that have been discussed thus far are indicative of comparing values of standard deviation and alpha when the desired customer service level remains constant. However, as the chosen customer service level increases, the inventory needed to buffer demand increases as shown in Figure 4.16. As discussed earlier, the greater the standard deviation, the more inventory that is necessary to shield the system from demand volatility. Yet, if both alpha and the standard deviation both increase, the level of inventory increases dramatically to achieve high customer service levels.

Additionally, similar charts are reviewed utilizing longer flex bound lengths. Figure 4.17 shows that as alpha and standard deviation increase for long flex bound lengths, the more the production will shift. The reasoning behind this phenomenon is that since the flex bound length is long, production is constant for a longer period of time. During this time, demand oscillates, but the flex limits constrain the production system from meeting the customers' demands. Then, when a new flex fence is updated, production must shift more to catch up to the volatile demand. For the longer flex

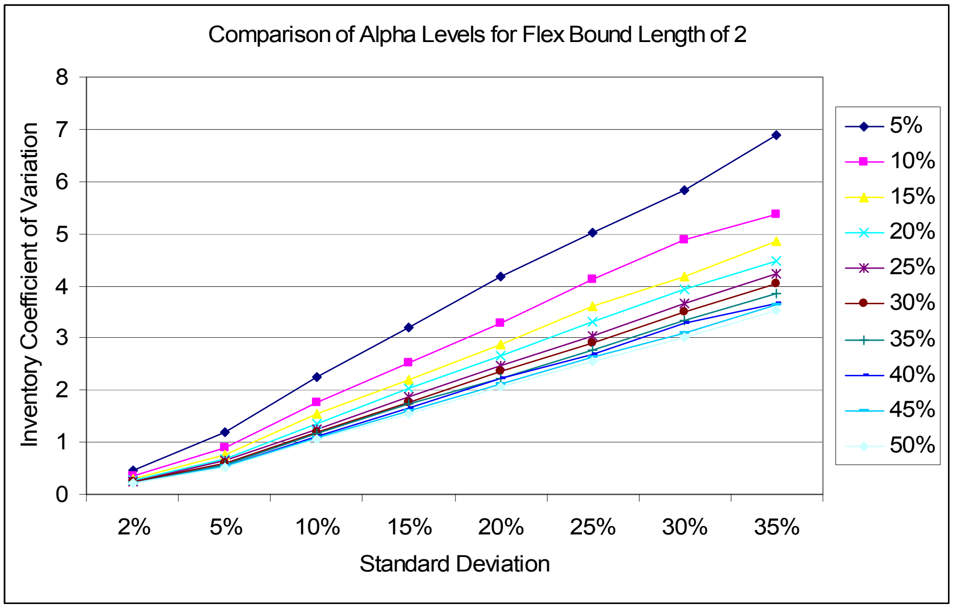

Figure 4.15. Retailer Smoothing Inventory Comparison of Alpha Levels for Flex Bound Length of 2.

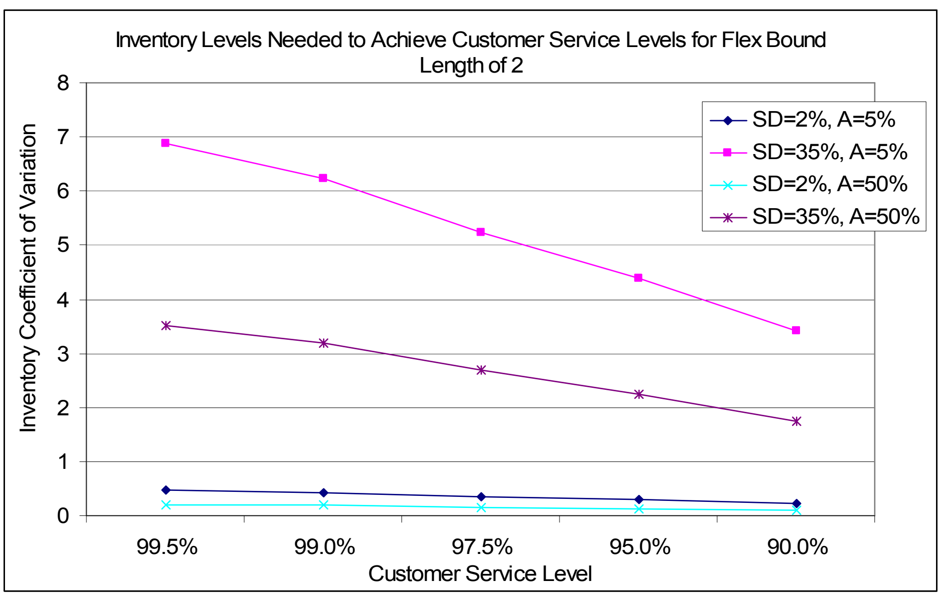

Figure 4.16. Retailer Smoothing Inventory Levels Needed to Achieve Customer Service Levels for Flex Bound Length of 2.

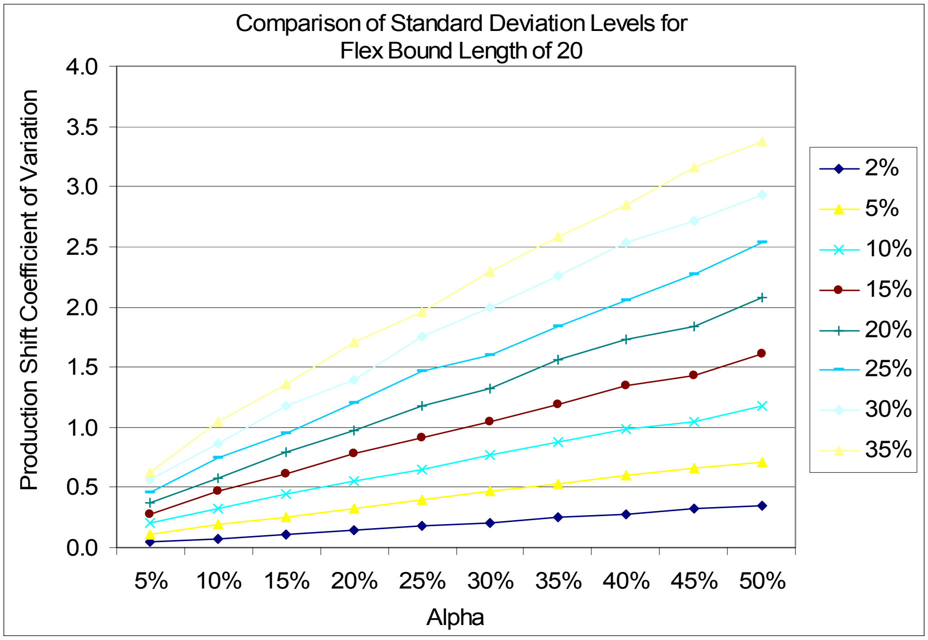

Figure 4.17. Retailer Smoothing Production Shift Comparison of Standard Deviation Levels for Flex Bound Length of 20.

bounds, standard deviation and alpha appear to have an equal impact on the production shift as also shown in Figure 4.18.

Not only did the production shift increase considerably for longer flex bounds, but the inventory increases even more. From Figures 4.19 and 4.20, the change in standard deviation has a greater impact on inventory than alpha. As the standard deviation increases, the inventory increases at an alarming rate. When flex bound length is long, production is maintained at a similar level for a longer period of time. Therefore, inventory is needed to buffer the demand variation. Then, when the flex fence is updated, production shifts significantly to try to return the system back to the target inventory level. Of course, as the desired customer service levels increase, a considerable amount of inventory is needed to achieve these service levels when standard deviation and alpha are large (Figure 4.21).

4.5.2 Using the Tables to Understand Production Smoothing Trends

For the Production Smoothing technique, the factors of flex bound length, flex bound width, standard deviation, and time periods were analyzed for trends by utilizing the tables in section 4.4.2. Alpha was not analyzed as it was earlier determined to not be significant. One trend noticed was the flex bound width has a greater impact on production shifts than flex bound length, regardless of standard deviation (Figure 4.22 and 4.23). This makes sense as the wider the flex limits, the more that production may shift within these limits to imitate demand. However, as the flex bound length decrease, the

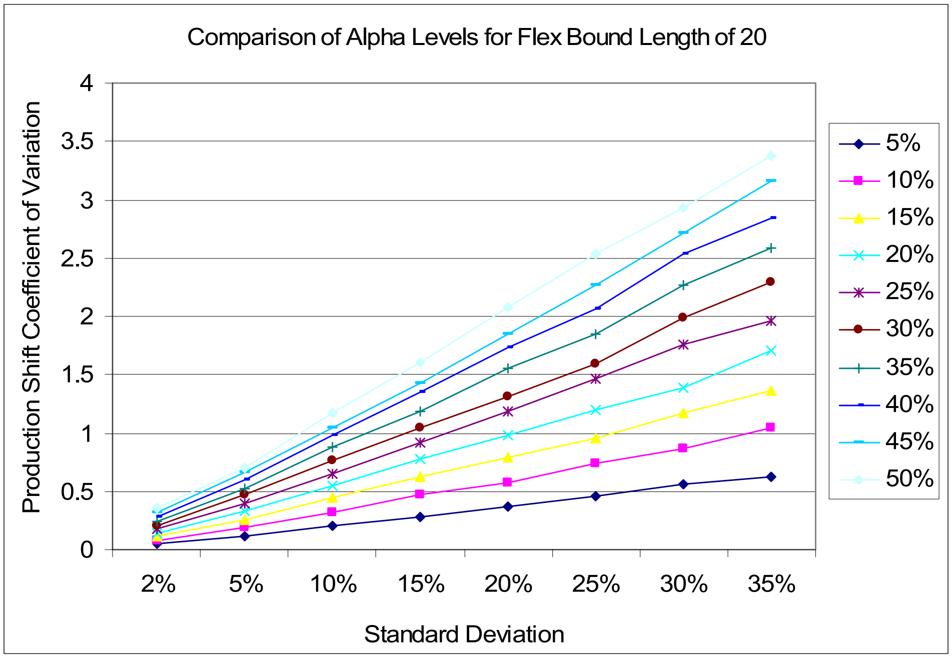

Figure 4.18. Retailer Smoothing Production Shift Comparison of Alpha Levels for Flex Bound Length of 20.

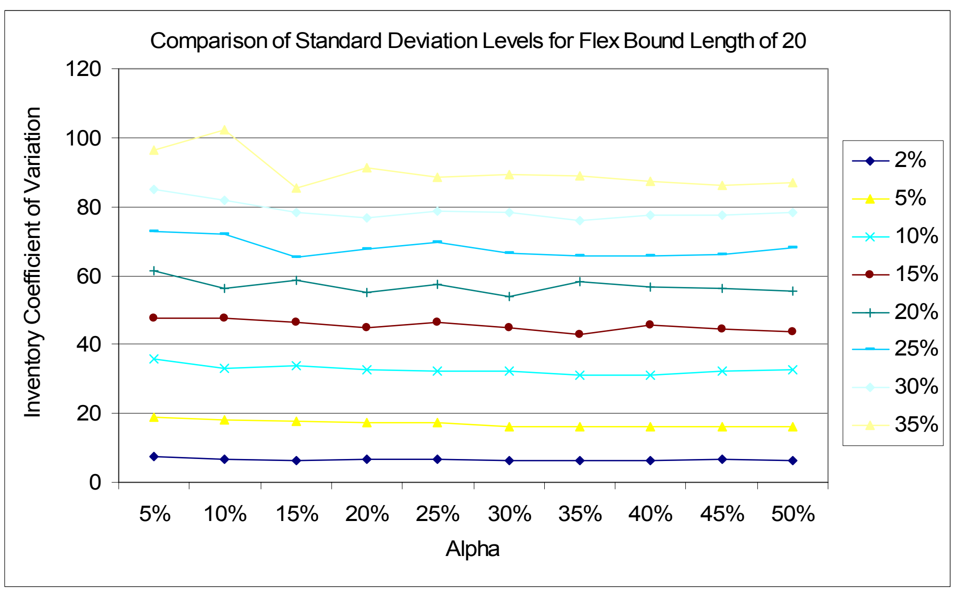

Figure 4.19. Retailer Smoothing Inventory Comparison of Standard Deviation Levels for Flex Bound Length of 20.

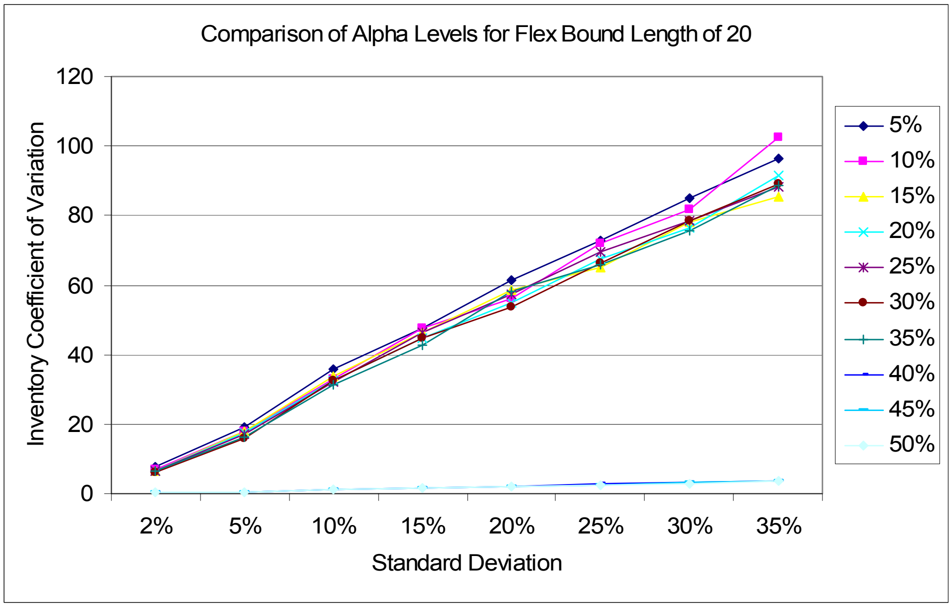

Figure 4.20. Retailer Smoothing Inventory Comparison of Alpha Levels for Flex Bound Length of 20.

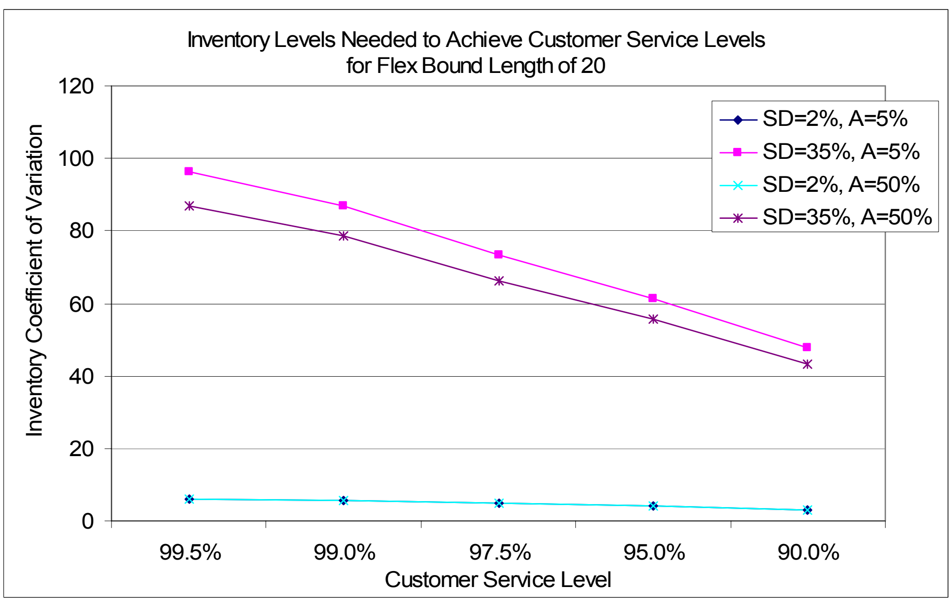

Figure 4.21. Retailer Smoothing Inventory Levels Needed to Achieve Customer Service Levels for Flex Bound Length of 20.

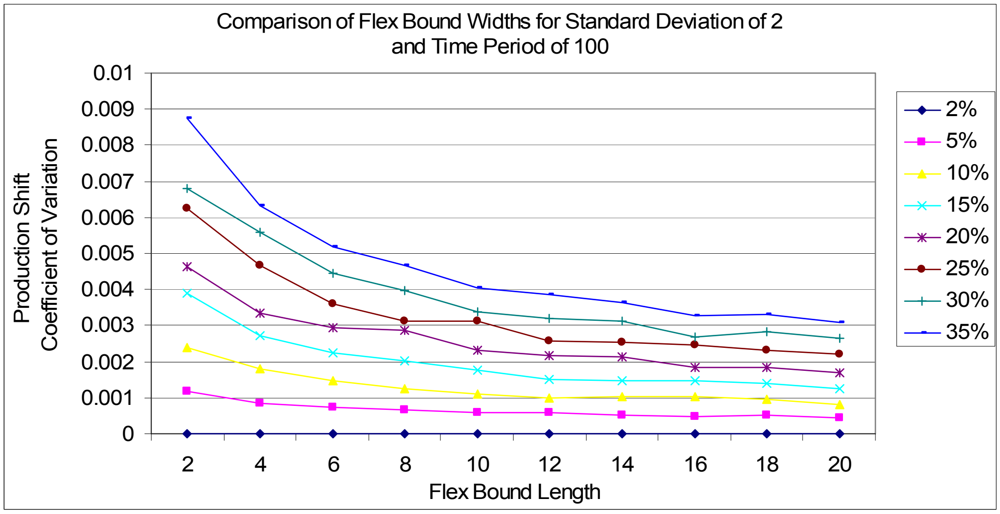

Figure 4.22. Production Smoothing Production Shift Comparison for Standard Deviation of 2 and Time Period of 100.

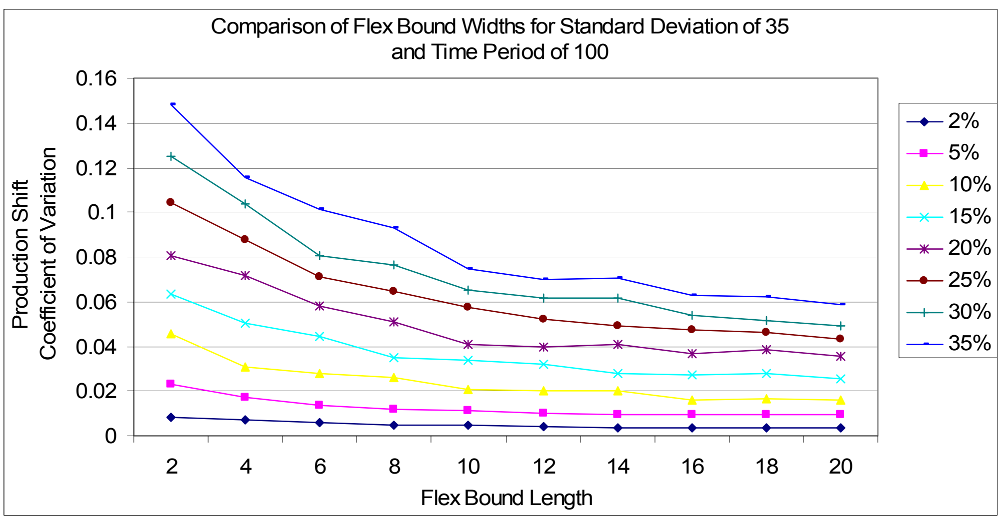

Figure 4.23. Production Smoothing Production Shift Comparison for Standard Deviation of 35 and Time Period of 100.

production shifts increase at an escalating rate. And the wider the flex limits, the more the production shifts increase. Therefore, to minimize fluctuations in the schedule, a company would want to first reduce the width of the flex limits, and second, lengthen the flex bounds. Also, the greater the standard deviation, the more production would shift since demand varies more. Similar trends are demonstrated regardless of the amount of time periods as shown in Figures 4.24 through 4.29. However, when comparing these charts, a trend is noticed that production shifts less as the time periods decrease. This trend makes sense as companies are not renovating their schedule as frequently to jump to the customers' orders. As a result, companies may want to schedule monthly as opposed to weekly, or weekly as opposed to daily to minimize fluctuations. There is a difference in the lines in Figures 4.28 and 4.29 as they slope to zero. Since the flex bound length is longer than the number of periods analyzed, production will never shift. Therefore, the data for flex bound length of fourteen through 20 is inconclusive when the amount of time periods is 12.

As seen in Figure 4.30, not much inventory is needed unless the standard deviation is high. When the standard deviation is excessive and the flex bound length is high, more inventory is needed regardless of flex bound width levels. Longer flex bounds impact inventory more since the flex bounds constrain production and inventory must increase to buffer the demand variation. Also, the fewer time periods used, the less inventory a company must utilize as noted when comparing Figures 4.30 through 4.33.

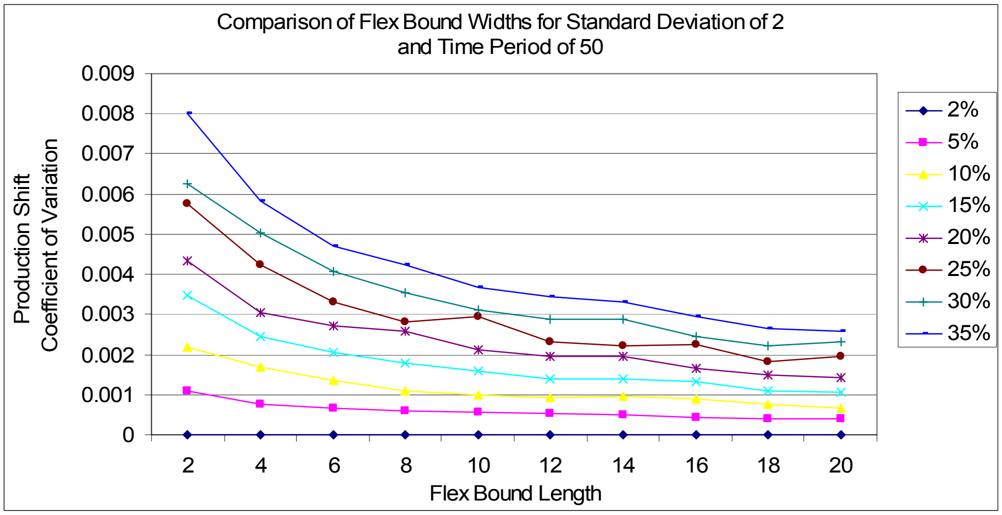

Figure 4.24. Production Smoothing Production Shift Comparison for Standard Deviation of 2 and Time Period of 50.

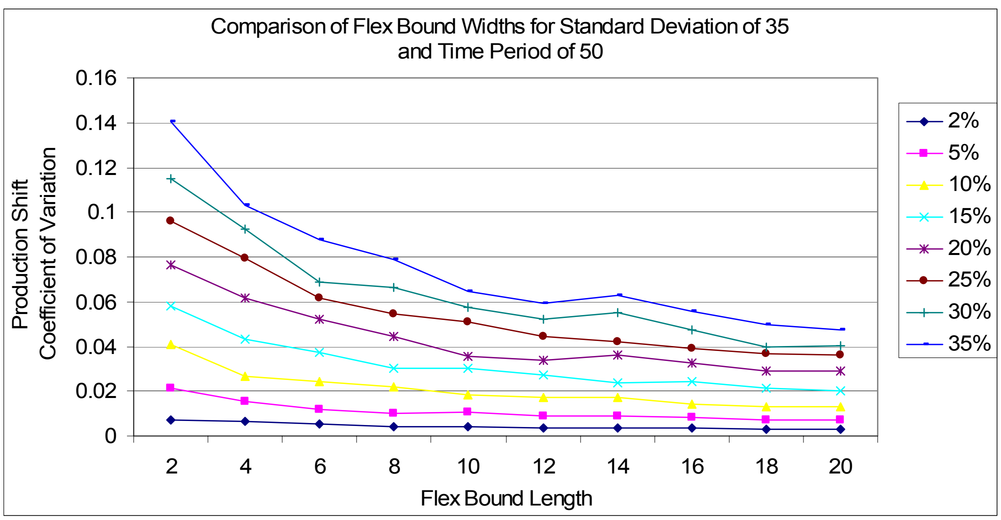

Figure 4.25. Production Smoothing Production Shift Comparison for Standard Deviation of 35 and Time Period of 50.

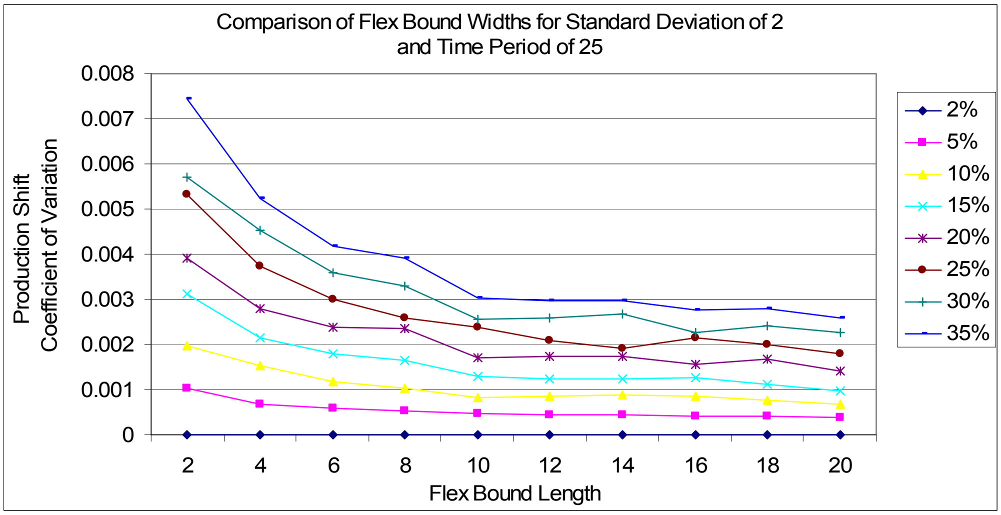

Figure 4.26. Production Smoothing Production Shift Comparison for Standard Deviation of 2 and Time Period of 25.

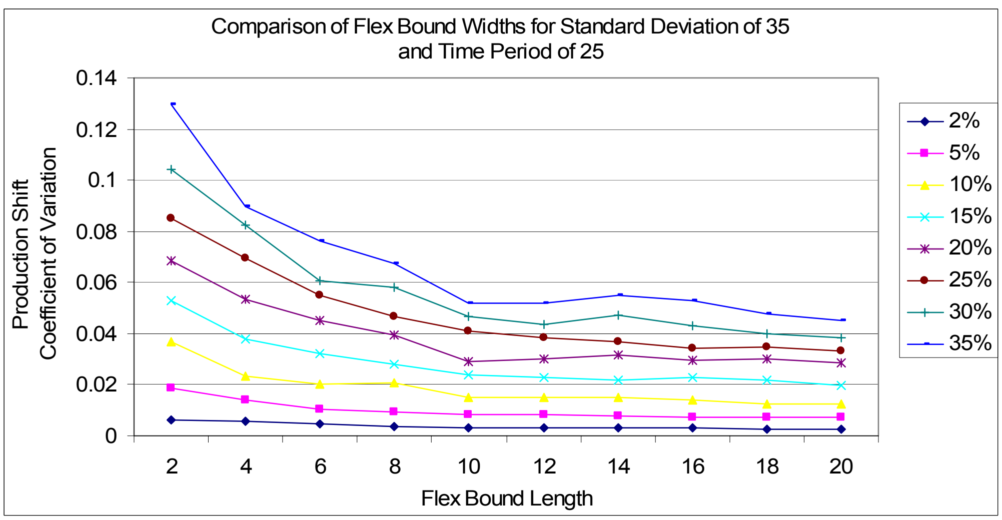

Figure 4.27. Production Smoothing Production Shift Comparison for Standard Deviation of 35 and Time Period of 25.

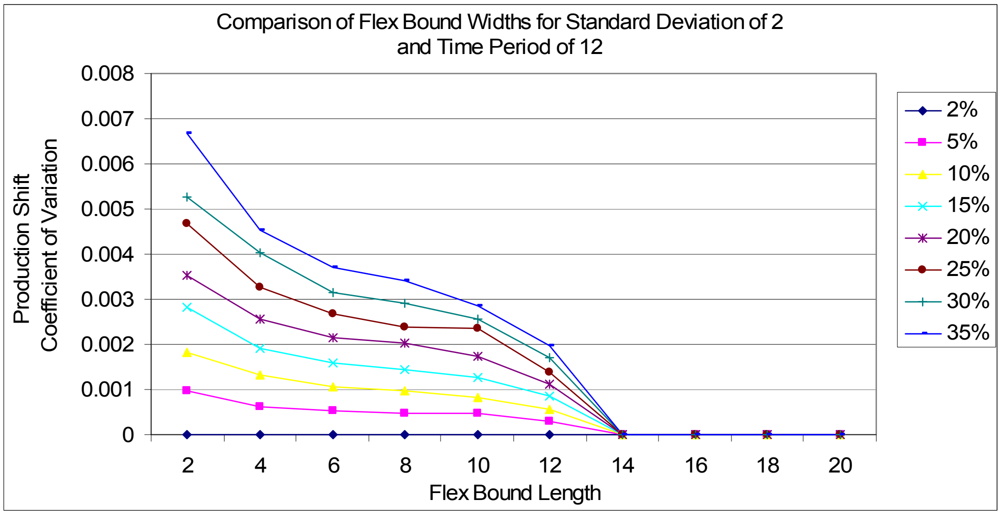

Figure 4.28. Production Smoothing Production Shift Comparison for Standard Deviation of 2 and Time Period of 12.

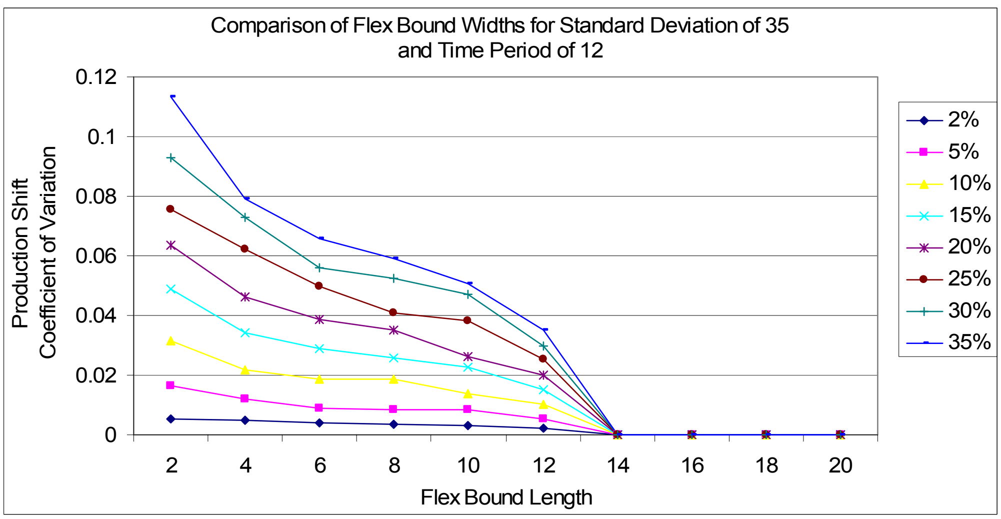

Figure 4.29. Production Smoothing Production Shift Comparison for Standard Deviation of 35 and Time Period of 12.

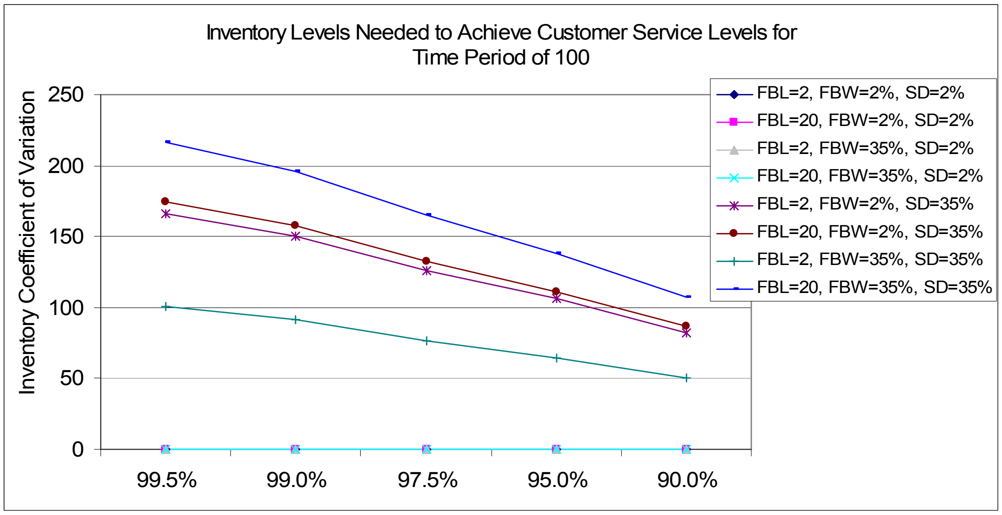

Figure 4.30. Production Smoothing Inventory Comparison to Achieve Customer Service Levels for Time Period of 100.

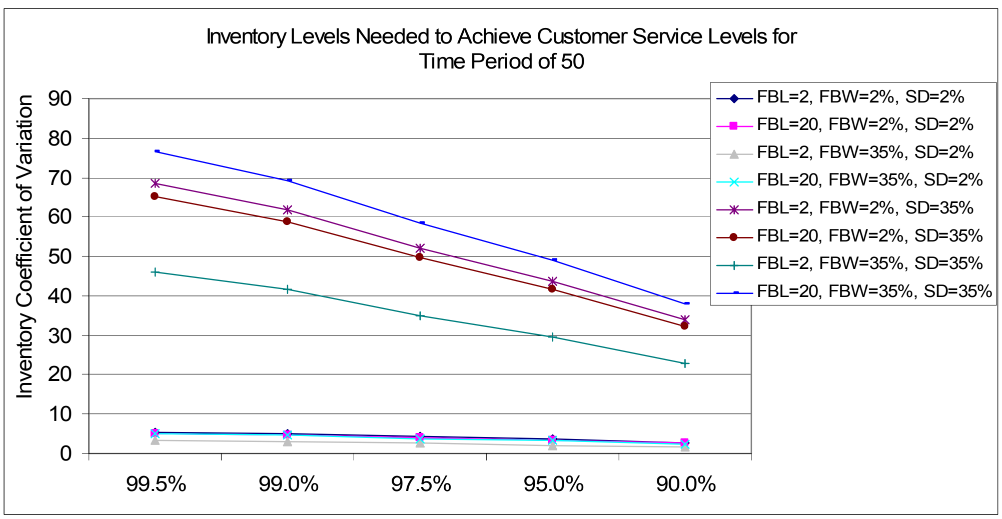

Figure 4.31. Production Smoothing Inventory Comparison to Achieve Customer Service Levels for Time Period of 50.

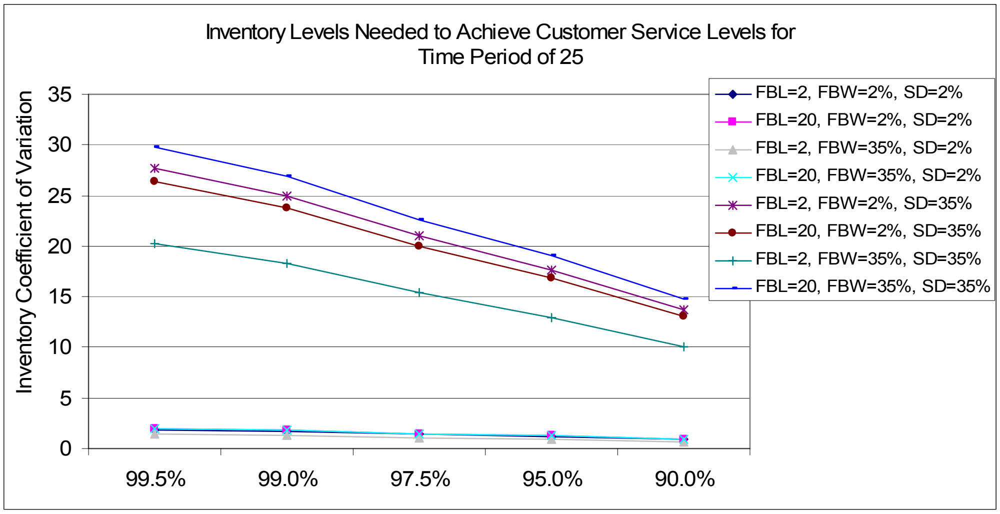

Figure 4.32. Production Smoothing Inventory Comparison to Achieve Customer Service Levels for Time Period of 25.

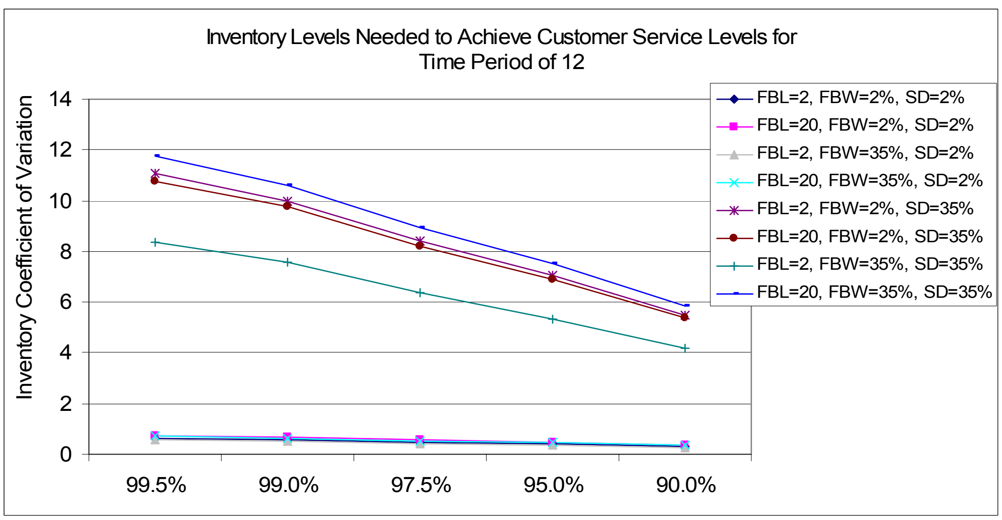

Figure 4.33. Production Smoothing Inventory Comparison to Achieve Customer Service Levels for Time Period of 12.

Chapter 5

Contributions and Conclusions

5.1 Contributions of this Research

The ideology and concepts of Rate Based Planning and Scheduling have been discussed for years. However, none of these pieces of literature brought the perspectives together into one paper. This research has consolidated the previous researchers' viewpoints to describe the theory of RBPS.

Also, this research provided two techniques to implement RBPS: Production Smoothing and Retailer Smoothing. Production Smoothing focuses on the manufacturing environment and seeks to minimize production fluctuations due to demand. However, the company may change factors such as the length and width of the flex limits to provide as much or little flexibility desired. On the other hand, Retailer Smoothing takes the customer's forecast, and limits the customer to changes within the flex period. The goal with RS is to minimize the fluctuations once the customer has made a commitment within the designated timeframe. Detailed flowcharts and explanations are provided for both techniques to develop the study and provide an implementation map for industry. The purpose is to limit the variability on the supplier while maintaining desired service levels with the minimum inventory levels possible.

Lastly, results of many simulations were compiled into tables so anyone may sort through them to understand the implications of changing the factors in their RBPS system. The tables allow anyone to utilize their cost data from their industry to choose levels of each factor to support their strategic initiatives.

5.2 Conclusions

Any good product delivery strategy must encompass both the customers' requirements as well as manufacturing's needs. As stated by Grossman and Jones (2002), "the operations strategy should be developed from the market and business requirements and defines how the operations of the business are to be structured." With both the customer and supplier in mind, the purpose of this dissertation is to find a means of balancing the needs between the customer and supplier while accounting for lead times, safety stock, and order quantities (Herron 1987). The balancing objective is accomplished through the concept of Rate-Based Planning and Scheduling.

The goal of this research was first to study Rate-Based Planning and Scheduling. Then a methodology was created for RBPS. As a result, two methods were developed, Retailer Smoothing and Production Smoothing. The Retailer Smoothing technique allows the customer to have more flexibility in their requirements. On the other hand, Production Smoothing minimizes changes to the production environment. Statistical analyses were performed and significant factors were utilized to evaluate both techniques. The end goal was to provide a set of tables for practitioners to use in industry. Every objective was met and exceeded as the methodology matured and more was learned about the techniques. I present this research as a tool and change in mindset for companies to try to reduce customer and/or production variation in the system.

An initial analysis was created with pilot simulations to achieve some preliminary results. Such a wide range of data resulted that a transformation was used to condense the data and translate the results. The transformation was successful and statistical hypotheses were substantiated. Retailer Smoothing required many more replications to perform statistical analyses due to the variation in the process. The Retailer Smoothing technique only used the significant factors of alpha, standard deviation, and flex bound length. So realistically, the user only influences the RS method by changing the length of the time fence, and changing alpha or the amount a company will follow spikes in the demand. Eight hundred scenarios were required with 250 replications to develop 10 tables to present the relationships between the three factors. On the other hand, Production Smoothing incorporates the standard deviation, flex bound length, and flex bound width factors. A time frame factor was added to Production Smoothing because the amount of inventory has to increase over time to buffer the system against demand variation. As a result, 640 scenarios were simulated with one hundred replications per situation to develop 32 tables.

As stated by Molinder (1997), “A high level of lead time variability and demand variability has a strong effect both on the level of optimal safety lead times and optimal safety stocks." This is true that variability has a large impact on lead time and inventory buffer. However, not all of the factors have been taken into account. First, a company must determine what type of product delivery strategy they will use. Will they produce to customer orders, produce to refill a buffer stock, or produce to their forecast? Another issue is how closely a company will follow demand. Do they choose to follow demand closely, or level production? How the company decides to follow demand with production is a significant factor in the Retailer Smoothing Strategy. An additional factor is the amount of flexibility allowed in production. Should a company allow extreme flexibility or a minimal amount? Flexibility is an important factor while using the Production Smoothing Strategy.

As discussed in section 4.5, this research assumes that as the volume of demand and production vary, the resulting inventory and production shifts will change by the same amount. Assuming the quantity changes by the same multiple is supported by Oke (2003) and Suarez et. al. (1996) as they discussed the concept of volume flexibility. As the volume changes, the theory of volume flexibility states there will not be an unfavorable consequence on efficiency or quality.

5.3 Limitations and Directions for Future Research

The purpose of this research is to be applicable to industry for a wide array of situations. As shown in the dissertation, the RBPS techniques cover a range of possibilities for industry. However, this study does have its limitations as any piece of research would. This section will focus on the limits of this research which will provide ideas for future research.

This dissertation uses the exponential smoothing model to develop the demand data. This model was used since many companies utilize exponential smoothing to anticipate demand. Even if companies do not use exponential smoothing, most models utilize the basic core assumptions of exponential smoothing. So if companies choose to use another tool to predict sales, the results of this research may not properly interpret the needs of the supply chain. Future research may compare the use of other demand generating models against exponential smoothing to anticipate any changes in the resulting tables.

Another potential limitation is the research only takes into account a single product. As stated in section 3.5, the single product assumption will suffice as long as all of a company's products have independent demand (Lin 1989). As stated earlier, the independent assumption is applicable for lean environments since only similar products are produced on a given line. However, future research may account for multiple products (Swaminathan and Tayur 1998) with demand correlation as may be the case in real demand environments (Liu and Yuan 2000).

The fact that there is only one flex fence in the study could be another limitation. The intention of the singular fence is to simplify the research and provide an applicable scenario for industries. Also, the production smoothing technique acts as if there are multiple fences as shown in Figure 3.8. In real-world situations, several flex fences may be hard to manage and might not be applicable. However, future research is needed to support the assumption that several flex fences are not necessary or feasible.

The flex fences in this study are assumed to be of constant length. This may not be realistic as the demand fence may be a different length than the flex fence. Once again, this assumption was made to simplify the input factors and to make reasonable conclusions from them. However, future research could analyze demand and flex fences of varying lengths to support or negate the fixed length assumption made in this research.

Finally, Song's (2000) study conveyed that lead time variability could be more important than investigating the effect of demand variability. Song even suggests accounting for lead time variability even if we may only do so "approximately or heuristically." This dissertation only accounts for lead time as a result of the flex fences causing potential stockouts. Further research could perform an in-depth investigation regarding the impact of lead time variability.

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Appendix

Retailer Smoothing Analysis

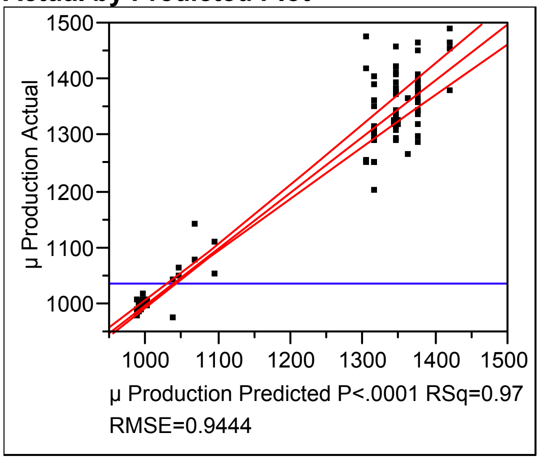
Demand Strategy=RS

Response μ Production

Weight: wgt for u Production

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.972701
RSquare Adj	0.969936
Root Mean Square Error	0.944395
Mean of Response	1037.59
Observations (or Sum Wgts)	0.191424

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	2510.5081	313.814	351.8551
Error	79	70.4587	0.892	Prob > F
C. Total	87	2580.9668		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	8.725677	1.24653	1.4538
Pure Error	72	61.733064	0.85740	Prob > F
Total Error	79	70.458741		0.1977
				Max RSq
				0.9761

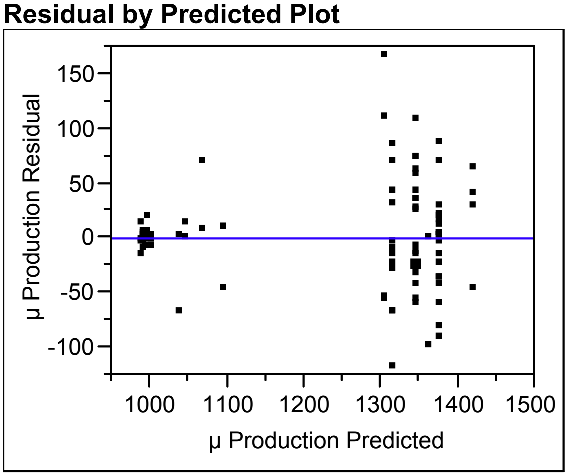
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1011.9771	10.20977	99.12	<.0001
Standard Deviation	-532.2288	439.0869	-1.21	0.2291
Alpha	-21.57546	13.24522	-1.63	0.1073
(Standard Deviation-0.04213)*(Alpha-0.31453)	-93.52189	325.8789	-0.29	0.7749
Flex Bound Length	-0.341599	0.274317	-1.25	0.2167
(Standard Deviation-0.04213)*(Flex Bound Length-12.3925)	-1.379558	7.480134	-0.18	0.8541
(Alpha-0.31453)*(Flex Bound Length-12.3925)	3.6647173	1.518198	2.41	0.0181
(Standard Deviation-0.04213)*(Alpha-0.31453)*(Flex Bound Length-12.3925)	131.58613	40.74199	3.23	0.0018
Standard Deviation2	11492.149	2056.37	5.59	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	1.310399	1.4693	0.2291
Alpha	1	1	2.366518	2.6534	0.1073
Standard Deviation*Alpha	1	1	0.073455	0.0824	0.7749
Flex Bound Length	1	1	1.383041	1.5507	0.2167
Standard Deviation*Flex Bound Length	1	1	0.030337	0.0340	0.8541
Alpha*Flex Bound Length	1	1	5.196748	5.8267	0.0181
Standard Deviation*Alpha*Flex Bound Length	1	1	9.303440	10.4312	0.0018
Standard Deviation2	1	1	27.855296	31.2320	<.0001

Residual by Predicted Plot

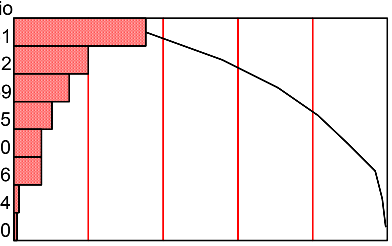


Effect Screening

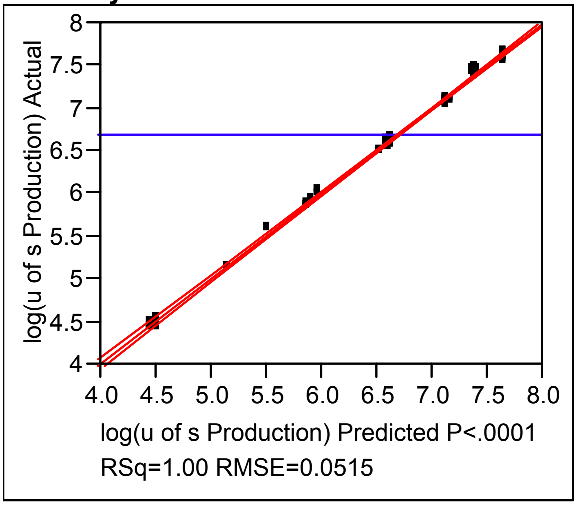
	Lenth PSE
t-Test Scale	2.1083344
Coded Scale	4.5508723

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation2	5.588561
(Standard Deviation-0.04213)*(Alpha-0.31453)*(Flex Bound Length-12.3925)	3.229742
(Alpha-0.31453)*(Flex Bound Length-12.3925)	2.413859
Alpha	-1.628925
Flex Bound Length	-1.245270
Standard Deviation	-1.212126
(Standard Deviation-0.04213)*(Alpha-0.31453)	-0.286984
(Standard Deviation-0.04213)*(Flex Bound Length-12.3925)	-0.184430



Demand Strategy=RS
Least Squares Fit
Response log(u of s Production)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.997811
RSquare Adj	0.997589
Root Mean Square Error	0.05147
Mean of Response	6.688819
Observations (or Sum Wgts)	88

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	95.390964	11.9239	4500.933
Error	79	0.209287	0.0026	Prob > F
C. Total	87	95.600251		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	0.13269533	0.018956	17.8201
Pure Error	72	0.07659147	0.001064	Prob > F
Total Error	79	0.20928679		<.0001
				Max RSq
				0.9992

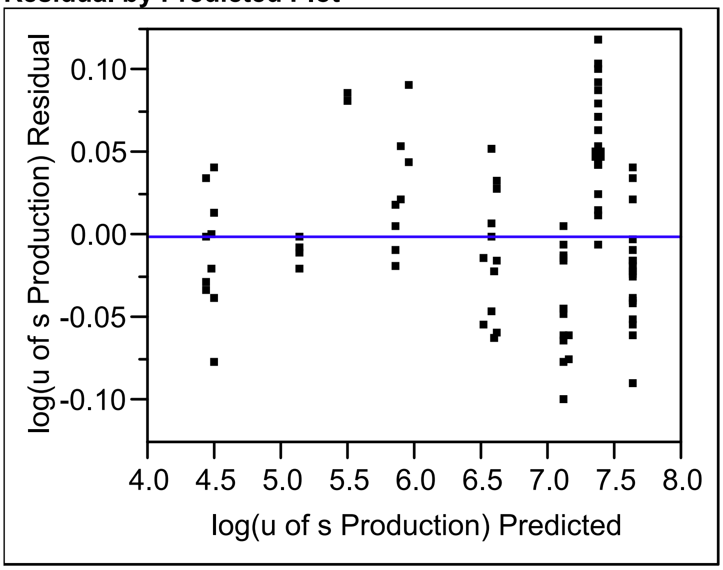
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.7246891	0.023855	156.14	<.0001
Standard Deviation	24.5848	0.560963	43.83	<.0001
Alpha	1.0689414	0.033774	31.65	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)	-2.034634	0.444042	-4.58	<.0001
Flex Bound Length	0.0482374	0.000759	63.55	<.0001
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-0.081918	0.00895	-9.15	<.0001
(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.0715702	0.004222	16.95	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-0.149983	0.050027	-3.00	0.0036
Standard Deviation2	-62.93432	2.460823	-25.57	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	5.088378	1920.723	<.0001
Alpha	1	1	2.653689	1001.694	<.0001
Standard Deviation*Alpha	1	1	0.055621	20.9954	<.0001
Flex Bound Length	1	1	10.699900	4038.918	<.0001
Standard Deviation*Flex Bound Length	1	1	0.221949	83.7796	<.0001
Alpha*Flex Bound Length	1	1	0.761295	287.3680	<.0001
Standard Deviation*Alpha*Flex Bound Length	1	1	0.023812	8.9883	0.0036
Standard Deviation2	1	1	1.732722	654.0550	<.0001

Residual by Predicted Plot

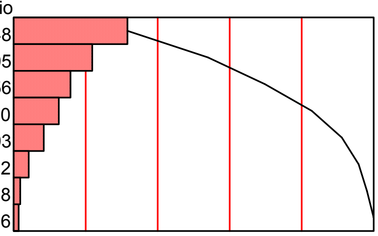


Effect Screening

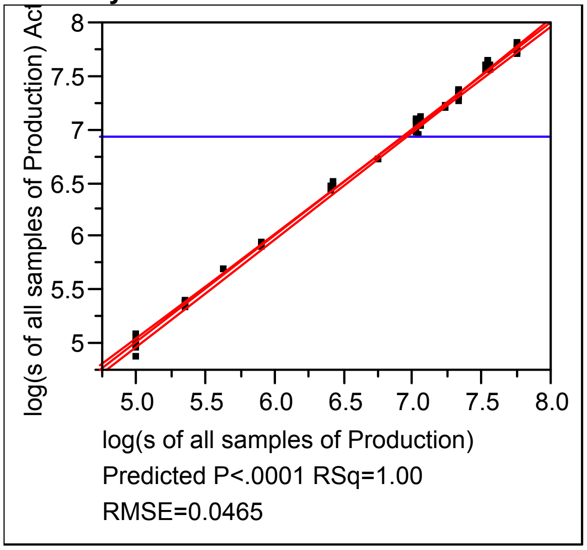
	Lenth PSE
t-Test Scale	27.605617
Coded Scale	0.1514654

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Length	63.55248
Standard Deviation	43.82605
Alpha	31.64956
Standard Deviation2	-25.57450
(Alpha-0.31818)*(Flex Bound Length-15.0909)	16.95193
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-9.15312
(Standard Deviation-0.15)*(Alpha-0.31818)	-4.58208
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-2.99806



Response log(s of all samples of Production)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.99784
RSquare Adj	0.997621
Root Mean Square Error	0.046539
Mean of Response	6.932053
Observations (or Sum Wgts)	88

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	79.029343	9.87867	4561.065
Error	79	0.171104	0.00217	Prob > F
C. Total	87	79.200447		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	0.07509108	0.010727	8.0444
Pure Error	72	0.09601254	0.001334	Prob > F
Total Error	79	0.17110361		<.0001
				Max RSq
				0.9988

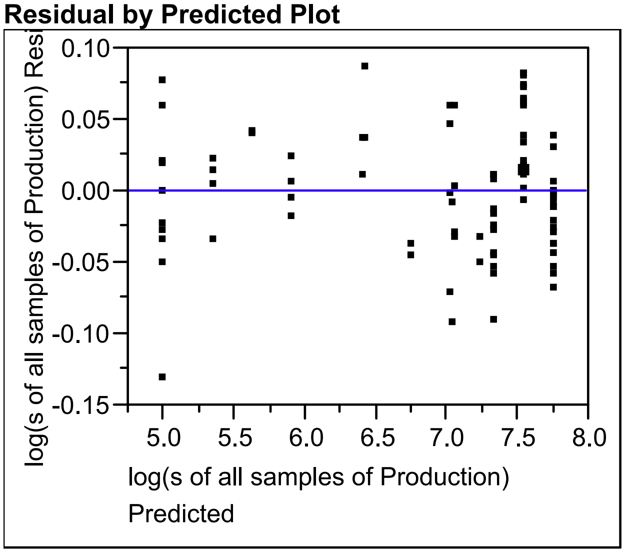
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.2739355	0.02157	198.14	<.0001
Standard Deviation	24.901065	0.507216	49.09	<.0001
Alpha	0.8143768	0.030538	26.67	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)	-1.461865	0.401497	-3.64	0.0005
Flex Bound Length	0.0316526	0.000686	46.12	<.0001
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-0.03937	0.008092	-4.87	<.0001
(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.0659485	0.003817	17.28	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-0.070372	0.045234	-1.56	0.1238
Standard Deviation2	-64.0292	2.225046	-28.78	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	5.2201367	2410.182	<.0001
Alpha	1	1	1.5402560	711.1494	<.0001
Standard Deviation*Alpha	1	1	0.0287132	13.2571	0.0005
Flex Bound Length	1	1	4.6071279	2127.15	<.0001
Standard Deviation*Flex Bound Length	1	1	0.0512654	23.6697	<.0001
Alpha*Flex Bound Length	1	1	0.6463963	298.4467	<.0001
Standard Deviation*Alpha*Flex Bound Length	1	1	0.0052421	2.4203	0.1238
Standard Deviation2	1	1	1.7935363	828.0910	<.0001

Residual by Predicted Plot

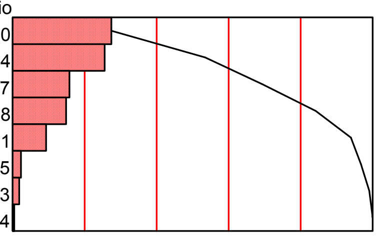


Effect Screening

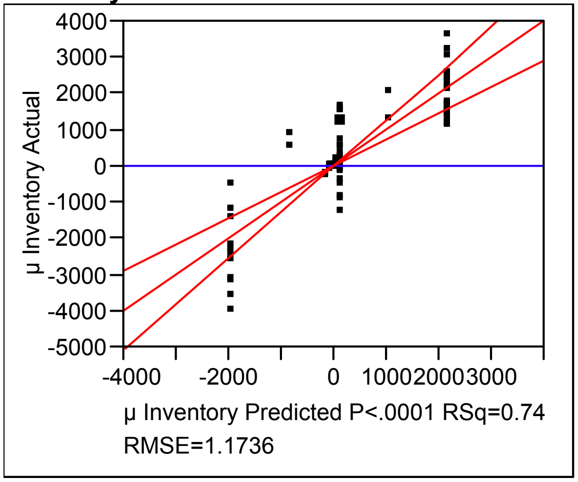
	Lenth PSE
t-Test Scale	27.446893
Coded Scale	0.1361658

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation	49.09360
Flex Bound Length	46.12104
Standard Deviation2	-28.77657
Alpha	26.66738
(Alpha-0.31818)*(Flex Bound Length-15.0909)	17.27561
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-4.86515
(Standard Deviation-0.15)*(Alpha-0.31818)	-3.64103
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-1.55574



Response μ Inventory
Weight: wgt for u Inventory
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.736443
RSquare Adj	0.709754
Root Mean Square Error	1.173638
Mean of Response	1.638334
Observations (or Sum Wgts)	1.835723

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	304.06029	38.0075	27.5932
Error	79	108.81665	1.3774	Prob > F
C. Total	87	412.87694		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	44.86596	6.40942	7.2162
Pure Error	72	63.95070	0.88820	Prob > F
Total Error	79	108.81665		<.0001
				Max RSq
				0.8451

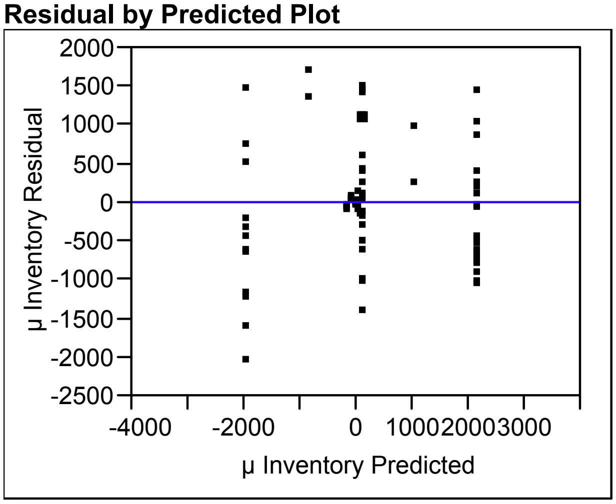
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-25.20439	8.166435	-3.09	0.0028
Standard Deviation	28.095113	201.5277	0.14	0.8895
Alpha	17.626433	7.560723	2.33	0.0223
(Standard Deviation-0.02312)*(Alpha-0.44162)	2539.5027	319.1162	7.96	<.0001
Flex Bound Length	9.2487773	3.200747	2.89	0.0050
(Standard Deviation-0.02312)*(Flex Bound Length-2.00565)	447.28884	54.04636	8.28	<.0001
(Alpha-0.44162)*(Flex Bound Length-2.00565)	22.630877	17.09336	1.32	0.1893
(Standard Deviation-0.02312)*(Alpha-0.44162)*(Flex Bound Length-2.00565)	2980.4544	306.6362	9.72	<.0001
Standard Deviation2	-51.92435	1001.889	-0.05	0.9588

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	0.02677	0.0194	0.8895
Alpha	1	1	7.48636	5.4350	0.0223
Standard Deviation*Alpha	1	1	87.23041	63.3286	<.0001
Flex Bound Length	1	1	11.50097	8.3496	0.0050
Standard Deviation*Flex Bound Length	1	1	94.34339	68.4925	<.0001
Alpha*Flex Bound Length	1	1	2.41444	1.7529	0.1893
Standard Deviation*Alpha*Flex Bound Length	1	1	130.13271	94.4753	<.0001
Standard Deviation2	1	1	0.00370	0.0027	0.9588

Residual by Predicted Plot

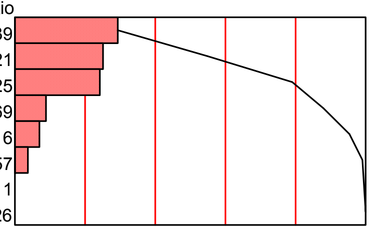


Effect Screening

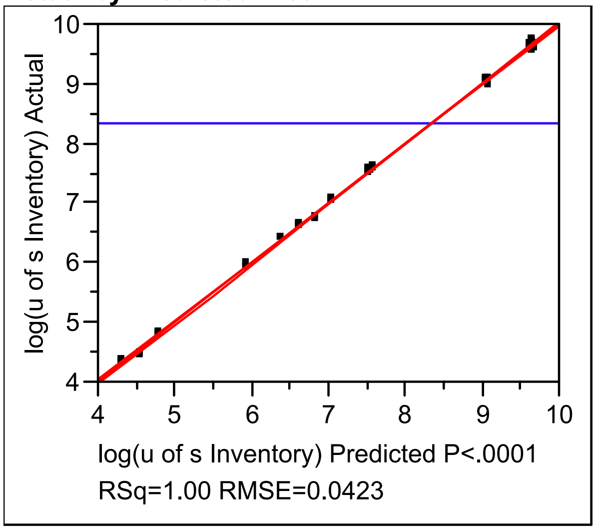
	Lenth PSE
t-Test Scale	5.6856425
Coded Scale	4.9250438

Pareto Plot of Estimates

Term	t Ratio
(Standard Deviation-0.02312)*(Alpha-0.44162)*(Flex Bound Length-2.00565)	9.719839
(Standard Deviation-0.02312)*(Flex Bound Length-2.00565)	8.276021
(Standard Deviation-0.02312)*(Alpha-0.44162)	7.957925
Flex Bound Length	2.889569
Alpha	2.331316
(Alpha-0.44162)*(Flex Bound Length-2.00565)	1.323957
Standard Deviation	0.139411
Standard Deviation2	-0.051826



Least Squares Fit
Response log(u of s Inventory)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.999499
RSquare Adj	0.999448
Root Mean Square Error	0.042261
Mean of Response	8.335679
Observations (or Sum Wgts)	88

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	281.33907	35.1674	19690.5
Error	79	0.14109	0.0018	Prob > F
C. Total	87	281.48017		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	0.04901744	0.007002	5.4756
Pure Error	72	0.09207720	0.001279	Prob > F
Total Error	79	0.14109464		<.0001
				Max RSq
				0.9997

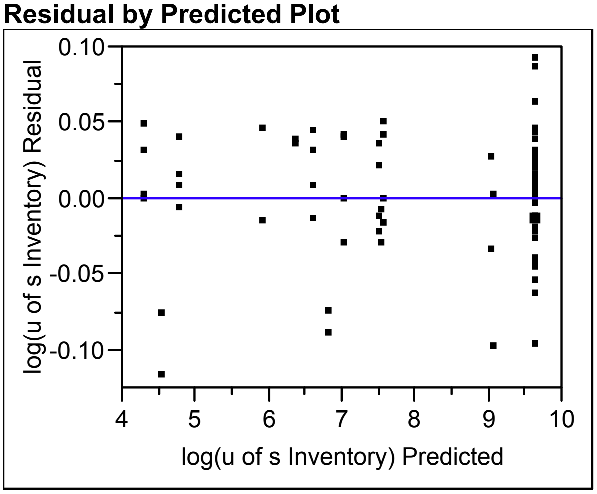
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.8743412	0.019587	197.80	<.0001
Standard Deviation	28.061262	0.460594	60.92	<.0001
Alpha	-0.313424	0.027731	-11.30	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)	0.7432061	0.364593	2.04	0.0449
Flex Bound Length	0.1608885	0.000623	258.16	<.0001
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-0.052854	0.007348	-7.19	<.0001
(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.0613425	0.003467	17.70	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.031323	0.041076	0.76	0.4480
Standard Deviation2	-73.26644	2.020527	-36.26	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	6.62919	3711.735	<.0001
Alpha	1	1	0.22814	127.7393	<.0001
Standard Deviation*Alpha	1	1	0.00742	4.1553	0.0449
Flex Bound Length	1	1	119.03162	66646.74	<.0001
Standard Deviation*Flex Bound Length	1	1	0.09239	51.7322	<.0001
Alpha*Flex Bound Length	1	1	0.55926	313.1327	<.0001
Standard Deviation*Alpha*Flex Bound Length	1	1	0.00104	0.5815	0.4480
Standard Deviation2	1	1	2.34836	1314.864	<.0001

Residual by Predicted Plot

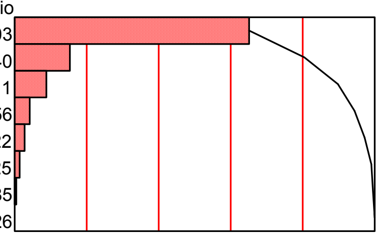


Effect Screening

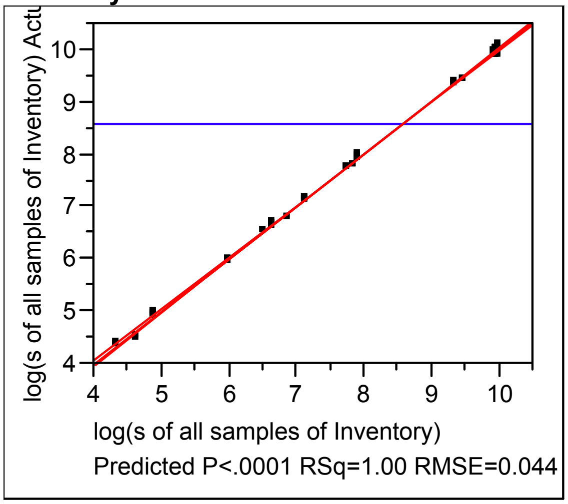
	Lenth PSE
t-Test Scale	19.476145
Coded Scale	0.0877412

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Length	258.1603
Standard Deviation	60.9240
Standard Deviation2	-36.2611
(Alpha-0.31818)*(Flex Bound Length-15.0909)	17.6956
Alpha	-11.3022
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-7.1925
(Standard Deviation-0.15)*(Alpha-0.31818)	2.0385
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.7626



Response log(s of all samples of Inventory)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.999511
RSquare Adj	0.999461
Root Mean Square Error	0.044028
Mean of Response	8.578355
Observations (or Sum Wgts)	88

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	312.90255	39.1128	20177.39
Error	79	0.15314	0.0019	Prob > F
C. Total	87	313.05569		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	0.07494972	0.010707	9.8598
Pure Error	72	0.07818767	0.001086	Prob > F
Total Error	79	0.15313739		<.0001
				Max RSq
				0.9998

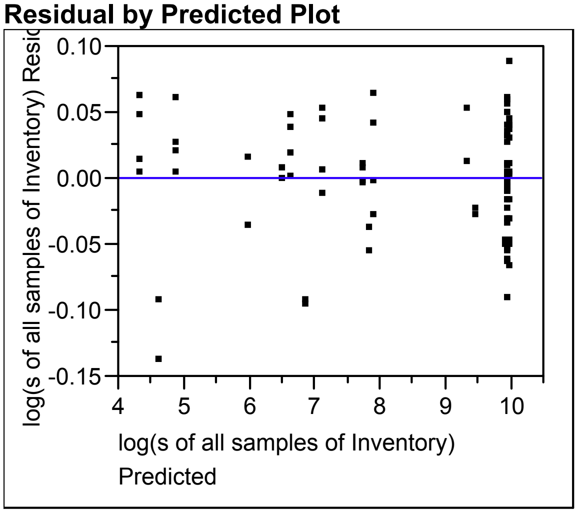
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.9254809	0.020406	192.37	<.0001
Standard Deviation	29.170168	0.479848	60.79	<.0001
Alpha	-0.498031	0.028891	-17.24	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)	1.5646831	0.379834	4.12	<.0001
Flex Bound Length	0.1745872	0.000649	268.90	<.0001
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-0.037547	0.007656	-4.90	<.0001
(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.0596872	0.003611	16.53	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.0489089	0.042793	1.14	0.2565
Standard Deviation2	-77.7418	2.10499	-36.93	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	7.16348	3695.47	<.0001
Alpha	1	1	0.57604	297.1673	<.0001
Standard Deviation*Alpha	1	1	0.03289	16.9694	<.0001
Flex Bound Length	1	1	140.16426	72307.47	<.0001
Standard Deviation*Flex Bound Length	1	1	0.04663	24.0541	<.0001
Alpha*Flex Bound Length	1	1	0.52948	273.1479	<.0001
Standard Deviation*Alpha*Flex Bound Length	1	1	0.00253	1.3063	0.2565
Standard Deviation2	1	1	2.64401	1363.983	<.0001

Residual by Predicted Plot

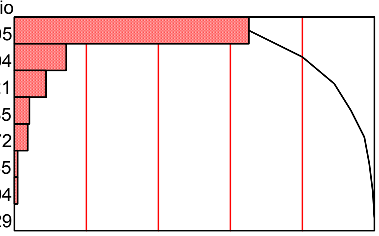


Effect Screening

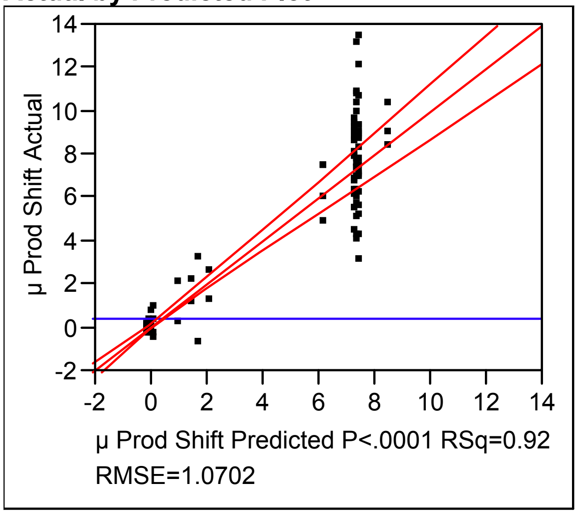
	Lenth PSE
t-Test Scale	18.674919
Coded Scale	0.0876485

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Length	268.9005
Standard Deviation	60.7904
Standard Deviation2	-36.9321
Alpha	-17.2385
(Alpha-0.31818)*(Flex Bound Length-15.0909)	16.5272
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-4.9045
(Standard Deviation-0.15)*(Alpha-0.31818)	4.1194
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	1.1429



Response μ Prod Shift
Weight: wgt u Prod Shift
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.921542
RSquare Adj	0.913597
Root Mean Square Error	1.070249
Mean of Response	0.474754
Observations (or Sum Wgts)	334.0885

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	1062.8642	132.858	115.9892
Error	79	90.4893	1.145	Prob > F
C. Total	87	1153.3534		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	6.661252	0.95161	0.8173
Pure Error	72	83.828028	1.16428	Prob > F
Total Error	79	90.489280		0.5760
				Max RSq
				0.9273

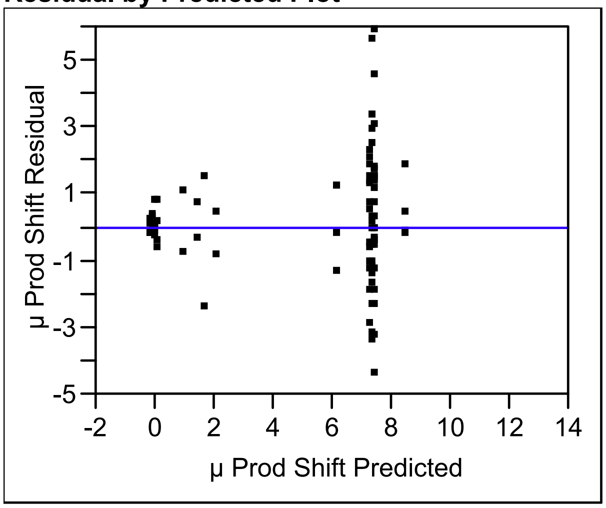
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.1272565	0.239468	0.53	0.5966
Standard Deviation	-5.175369	10.70069	-0.48	0.6300
Alpha	-0.383033	0.34699	-1.10	0.2730
(Standard Deviation-0.03288)*(Alpha-0.27957)	-22.03329	10.2741	-2.14	0.0351
Flex Bound Length	-0.000303	0.008008	-0.04	0.9699
(Standard Deviation-0.03288)*(Flex Bound Length-6.94036)	-0.022249	0.174355	-0.13	0.8988
(Alpha-0.27957)*(Flex Bound Length-6.94036)	0.066878	0.045561	1.47	0.1461
(Standard Deviation-0.03288)*(Alpha-0.27957)*(Flex Bound Length-6.94036)	1.6495006	0.952635	1.73	0.0873
Standard Deviation2	212.4019	51.20896	4.15	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	0.267935	0.2339	0.6300
Alpha	1	1	1.395757	1.2185	0.2730
Standard Deviation*Alpha	1	1	5.267945	4.5991	0.0351
Flex Bound Length	1	1	0.001641	0.0014	0.9699
Standard Deviation*Flex Bound Length	1	1	0.018651	0.0163	0.8988
Alpha*Flex Bound Length	1	1	2.468029	2.1547	0.1461
Standard Deviation*Alpha*Flex Bound Length	1	1	3.434173	2.9981	0.0873
Standard Deviation2	1	1	19.705838	17.2038	<.0001

Residual by Predicted Plot

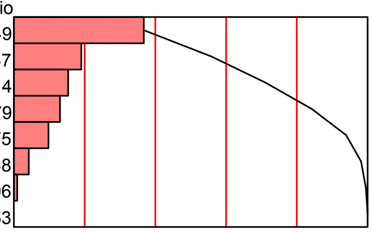


Effect Screening

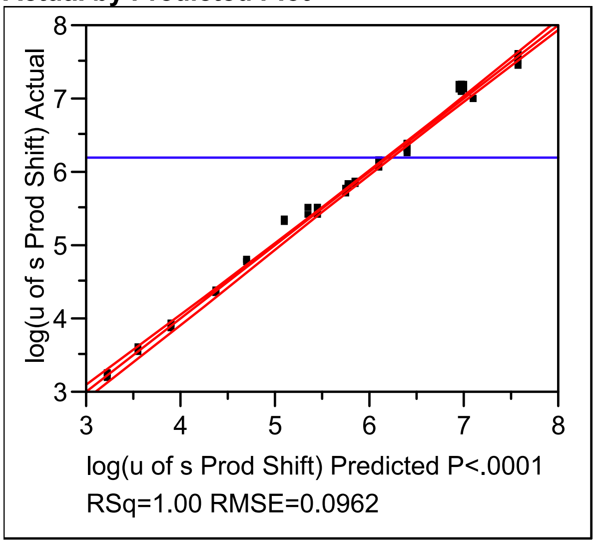
	Lenth PSE
t-Test Scale	2.2579433
Coded Scale	0.1322109

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation2	4.147749
(Standard Deviation-0.03288)*(Alpha-0.27957)	-2.144547
(Standard Deviation-0.03288)*(Alpha-0.27957)*(Flex Bound Length-6.94036)	1.731514
(Alpha-0.27957)*(Flex Bound Length-6.94036)	1.467879
Alpha	-1.103875
Standard Deviation	-0.483648
(Standard Deviation-0.03288)*(Flex Bound Length-6.94036)	-0.127606
Flex Bound Length	-0.037853



Demand Strategy=RS
Least Squares Fit
Response log(u of s Prod Shift)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.995045
RSquare Adj	0.994543
Root Mean Square Error	0.096181
Mean of Response	6.196514
Observations (or Sum Wgts)	88

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	146.74930	18.3437	1982.921
Error	79	0.73082	0.0093	Prob > F
C. Total	87	147.48012		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	0.63231045	0.090330	66.0247
Pure Error	72	0.09850507	0.001368	Prob > F
Total Error	79	0.73081552		<.0001
				Max RSq
				0.9993

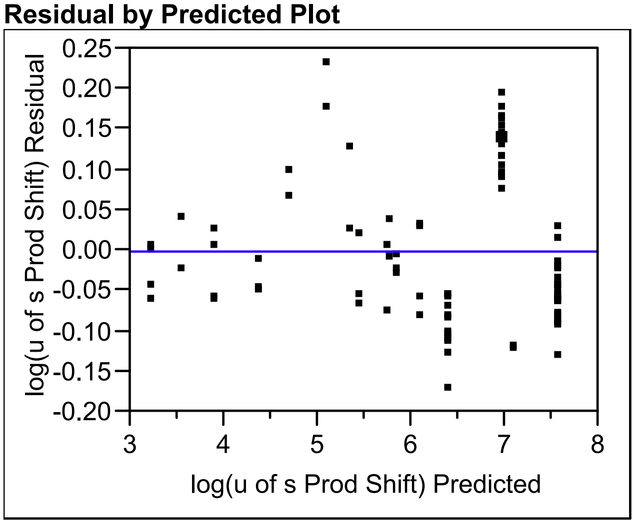
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.3142351	0.044578	51.91	<.0001
Standard Deviation	24.154981	1.048256	23.04	<.0001
Alpha	2.7249722	0.063113	43.18	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)	-3.452105	0.829768	-4.16	<.0001
Flex Bound Length	0.0738569	0.001418	52.07	<.0001
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-0.110843	0.016724	-6.63	<.0001
(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.0826244	0.007889	10.47	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-0.224608	0.093484	-2.40	0.0186
Standard Deviation2	-60.26902	4.59847	-13.11	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	4.912012	530.9807	<.0001
Alpha	1	1	17.245124	1864.171	<.0001
Standard Deviation*Alpha	1	1	0.160116	17.3083	<.0001
Flex Bound Length	1	1	25.083889	2711.529	<.0001
Standard Deviation*Flex Bound Length	1	1	0.406360	43.9268	<.0001
Alpha*Flex Bound Length	1	1	1.014625	109.6794	<.0001
Standard Deviation*Alpha*Flex Bound Length	1	1	0.053402	5.7727	0.0186
Standard Deviation2	1	1	1.589067	171.7756	<.0001

Residual by Predicted Plot

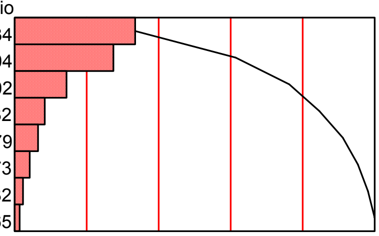


Effect Screening

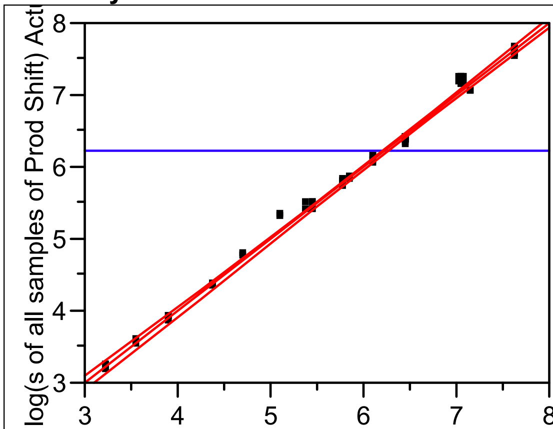
	Lenth PSE
t-Test Scale	14.197004
Coded Scale	0.1455612

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Length	52.07234
Alpha	43.17604
Standard Deviation	23.04302
Standard Deviation2	-13.10632
(Alpha-0.31818)*(Flex Bound Length-15.0909)	10.47279
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-6.62773
(Standard Deviation-0.15)*(Alpha-0.31818)	-4.16032
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-2.40265



Response log(s of all samples of Prod Shift)
Whole Model
Actual by Predicted Plot



log(s of all samples of Prod Shift)
Predicted P<.0001 RSq=1.00
RMSE=0.0956

Summary of Fit

RSquare	0.995294
RSquare Adj	0.994817
Root Mean Square Error	0.095601
Mean of Response	6.23368
Observations (or Sum Wgts)	88

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	152.69179	19.0865	2088.326
Error	79	0.72203	0.0091	Prob > F
C. Total	87	153.41382		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	0.63801661	0.091145	78.1132
Pure Error	72	0.08401219	0.001167	Prob > F
Total Error	79	0.72202880		<.0001
				Max RSq
				0.9995

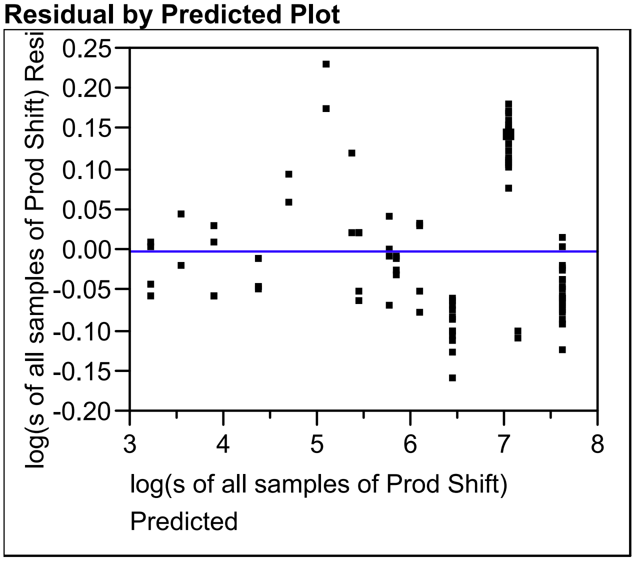
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.2610317	0.044309	51.03	<.0001
Standard Deviation	24.651461	1.041935	23.66	<.0001
Alpha	2.7512612	0.062733	43.86	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)	-3.283391	0.824765	-3.98	0.0002
Flex Bound Length	0.0762727	0.00141	54.10	<.0001
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-0.09385	0.016623	-5.65	<.0001
(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.084533	0.007842	10.78	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-0.215638	0.09292	-2.32	0.0229
Standard Deviation2	-61.42669	4.570742	-13.44	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	5.116009	559.7626	<.0001
Alpha	1	1	17.579471	1923.439	<.0001
Standard Deviation*Alpha	1	1	0.144848	15.8484	0.0002
Flex Bound Length	1	1	26.751674	2927.006	<.0001
Standard Deviation*Flex Bound Length	1	1	0.291310	31.8734	<.0001
Alpha*Flex Bound Length	1	1	1.062041	116.2020	<.0001
Standard Deviation*Alpha*Flex Bound Length	1	1	0.049222	5.3856	0.0229
Standard Deviation2	1	1	1.650700	180.6095	<.0001

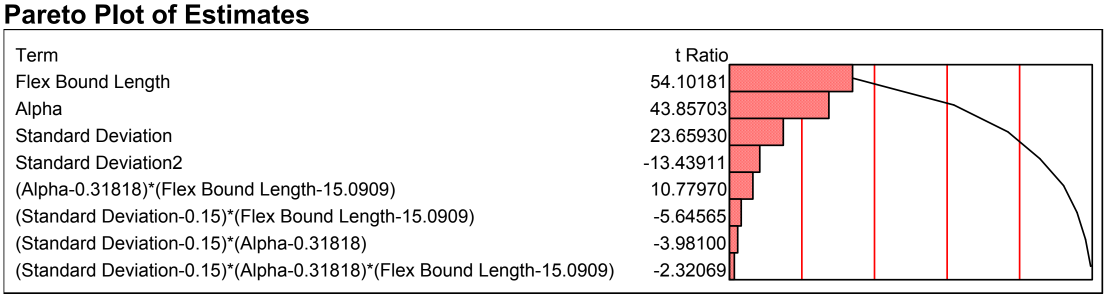
Residual by Predicted Plot



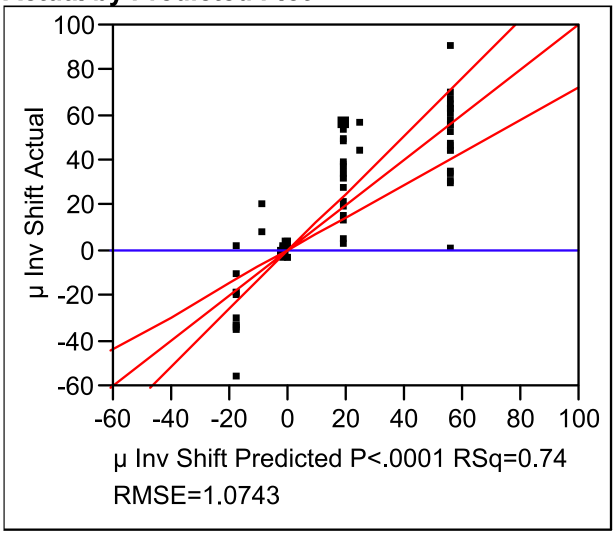
Effect Screening

	Lenth PSE
t-Test Scale	13.697849
Coded Scale	0.1395966

Pareto Plot of Estimates



Response μ Inv Shift
Weight: wgt for u Inv Shift
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.735138
RSquare Adj	0.708316
Root Mean Square Error	1.074255
Mean of Response	-0.01055
Observations (or Sum Wgts)	1116.943

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	253.04058	31.6301	27.4085
Error	79	91.16783	1.1540	Prob > F
C. Total	87	344.20841		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	32.942249	4.70604	5.8193
Pure Error	72	58.225585	0.80869	Prob > F
Total Error	79	91.167834		<.0001
				Max RSq
				0.8308

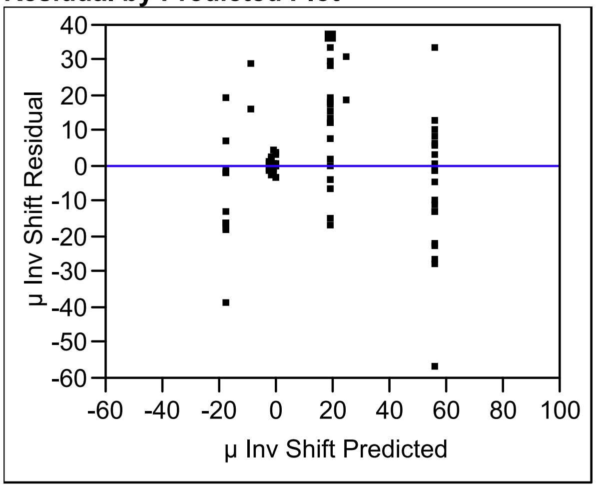
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.08825	0.20174	-0.44	0.6630
Standard Deviation	0.0930538	7.754069	0.01	0.9905
Alpha	0.1573445	0.20218	0.78	0.4388
(Standard Deviation-0.023)*(Alpha-0.37057)	21.161189	9.884316	2.14	0.0354
Flex Bound Length	0.0133854	0.058851	0.23	0.8207
(Standard Deviation-0.023)*(Flex Bound Length-2.01981)	10.398202	0.919589	11.31	<.0001
(Alpha-0.37057)*(Flex Bound Length-2.01981)	0.3222279	0.325831	0.99	0.3257
(Standard Deviation-0.023)*(Alpha-0.37057)*(Flex Bound Length-2.01981)	55.319954	5.815249	9.51	<.0001
Standard Deviation2	-15.31016	38.15351	-0.40	0.6893

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	0.00017	0.0001	0.9905
Alpha	1	1	0.69894	0.6057	0.4388
Standard Deviation*Alpha	1	1	5.28934	4.5834	0.0354
Flex Bound Length	1	1	0.05970	0.0517	0.8207
Standard Deviation*Flex Bound Length	1	1	147.55139	127.8583	<.0001
Alpha*Flex Bound Length	1	1	1.12864	0.9780	0.3257
Standard Deviation*Alpha*Flex Bound Length	1	1	104.43389	90.4955	<.0001
Standard Deviation2	1	1	0.18583	0.1610	0.6893

Residual by Predicted Plot

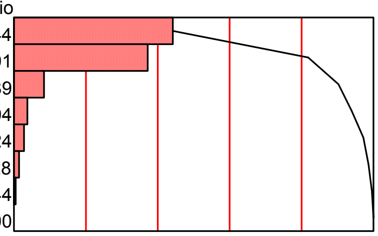


Effect Screening

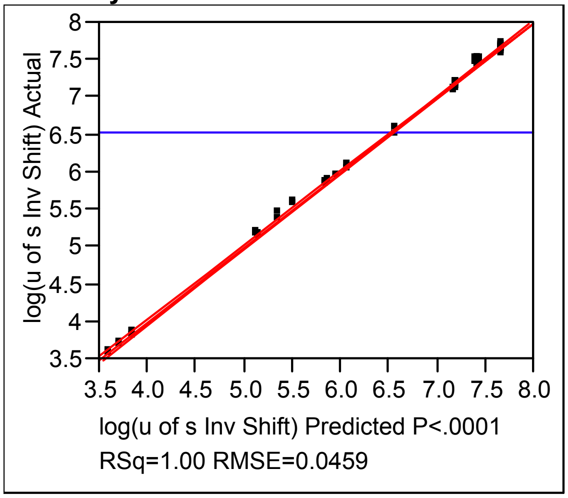
	Lenth PSE
t-Test Scale	4.6125077
Coded Scale	0.1482617

Pareto Plot of Estimates

Term	t Ratio
(Standard Deviation-0.023)*(Flex Bound Length-2.01981)	11.30744
(Standard Deviation-0.023)*(Alpha-0.37057)*(Flex Bound Length-2.01981)	9.51291
(Standard Deviation-0.023)*(Alpha-0.37057)	2.14089
(Alpha-0.37057)*(Flex Bound Length-2.01981)	0.98894
Alpha	0.77824
Standard Deviation2	-0.40128
Flex Bound Length	0.22744
Standard Deviation	0.01200



Response log(u of s Inv Shift)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.998868
RSquare Adj	0.998753
Root Mean Square Error	0.045936
Mean of Response	6.525293
Observations (or Sum Wgts)	88

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	147.09227	18.3865	8713.654
Error	79	0.16670	0.0021	Prob > F
C. Total	87	147.25897		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	0.10203247	0.014576	16.2297
Pure Error	72	0.06466408	0.000898	Prob > F
Total Error	79	0.16669655		<.0001
				Max RSq
				0.9996

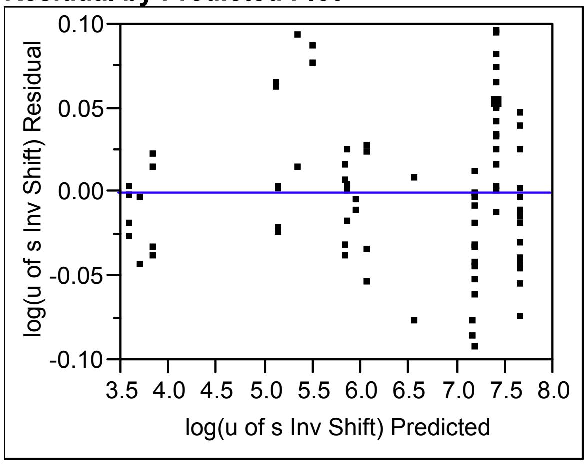
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.8994157	0.02129	136.19	<.0001
Standard Deviation	25.262388	0.500641	50.46	<.0001
Alpha	1.1277349	0.030142	37.41	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)	-2.597566	0.396293	-6.55	<.0001
Flex Bound Length	0.0870646	0.000677	128.53	<.0001
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-0.103265	0.007987	-12.93	<.0001
(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.0425727	0.003768	11.30	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-0.172101	0.044647	-3.85	0.0002
Standard Deviation2	-64.24488	2.196205	-29.25	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	5.372728	2546.216	<.0001
Alpha	1	1	2.953631	1399.77	<.0001
Standard Deviation*Alpha	1	1	0.090657	42.9636	<.0001
Flex Bound Length	1	1	34.857479	16519.48	<.0001
Standard Deviation*Flex Bound Length	1	1	0.352691	167.1457	<.0001
Alpha*Flex Bound Length	1	1	0.269371	127.6592	<.0001
Standard Deviation*Alpha*Flex Bound Length	1	1	0.031353	14.8585	0.0002
Standard Deviation2	1	1	1.805639	855.7196	<.0001

Residual by Predicted Plot

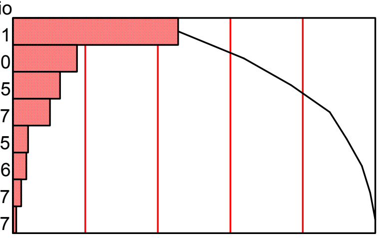


Effect Screening

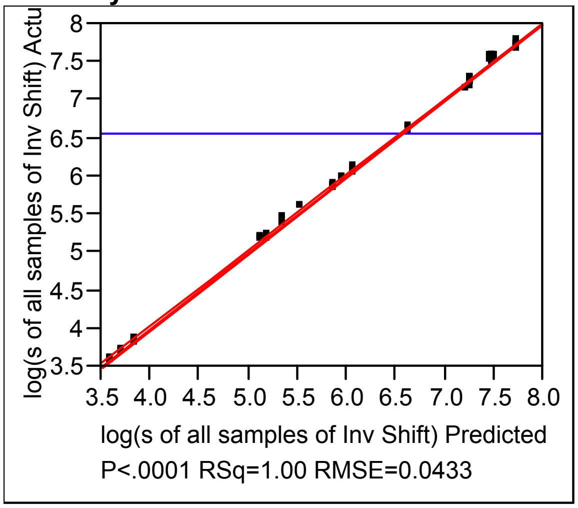
	Lenth PSE
t-Test Scale	20.78449
Coded Scale	0.1017766

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Length	128.5281
Standard Deviation	50.4600
Alpha	37.4135
Standard Deviation2	-29.2527
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-12.9285
(Alpha-0.31818)*(Flex Bound Length-15.0909)	11.2986
(Standard Deviation-0.15)*(Alpha-0.31818)	-6.5547
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-3.8547



Response log(s of all samples of Inv Shift)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.999031
RSquare Adj	0.998933
Root Mean Square Error	0.043328
Mean of Response	6.568352
Observations (or Sum Wgts)	88

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	152.89304	19.1116	10180.47
Error	79	0.14831	0.0019	Prob > F
C. Total	87	153.04135		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	7	0.08755678	0.012508	14.8248
Pure Error	72	0.06074860	0.000844	Prob > F
Total Error	79	0.14830537		<.0001
				Max RSq
				0.9996

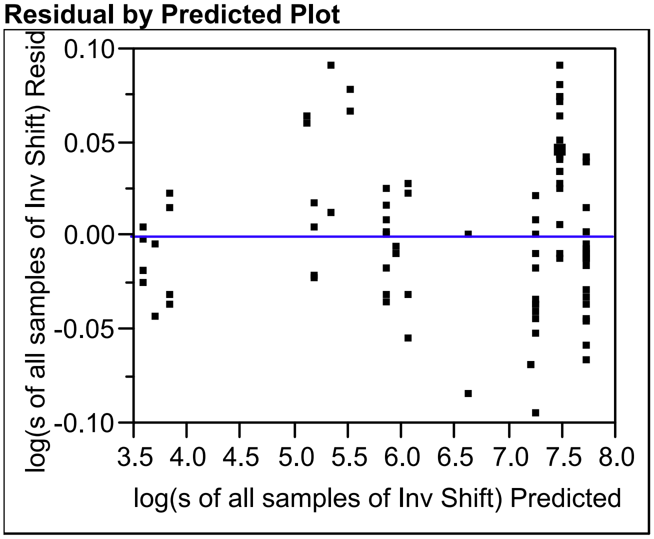
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.8760399	0.020081	143.22	<.0001
Standard Deviation	25.517909	0.472217	54.04	<.0001
Alpha	1.0958875	0.028431	38.55	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)	-2.313634	0.373793	-6.19	<.0001
Flex Bound Length	0.0900229	0.000639	140.89	<.0001
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-0.090218	0.007534	-11.97	<.0001
(Alpha-0.31818)*(Flex Bound Length-15.0909)	0.0401671	0.003554	11.30	<.0001
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-0.150977	0.042112	-3.59	0.0006
Standard Deviation2	-64.56788	2.071514	-31.17	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	5.481964	2920.158	<.0001
Alpha	1	1	2.789164	1485.745	<.0001
Standard Deviation*Alpha	1	1	0.071921	38.3113	<.0001
Flex Bound Length	1	1	37.266515	19851.3	<.0001
Standard Deviation*Flex Bound Length	1	1	0.269199	143.3983	<.0001
Alpha*Flex Bound Length	1	1	0.239790	127.7324	<.0001
Standard Deviation*Alpha*Flex Bound Length	1	1	0.024129	12.8530	0.0006
Standard Deviation2	1	1	1.823841	971.5323	<.0001

Residual by Predicted Plot

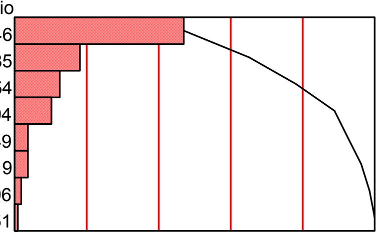


Effect Screening

	Lenth PSE
t-Test Scale	20.140564
Coded Scale	0.093024

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Length	140.8946
Standard Deviation	54.0385
Alpha	38.5454
Standard Deviation2	-31.1694
(Standard Deviation-0.15)*(Flex Bound Length-15.0909)	-11.9749
(Alpha-0.31818)*(Flex Bound Length-15.0909)	11.3019
(Standard Deviation-0.15)*(Alpha-0.31818)	-6.1896
(Standard Deviation-0.15)*(Alpha-0.31818)*(Flex Bound Length-15.0909)	-3.5851

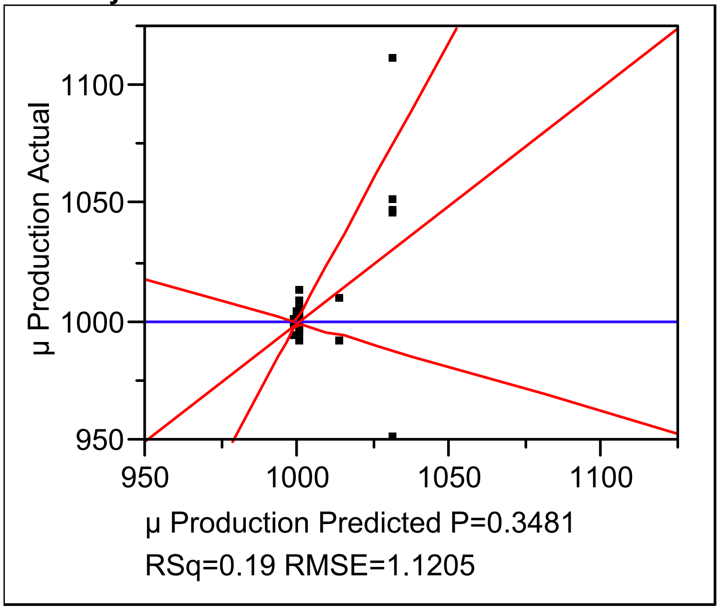


Production Smoothing Analysis

Response µ Production
Weight: wgt for u Production

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.192037
RSquare Adj	0.026301
Root Mean Square Error	1.12048
Mean of Response	999.9806
Observations (or Sum Wgts)	607.0924

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	11.637676	1.45471	1.1587
Error	39	48.963541	1.25548	Prob > F
C. Total	47	60.601217		0.3481

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	4.673906	1.55797	1.2664
Pure Error	36	44.289635	1.23027	Prob > F
Total Error	39	48.963541		0.3005
				Max RSq
				0.2692

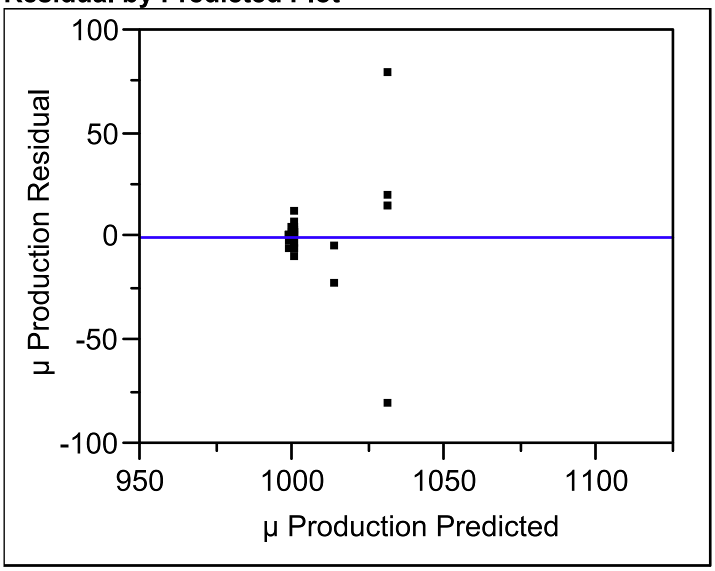
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1000.1606	0.676716	1478	<.0001
Standard Deviation	-14.58928	6.598987	-2.21	0.0330
Flex Bound Width	0.379337	1.16066	0.33	0.7455
(Standard Deviation-0.03024)*(Flex Bound Width-0.03542)	45.224611	52.60424	0.86	0.3952
Flex Bound Length	0.0041552	0.033243	0.12	0.9012
(Standard Deviation-0.03024)*(Flex Bound Length-19.8947)	-0.817895	0.956817	-0.85	0.3979
(Flex Bound Width-0.03542)*(Flex Bound Length-19.8947)	-1.13814	0.801366	-1.42	0.1635
(Standard Deviation-0.03024)*(Flex Bound Width-0.03542)*(Flex Bound Length-19.8947)	-49.38951	34.93858	-1.41	0.1654
Standard Deviation2	71.906967	31.66833	2.27	0.0288

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	6.1365133	4.8878	0.0330
Flex Bound Width	1	1	0.1341061	0.1068	0.7455
Standard Deviation*Flex Bound Width	1	1	0.9279324	0.7391	0.3952
Flex Bound Length	1	1	0.0196155	0.0156	0.9012
Standard Deviation*Flex Bound Length	1	1	0.9173713	0.7307	0.3979
Flex Bound Width*Flex Bound Length	1	1	2.5324327	2.0171	0.1635
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	2.5088063	1.9983	0.1654
Standard Deviation2	1	1	6.4729144	5.1557	0.0288

Residual by Predicted Plot

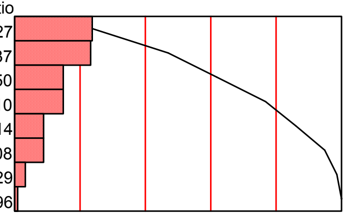


Effect Screening

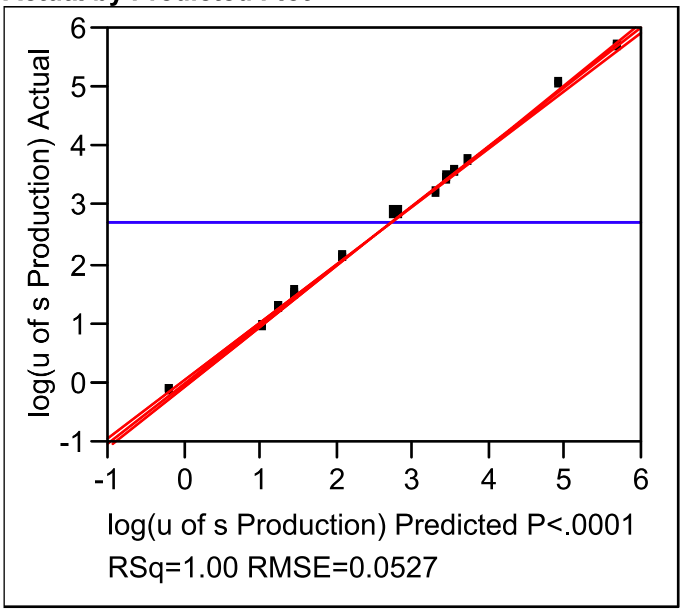
	Lenth PSE
t-Test Scale	0.9887422
Coded Scale	0.0449635

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation2	2.270627
Standard Deviation	-2.210837
(Flex Bound Width-0.03542)*(Flex Bound Length-19.8947)	-1.420250
(Standard Deviation-0.03024)*(Flex Bound Width-0.03542)*(Flex Bound Length-19.8947)	-1.413610
(Standard Deviation-0.03024)*(Flex Bound Width-0.03542)	0.859714
(Standard Deviation-0.03024)*(Flex Bound Length-19.8947)	-0.854808
Flex Bound Width	0.326829
Flex Bound Length	0.124996



Demand Strategy=PS
Response log(u of s Production)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.999191
RSquare Adj	0.999025
Root Mean Square Error	0.052656
Mean of Response	2.705673
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	133.60018	16.7000	6023.034
Error	39	0.10814	0.0028	Prob > F
C. Total	47	133.70832		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	0.09057981	0.030193	61.9165
Pure Error	36	0.01755521	0.000488	Prob > F
Total Error	39	0.10813502		<.0001
				Max RSq
				0.9999

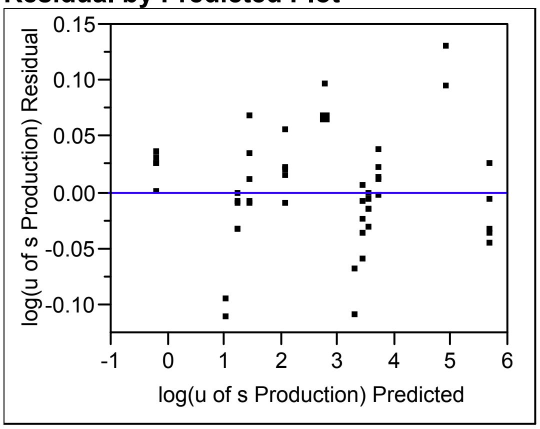
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.4573127	0.023185	62.85	<.0001
Standard Deviation	24.243573	0.573096	42.30	<.0001
Flex Bound Width	9.7908264	0.08686	112.72	<.0001
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	19.89358	1.056146	18.84	<.0001
Flex Bound Length	-0.122702	0.000844	-145.3	<.0001
(Standard Deviation-0.10833)*(Flex Bound Length-11)	0.0111036	0.010268	1.08	0.2862
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.0314129	0.009651	3.25	0.0023
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.1302229	0.11735	1.11	0.2739
Standard Deviation2	-61.06897	2.551837	-23.93	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	4.961813	1789.528	<.0001
Flex Bound Width	1	1	35.228654	12705.57	<.0001
Standard Deviation*Flex Bound Width	1	1	0.983739	354.7954	<.0001
Flex Bound Length	1	1	58.536559	21111.81	<.0001
Standard Deviation*Flex Bound Length	1	1	0.003242	1.1694	0.2862
Flex Bound Width*Flex Bound Length	1	1	0.029374	10.5939	0.0023
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.003414	1.2314	0.2739
Standard Deviation2	1	1	1.587951	572.7109	<.0001

Residual by Predicted Plot

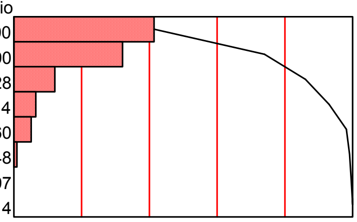


Effect Screening

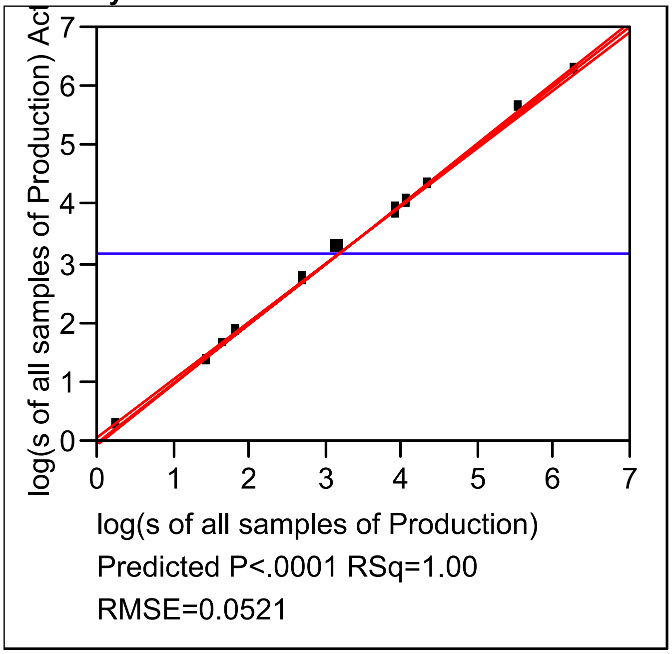
	Lenth PSE
t-Test Scale	4.8822435
Coded Scale	0.0371065

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Length	-145.2990
Flex Bound Width	112.7190
Standard Deviation	42.3028
Standard Deviation2	-23.9314
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	18.8360
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	3.2548
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	1.1097
(Standard Deviation-0.10833)*(Flex Bound Length-11)	1.0814



Response log(s of all samples of Production)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.999268
RSquare Adj	0.999118
Root Mean Square Error	0.052097
Mean of Response	3.204948
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	144.46874	18.0586	6653.666
Error	39	0.10585	0.0027	Prob > F
C. Total	47	144.57459		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	0.08689053	0.028964	54.9979
Pure Error	36	0.01895866	0.000527	Prob > F
Total Error	39	0.10584919		<.0001
				Max RSq
				0.9999

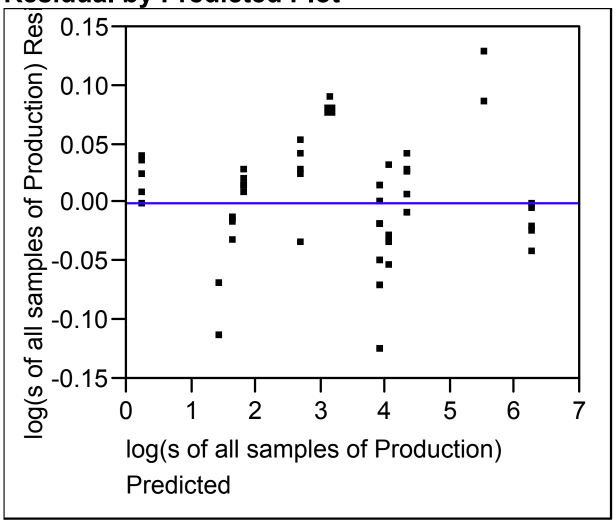
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.0978782	0.022939	91.45	<.0001
Standard Deviation	24.485987	0.567006	43.18	<.0001
Flex Bound Width	9.7074039	0.085938	112.96	<.0001
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	20.353269	1.044924	19.48	<.0001
Flex Bound Length	-0.13461	0.000836	-161.1	<.0001
(Standard Deviation-0.10833)*(Flex Bound Length-11)	0.0045424	0.010159	0.45	0.6573
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.0334134	0.009549	3.50	0.0012
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.1899311	0.116103	1.64	0.1099
Standard Deviation2	-62.53773	2.524721	-24.77	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	5.061536	1864.917	<.0001
Flex Bound Width	1	1	34.630882	12759.7	<.0001
Standard Deviation*Flex Bound Width	1	1	1.029727	379.4017	<.0001
Flex Bound Length	1	1	70.450335	25957.34	<.0001
Standard Deviation*Flex Bound Length	1	1	0.000543	0.1999	0.6573
Flex Bound Width*Flex Bound Length	1	1	0.033234	12.2451	0.0012
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.007263	2.6761	0.1099
Standard Deviation2	1	1	1.665253	613.5605	<.0001

Residual by Predicted Plot

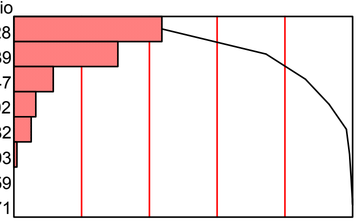


Effect Screening

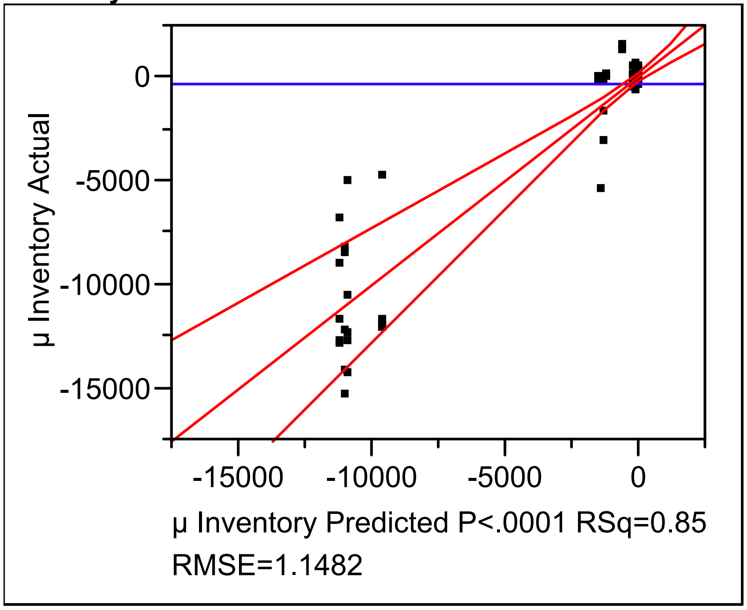
	Lenth PSE
t-Test Scale	5.2489444
Coded Scale	0.0394696

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Length	-161.1128
Flex Bound Width	112.9589
Standard Deviation	43.1847
Standard Deviation2	-24.7702
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	19.4782
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	3.4993
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	1.6359
(Standard Deviation-0.10833)*(Flex Bound Length-11)	0.4471



Response μ Inventory
Weight: wgt for u Inventory
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.847952
RSquare Adj	0.816763
Root Mean Square Error	1.148193
Mean of Response	-234.988
Observations (or Sum Wgts)	0.000139

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	286.73866	35.8423	27.1873
Error	39	51.41554	1.3183	Prob > F
C. Total	47	338.15420		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	5.381307	1.79377	1.4028
Pure Error	36	46.034232	1.27873	Prob > F
Total Error	39	51.415539		0.2578
				Max RSq
				0.8639

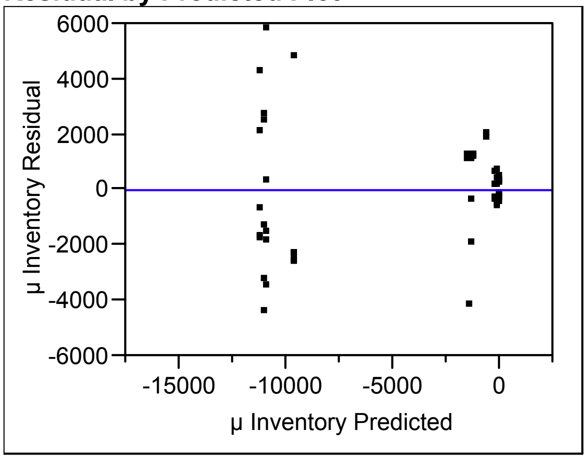
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-556.8008	442.8118	-1.26	0.2161
Standard Deviation	41047.449	21320.36	1.93	0.0615
Flex Bound Width	-891.6318	1123.94	-0.79	0.4324
(Standard Deviation-0.02462)*(Flex Bound Width-0.12246)	-12070.74	44795.15	-0.27	0.7890
Flex Bound Length	0.8038489	11.23133	0.07	0.9433
(Standard Deviation-0.02462)*(Flex Bound Length-8.70501)	164.26462	435.2971	0.38	0.7080
(Flex Bound Width-0.12246)*(Flex Bound Length-8.70501)	18.652052	128.6816	0.14	0.8855
(Standard Deviation-0.02462)*(Flex Bound Width-0.12246)*(Flex Bound Length-8.70501)	-3177.124	5040.875	-0.63	0.5322
Standard Deviation2	-457277.4	102499.9	-4.46	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	4.886672	3.7067	0.0615
Flex Bound Width	1	1	0.829687	0.6293	0.4324
Standard Deviation*Flex Bound Width	1	1	0.095727	0.0726	0.7890
Flex Bound Length	1	1	0.006753	0.0051	0.9433
Standard Deviation*Flex Bound Length	1	1	0.187735	0.1424	0.7080
Flex Bound Width*Flex Bound Length	1	1	0.027698	0.0210	0.8855
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.523704	0.3972	0.5322
Standard Deviation2	1	1	26.238703	19.9027	<.0001

Residual by Predicted Plot

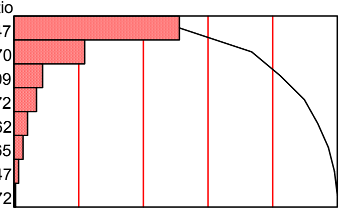


Effect Screening

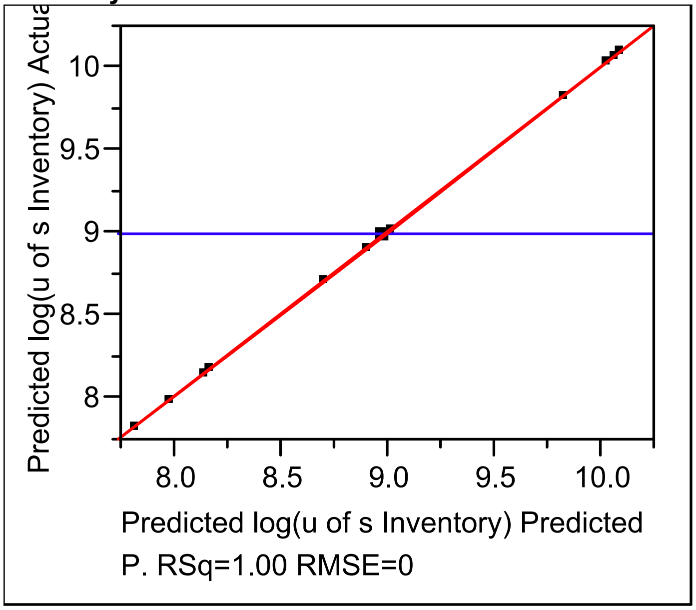
	Lenth PSE
t-Test Scale	0.7027409
Coded Scale	68.46626

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation2	-4.461247
Standard Deviation	1.925270
Flex Bound Width	-0.793309
(Standard Deviation-0.02462)*(Flex Bound Width-0.12246)*(Flex Bound Length-8.70501)	-0.630272
(Standard Deviation-0.02462)*(Flex Bound Length-8.70501)	0.377362
(Standard Deviation-0.02462)*(Flex Bound Width-0.12246)	-0.269465
(Flex Bound Width-0.12246)*(Flex Bound Length-8.70501)	0.144947
Flex Bound Length	0.071572



Response Predicted log(u of s Inventory)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	1
RSquare Adj	1
Root Mean Square Error	0
Mean of Response	8.998081
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	39.802912	4.97536	.
Error	39	0.000000	0.00000	Prob > F
C. Total	47	39.802912		.

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	0	0	.
Pure Error	36	0	0	Prob > F
Total Error	39	0		.
				Max RSq
				1.0000

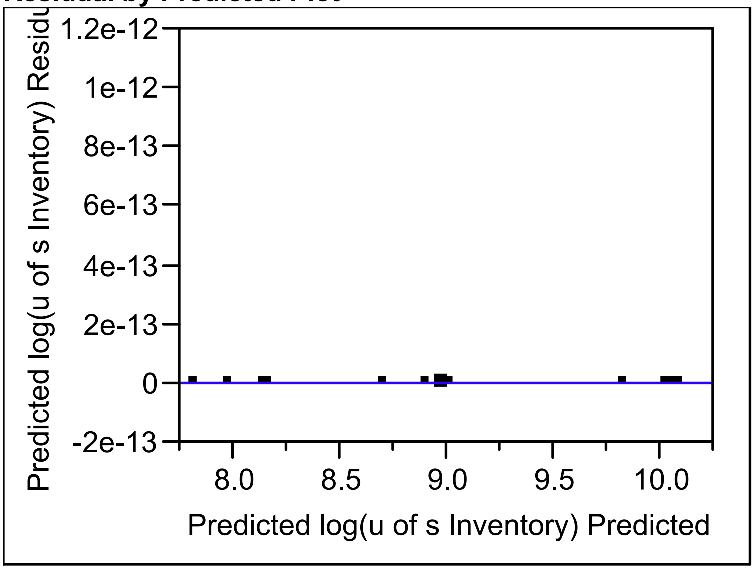
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	7.7729783	0	.	.
Standard Deviation	10.969563	0	.	.
Flex Bound Width	-0.690574	0	.	.
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	-1.806221	0	.	.
Flex Bound Length	0.0104021	0	.	.
(Standard Deviation-0.10833)*(Flex Bound Length-11)	-0.045191	0	.	.
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.0507987	0	.	.
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.0613727	0	.	.
Standard Deviation2	1.313e-11	0	.	.

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	1.0158411	.	.
Flex Bound Width	1	1	0.1752581	.	.
Standard Deviation*Flex Bound Width	1	1	0.0081095	.	.
Flex Bound Length	1	1	0.4206967	.	.
Standard Deviation*Flex Bound Length	1	1	0.0537067	.	.
Flex Bound Width*Flex Bound Length	1	1	0.0768152	.	.
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.0007584	.	.
Standard Deviation2	1	1	7.3454e-26	.	.

Residual by Predicted Plot

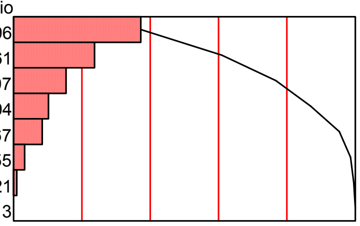


Effect Screening

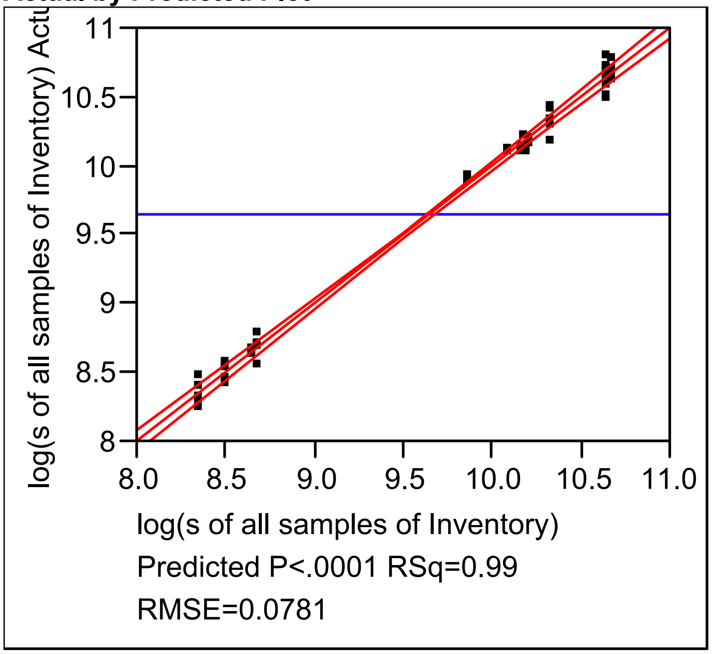
	Lenth PSE
t-Test Scale	0.3476204
Coded Scale	0.0501747

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation	2.899396
Flex Bound Length	1.865861
Flex Bound Width	-1.204297
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.797294
(Standard Deviation-0.10833)*(Flex Bound Length-11)	-0.666667
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	-0.259055
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.079221
Standard Deviation2	7.7965e-13



Response log(s of all samples of Inventory)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.994625
RSquare Adj	0.993522
Root Mean Square Error	0.078129
Mean of Response	9.650207
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	44.048608	5.50608	902.0186
Error	39	0.238063	0.00610	Prob > F
C. Total	47	44.286671		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	0.00591284	0.001971	0.3056
Pure Error	36	0.23214986	0.006449	Prob > F
Total Error	39	0.23806269		0.8211
				Max RSq
				0.9948

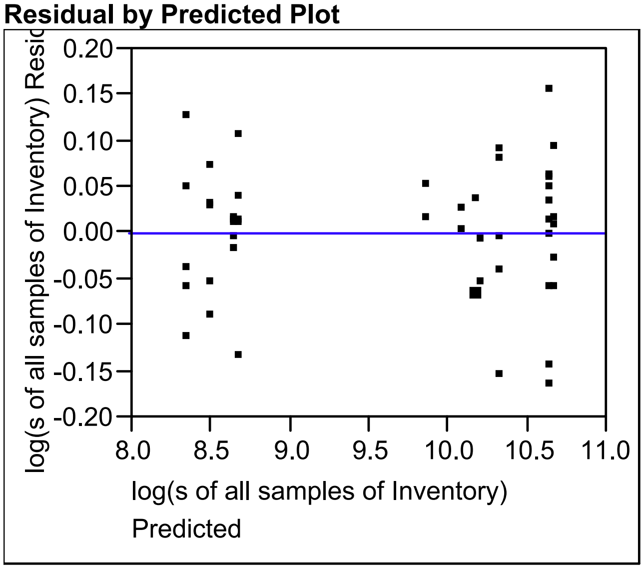
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	7.9576921	0.034402	231.32	<.0001
Standard Deviation	28.933829	0.850335	34.03	<.0001
Flex Bound Width	-0.753979	0.12888	-5.85	<.0001
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	-3.026981	1.567063	-1.93	0.0607
Flex Bound Length	0.0115135	0.001253	9.19	<.0001
(Standard Deviation-0.10833)*(Flex Bound Length-11)	-0.01969	0.015235	-1.29	0.2038
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.0643307	0.01432	4.49	<.0001
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.2869573	0.174118	1.65	0.1074
Standard Deviation2	-80.2059	3.786303	-21.18	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	7.0673880	1157.796	<.0001
Flex Bound Width	1	1	0.2089182	34.2255	<.0001
Standard Deviation*Flex Bound Width	1	1	0.0227758	3.7312	0.0607
Flex Bound Length	1	1	0.5153947	84.4332	<.0001
Standard Deviation*Flex Bound Length	1	1	0.0101961	1.6703	0.2038
Flex Bound Width*Flex Bound Length	1	1	0.1231909	20.1814	<.0001
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.0165796	2.7161	0.1074
Standard Deviation2	1	1	2.7391047	448.7267	<.0001

Residual by Predicted Plot

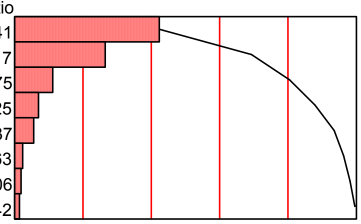


Effect Screening

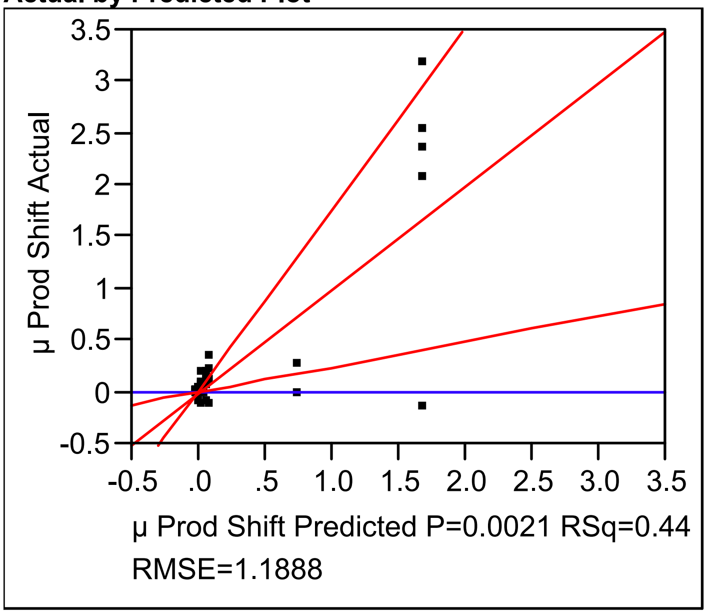
	Lenth PSE
t-Test Scale	4.8180013
Coded Scale	0.0543325

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation	34.02641
Standard Deviation2	-21.18317
Flex Bound Length	9.18875
Flex Bound Width	-5.85025
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	4.49237
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	-1.93163
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	1.64806
(Standard Deviation-0.10833)*(Flex Bound Length-11)	-1.29242



Response μ Prod Shift
Weight: wgt u Prod Shift
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.439936
RSquare Adj	0.325051
Root Mean Square Error	1.188769
Mean of Response	-0.00002
Observations (or Sum Wgts)	1101804

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	43.292327	5.41154	3.8294
Error	39	55.113662	1.41317	Prob > F
C. Total	47	98.405989		0.0021

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	7.039290	2.34643	1.7571
Pure Error	36	48.074372	1.33540	Prob > F
Total Error	39	55.113662		0.1728
				Max RSq
				0.5115

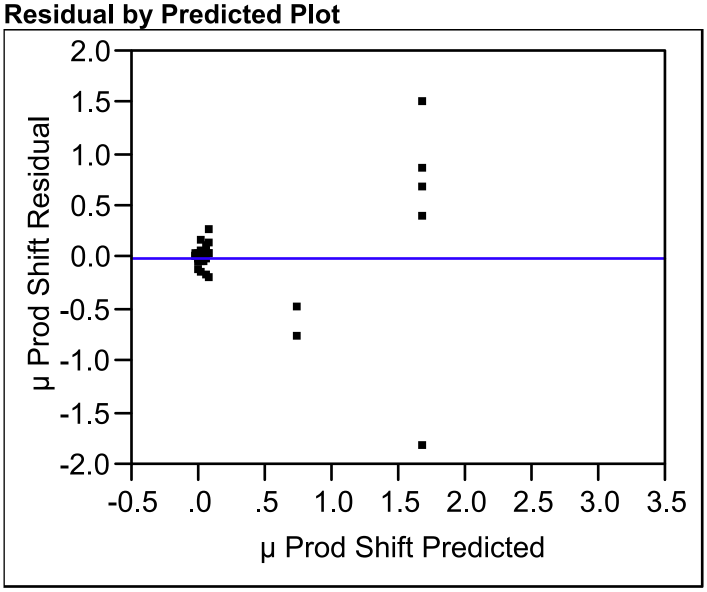
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0115551	0.014827	0.78	0.4405
Standard Deviation	-0.291272	0.162816	-1.79	0.0814
Flex Bound Width	0.0225991	0.029041	0.78	0.4412
(Standard Deviation-0.03031)*(Flex Bound Width-0.03546)	2.6040138	1.342267	1.94	0.0596
Flex Bound Length	-0.000372	0.000725	-0.51	0.6103
(Standard Deviation-0.03031)*(Flex Bound Length-19.8626)	-0.051427	0.020472	-2.51	0.0163
(Flex Bound Width-0.03546)*(Flex Bound Length-19.8626)	-0.039222	0.017135	-2.29	0.0276
(Standard Deviation-0.03031)*(Flex Bound Width-0.03546)*(Flex Bound Length-19.8626)	-2.637625	0.692114	-3.81	0.0005
Standard Deviation2	1.7207787	0.781895	2.20	0.0337

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	4.522711	3.2004	0.0814
Flex Bound Width	1	1	0.855753	0.6056	0.4412
Standard Deviation*Flex Bound Width	1	1	5.318673	3.7636	0.0596
Flex Bound Length	1	1	0.373067	0.2640	0.6103
Standard Deviation*Flex Bound Length	1	1	8.917750	6.3105	0.0163
Flex Bound Width*Flex Bound Length	1	1	7.403798	5.2391	0.0276
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	20.524134	14.5235	0.0005
Standard Deviation2	1	1	6.844591	4.8434	0.0337

Residual by Predicted Plot

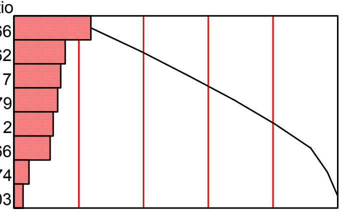


Effect Screening

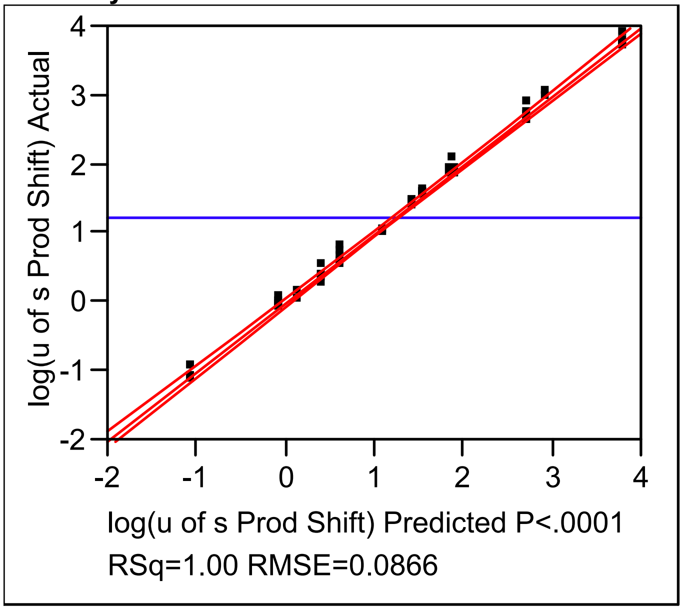
	Lenth PSE
t-Test Scale	2.3579428
Coded Scale	0.0026704

Pareto Plot of Estimates

Term	t Ratio
(Standard Deviation-0.03031)*(Flex Bound Width-0.03546)*(Flex Bound Length-19.8626)	-3.810966
(Standard Deviation-0.03031)*(Flex Bound Length-19.8626)	-2.512062
(Flex Bound Width-0.03546)*(Flex Bound Length-19.8626)	-2.288917
Standard Deviation2	2.200779
(Standard Deviation-0.03031)*(Flex Bound Width-0.03546)	1.940012
Standard Deviation	-1.788966
Flex Bound Width	0.778174
Flex Bound Length	-0.513803



Response log(u of s Prod Shift)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.996881
RSquare Adj	0.996242
Root Mean Square Error	0.086572
Mean of Response	1.241315
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	93.431360	11.6789	1558.276
Error	39	0.292296	0.0075	Prob > F
C. Total	47	93.723656		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	0.06677642	0.022259	3.5532
Pure Error	36	0.22551956	0.006264	Prob > F
Total Error	39	0.29229598		0.0237
				Max RSq
				0.9976

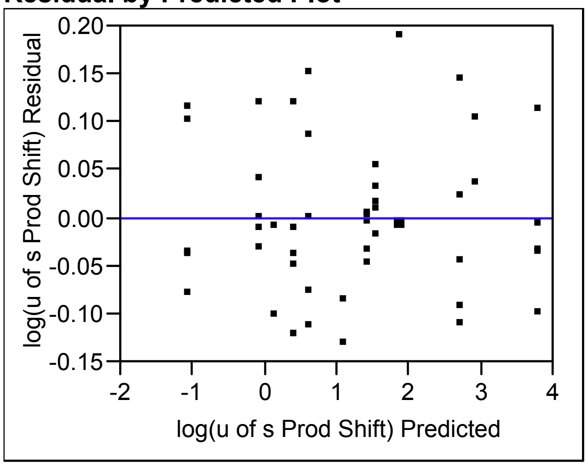
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.811113	0.038119	-21.28	<.0001
Standard Deviation	23.461632	0.942227	24.90	<.0001
Flex Bound Width	10.367064	0.142807	72.59	<.0001
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	21.94288	1.73641	12.64	<.0001
Flex Bound Length	-0.055875	0.001388	-40.24	<.0001
(Standard Deviation-0.10833)*(Flex Bound Length-11)	0.0087476	0.016882	0.52	0.6073
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-0.02908	0.015867	-1.83	0.0745
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-0.156717	0.192934	-0.81	0.4216
Standard Deviation2	-56.26577	4.195475	-13.41	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	4.646902	620.0195	<.0001
Flex Bound Width	1	1	39.497433	5270	<.0001
Standard Deviation*Flex Bound Width	1	1	1.196854	159.6919	<.0001
Flex Bound Length	1	1	12.138448	1619.589	<.0001
Standard Deviation*Flex Bound Length	1	1	0.002012	0.2685	0.6073
Flex Bound Width*Flex Bound Length	1	1	0.025173	3.3587	0.0745
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.004945	0.6598	0.4216
Standard Deviation2	1	1	1.347984	179.8566	<.0001

Residual by Predicted Plot

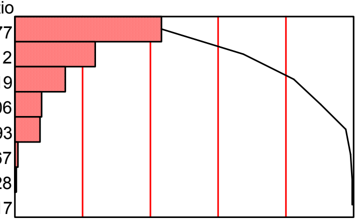


Effect Screening

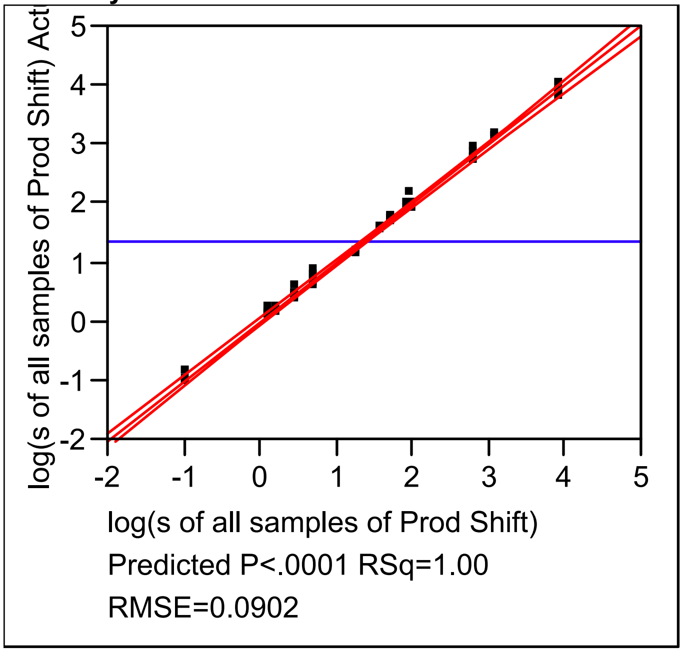
	Lenth PSE
t-Test Scale	10.852198
Coded Scale	0.1356052

Pareto Plot of Estimates

Term	t Ratio
Flex Bound Width	72.59477
Flex Bound Length	-40.24412
Standard Deviation	24.90019
Standard Deviation2	-13.41106
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	12.63693
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-1.83267
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-0.81228
(Standard Deviation-0.10833)*(Flex Bound Length-11)	0.51817



Response log(s of all samples of Prod Shift)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.996639
RSquare Adj	0.995949
Root Mean Square Error	0.090224
Mean of Response	1.353627
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	94.136558	11.7671	1445.52
Error	39	0.317474	0.0081	Prob > F
C. Total	47	94.454033		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	0.07452878	0.024843	3.6813
Pure Error	36	0.24294571	0.006748	Prob > F
Total Error	39	0.31747449		0.0207
				Max RSq
				0.9974

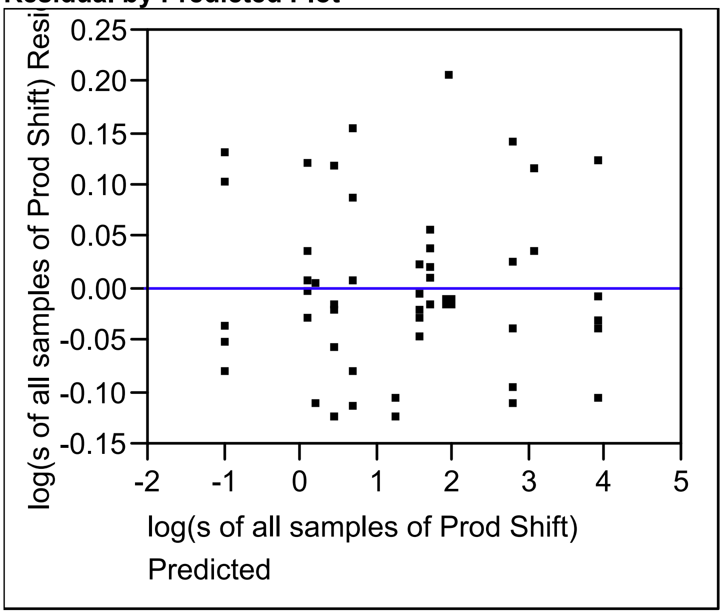
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.649562	0.039727	-16.35	<.0001
Standard Deviation	23.654837	0.981971	24.09	<.0001
Flex Bound Width	10.285444	0.148831	69.11	<.0001
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	22.072065	1.809653	12.20	<.0001
Flex Bound Length	-0.059551	0.001447	-41.16	<.0001
(Standard Deviation-0.10833)*(Flex Bound Length-11)	0.0082816	0.017594	0.47	0.6405
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-0.01925	0.016537	-1.16	0.2515
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-0.132569	0.201073	-0.66	0.5136
Standard Deviation2	-57.37654	4.372442	-13.12	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	4.723751	580.2869	<.0001
Flex Bound Width	1	1	38.877958	4775.944	<.0001
Standard Deviation*Flex Bound Width	1	1	1.210988	148.7632	<.0001
Flex Bound Length	1	1	13.788249	1693.811	<.0001
Standard Deviation*Flex Bound Length	1	1	0.001804	0.2216	0.6405
Flex Bound Width*Flex Bound Length	1	1	0.011031	1.3550	0.2515
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.003539	0.4347	0.5136
Standard Deviation2	1	1	1.401731	172.1950	<.0001

Residual by Predicted Plot

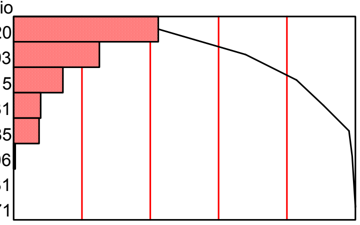


Effect Screening

	Lenth PSE
t-Test Scale	10.020685
Coded Scale	0.1304965

Pareto Plot of Estimates

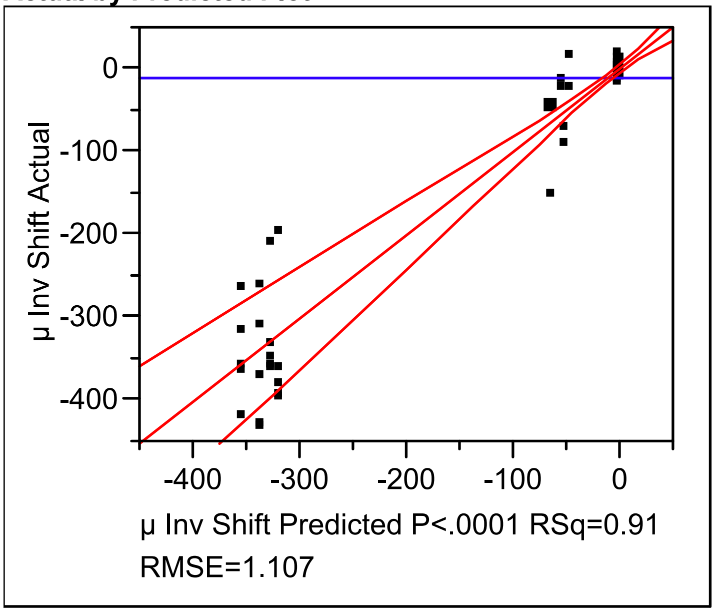
Term	t Ratio
Flex Bound Width	69.10820
Flex Bound Length	-41.15593
Standard Deviation	24.08915
Standard Deviation2	-13.12231
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	12.19685
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-1.16406
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-0.65931
(Standard Deviation-0.10833)*(Flex Bound Length-11)	0.47071



Response μ Inv Shift
Weight: wgt for u Inv Shift

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.909421
RSquare Adj	0.890841
Root Mean Square Error	1.106984
Mean of Response	-8.11736
Observations (or Sum Wgts)	0.217808

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	479.82816	59.9785	48.9455
Error	39	47.79114	1.2254	Prob > F
C. Total	47	527.61930		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	5.839990	1.94666	1.6705
Pure Error	36	41.951150	1.16531	Prob > F
Total Error	39	47.791139		0.1906
				Max RSq
				0.9205

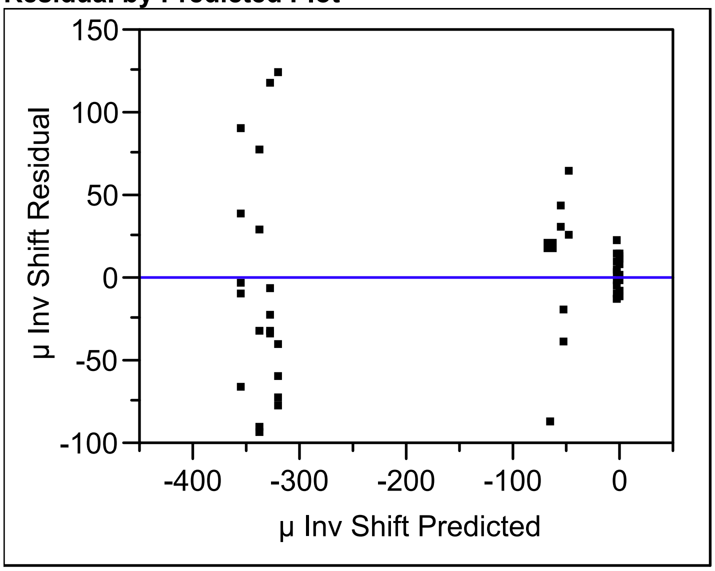
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-9.02988	10.41855	-0.87	0.3914
Standard Deviation	770.94552	495.5679	1.56	0.1279
Flex Bound Width	-13.37304	27.41311	-0.49	0.6284
(Standard Deviation-0.02507)*(Flex Bound Width-0.12327)	-93.81735	1036.055	-0.09	0.9283
Flex Bound Length	-0.058655	0.275417	-0.21	0.8325
(Standard Deviation-0.02507)*(Flex Bound Length-8.51126)	-2.07472	10.07001	-0.21	0.8378
(Flex Bound Width-0.12327)*(Flex Bound Length-8.51126)	-0.548597	3.154636	-0.17	0.8628
(Standard Deviation-0.02507)*(Flex Bound Width-0.12327)*(Flex Bound Length-8.51126)	-78.66942	116.6521	-0.67	0.5040
Standard Deviation2	-11918.28	2379.644	-5.01	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	2.965676	2.4201	0.1279
Flex Bound Width	1	1	0.291626	0.2380	0.6284
Standard Deviation*Flex Bound Width	1	1	0.010048	0.0082	0.9283
Flex Bound Length	1	1	0.055580	0.0454	0.8325
Standard Deviation*Flex Bound Length	1	1	0.052017	0.0424	0.8378
Flex Bound Width*Flex Bound Length	1	1	0.037059	0.0302	0.8628
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.557326	0.4548	0.5040
Standard Deviation2	1	1	30.738750	25.0844	<.0001

Residual by Predicted Plot

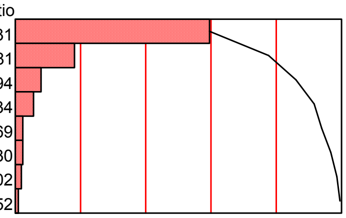


Effect Screening

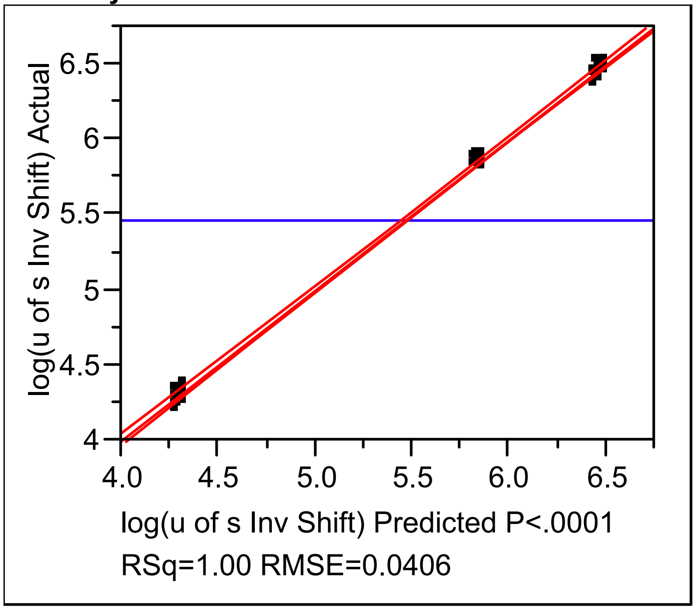
	Lenth PSE
t-Test Scale	0.3612949
Coded Scale	0.8569716

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation2	-5.008431
Standard Deviation	1.555681
(Standard Deviation-0.02507)*(Flex Bound Width-0.12327)*(Flex Bound Length-8.51126)	-0.674394
Flex Bound Width	-0.487834
Flex Bound Length	-0.212969
(Standard Deviation-0.02507)*(Flex Bound Length-8.51126)	-0.206030
(Flex Bound Width-0.12327)*(Flex Bound Length-8.51126)	-0.173902
(Standard Deviation-0.02507)*(Flex Bound Width-0.12327)	-0.090552



Response log(u of s Inv Shift)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.998657
RSquare Adj	0.998381
Root Mean Square Error	0.040626
Mean of Response	5.461866
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	47.860370	5.98255	3624.791
Error	39	0.064368	0.00165	Prob > F
C. Total	47	47.924737		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	0.00370669	0.001236	0.7333
Pure Error	36	0.06066096	0.001685	Prob > F
Total Error	39	0.06436765		0.5390
				Max RSq
				0.9987

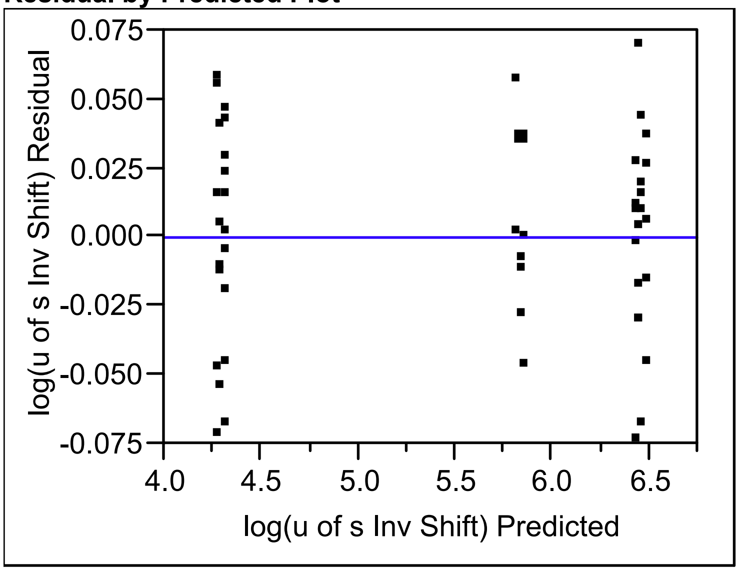
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	3.7655683	0.017888	210.51	<.0001
Standard Deviation	27.890307	0.442158	63.08	<.0001
Flex Bound Width	0.0312206	0.067015	0.47	0.6439
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	0.949028	0.814844	1.16	0.2512
Flex Bound Length	0.0009024	0.000652	1.39	0.1739
(Standard Deviation-0.10833)*(Flex Bound Length-11)	-0.013324	0.007922	-1.68	0.1006
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-0.010107	0.007446	-1.36	0.1825
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-0.133939	0.090538	-1.48	0.1471
Standard Deviation2	-72.35628	1.968809	-36.75	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	6.5667985	3978.787	<.0001
Flex Bound Width	1	1	0.0003582	0.2170	0.6439
Standard Deviation*Flex Bound Width	1	1	0.0022388	1.3565	0.2512
Flex Bound Length	1	1	0.0031661	1.9183	0.1739
Standard Deviation*Flex Bound Length	1	1	0.0046686	2.8287	0.1006
Flex Bound Width*Flex Bound Length	1	1	0.0030410	1.8425	0.1825
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.0036120	2.1885	0.1471
Standard Deviation2	1	1	2.2291973	1350.658	<.0001

Residual by Predicted Plot

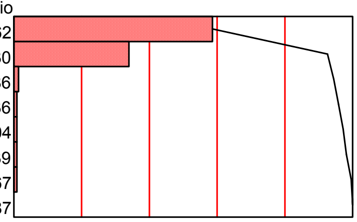


Effect Screening

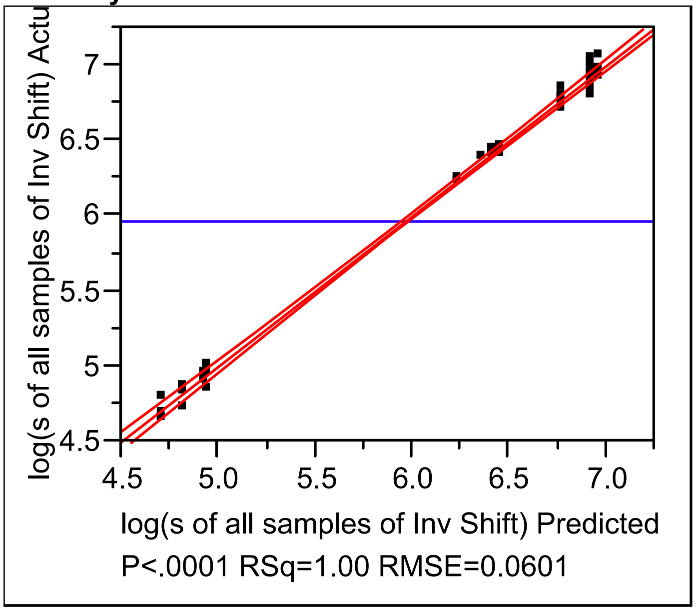
	Lenth PSE
t-Test Scale	2.0568252
Coded Scale	0.0120609

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation	63.07762
Standard Deviation2	-36.75130
(Standard Deviation-0.10833)*(Flex Bound Length-11)	-1.68186
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-1.47936
Flex Bound Length	1.38504
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	-1.35739
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	1.16467
Flex Bound Width	0.46587



Response log(s of all samples of Inv Shift)
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.996797
RSquare Adj	0.99614
Root Mean Square Error	0.060146
Mean of Response	5.961087
Observations (or Sum Wgts)	48

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	43.902922	5.48787	1517.034
Error	39	0.141082	0.00362	Prob > F
C. Total	47	44.044005		<.0001

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	3	0.00376039	0.001253	0.3286
Pure Error	36	0.13732196	0.003814	Prob > F
Total Error	39	0.14108235		0.8047
				Max RSq
				0.9969

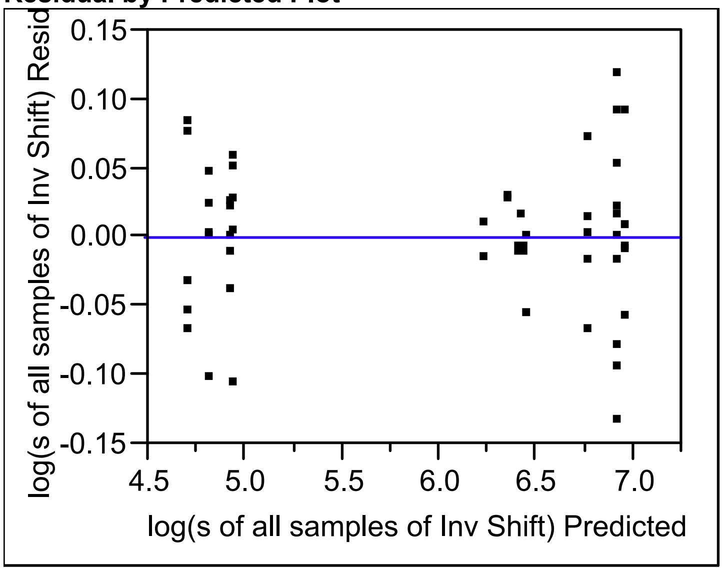
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.2865474	0.026483	161.86	<.0001
Standard Deviation	28.083149	0.654607	42.90	<.0001
Flex Bound Width	-0.431686	0.099215	-4.35	<.0001
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	-0.970945	1.206361	-0.80	0.4258
Flex Bound Length	0.0077909	0.000965	8.08	<.0001
(Standard Deviation-0.10833)*(Flex Bound Length-11)	-0.023152	0.011729	-1.97	0.0555
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.0307196	0.011024	2.79	0.0082
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.0105953	0.13404	0.08	0.9374
Standard Deviation2	-75.94252	2.914782	-26.05	<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Standard Deviation	1	1	6.6579221	1840.478	<.0001
Flex Bound Width	1	1	0.0684847	18.9315	<.0001
Standard Deviation*Flex Bound Width	1	1	0.0023434	0.6478	0.4258
Flex Bound Length	1	1	0.2359958	65.2373	<.0001
Standard Deviation*Flex Bound Length	1	1	0.0140958	3.8966	0.0555
Flex Bound Width*Flex Bound Length	1	1	0.0280914	7.7654	0.0082
Standard Deviation*Flex Bound Width*Flex Bound Length	1	1	0.0000226	0.0062	0.9374
Standard Deviation2	1	1	2.4556476	678.8252	<.0001

Residual by Predicted Plot

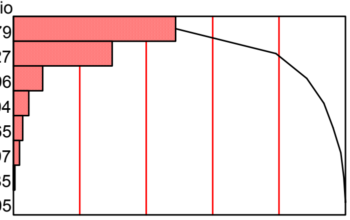


Effect Screening

	Lenth PSE
t-Test Scale	3.5704676
Coded Scale	0.0309962

Pareto Plot of Estimates

Term	t Ratio
Standard Deviation	42.90079
Standard Deviation2	-26.05427
Flex Bound Length	8.07696
Flex Bound Width	-4.35104
(Flex Bound Width-0.1125)*(Flex Bound Length-11)	2.78665
(Standard Deviation-0.10833)*(Flex Bound Length-11)	-1.97397
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)	-0.80485
(Standard Deviation-0.10833)*(Flex Bound Width-0.1125)*(Flex Bound Length-11)	0.07905



Vita

Chad Toney received his Bachelors of Science and Masters of Science degrees in Industrial Engineering at the University of Tennessee. For the first two years of his graduate education, Chad worked in the department of Industrial Engineering and Center for Industrial Services consulting with companies, developing training material, and performing research in the area of flow. During his doctoral program, Chad has been associated with the Center for Executive Education at the University of Tennessee, primarily working with the Lean Enterprise Systems Design Institute. Also at this time, he assisted with the development of the Systems Simulation Design Institute, a program for the continuous processing industry, and the Aerospace Executive MBA program at UT. His current interests are in the areas of the pull execution systems, rate based planning and scheduling, demand management, and supply chain management. Chad completed the requirements for the Ph.D. in Engineering with a major in Industrial Engineering at the University of Tennessee in the summer of 2005.