Strategic Inventory Management of Externally Sourced Medical Devices

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Abstract

The purpose of this research was to determine inventory strategies for externally sourced medical devices. In the medical device industry, the desire for high levels of customer service often results in less than optimal inventory levels. In this study, we analyzed the details of the current inventory model utilized by the medical device company. In assigning appropriate inventory levels, we determined that key inputs were not regarded. When evaluating inventory levels, it was determined that pipeline inventory should be removed from the target on hand inventory levels if inventory ownership occurs upon receipt. When calculating safety stock, we determined that supply variability should be incorporated into the safety stock formula and extra buffers currently in place should be removed. In addition, a more robust measure of demand variability such as the Root Mean Squared Error (RMSE) or the Mean Absolute Percent Error (MAPE) should be incorporated into the formula instead of the use of the maximum of standard deviation of demand and standard deviation of forecast. Also, a gap was identified between the customer service safety factor used in the safety stock formula and the measurement of customer service by the company. Following the analysis of the current inventory modeling approach, we segmented the medical device SKU's based on key factors that drive inventory: demand, lead time, criticality and customer service. We also redefined the model used to determine slow moving inventory levels by incorporating the lead time of the part in setting cycle and safety stock levels and simulating the results to validate the relationships between the various inventory drivers. The application of the methodologies, concepts and findings in this research covering externally sourced medical devices can be extended to other subsidiaries and other industries.

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1. Introduction

1.1. Overview of the Medical Device Industry

The medical device industry continues to navigate a difficult business environment. Increasing healthcare costs are forcing medical device companies to reduce the prices of their products and subsequently, cut costs across their entire operations. In addition to increasing healthcare costs, a number of other recent developments are impacting medical device companies. First, the implementation of a new 2.3% medical device excise tax that manufacturers and importers will pay on sales of certain medical devices beginning Jan. 1, 2013 (IRS 26 CFR Part 48). Next, the constant pricing challenges predicated by the pressure from hospitals to cut their own budgets. Finally, the state of the economy in the United States and Europe has reduced surgical volumes and thus, the demand for medical device products.

As a result, many medical device companies striving to maintain the high service standards demanded by the industry look to their supply chains to drive operational efficiencies. One area of operational concern is the amount of working capital that is tied up in inventory. Therefore, this thesis dissects the current inventory model used at a medical device company and segments products in to groups based on key inventory parameters. Unique inventory management strategies are then applied to each of these groups to determine appropriate cycle stock and safety stock levels.

1.2. Medical Device Company Background

Our research is centered on inventory drivers and inventory management strategies for a medical device company, subsequently referred to as "MedCo". MedCo is a $5 Billion subsidiary of a global leader in the medical device industry. MedCo supplies products related to orthopedics, spinal care, sports medicine, and neuroscience therapies to its own sales representatives and to medical facilities. The organization aims to maintain high customer service due to the critical nature of the products provided during patient care.

The focus of our research relates to the inventory management of 137 externally sourced medical device stock keeping units (SKUs) used in brain surgery related operations. These SKUs are provided primarily to hospitals, sales representatives, and distributors in the United States, to MedCo's European distribution center, and to MedCo's affiliates around the globe.

1.3. Current State Inventory Practices

MedCo's SKUs display a wide variety of characteristics. Annual demand for the SKUs range from 0-17,000 units, lead time ranges from 5-132 days, customer service levels range from 90%-99.5%, demand variability ranges from .5-480 units per six month period, and product cost ranges from $3-$11,000. Supply variability is not measured due to lack of available data. As a result, MedCo currently holds inventory of $0-$409,000 for each SKU with total inventory of ~$2.7 million.

MedCo currently defines a fast moving product as a product with a demand or forecast of six or more per month and a slow moving product as a product with a demand or forecast of less than six per month. The safety stock level and investment for fast moving products is driven by demand, lead time, customer service level (criticality), demand or forecast variability, and the cost of each part. MedCo has also decided that a safety stock of at least two weeks will be held for each of these parts. MedCo determines the safety stock level of slow moving SKUs using a grid structure which is explained in detail in section 3.1. As a result, each fast and slow moving SKU possesses a unique safety stock level.

1.4. Inventory Challenges

In recent years, MedCo's inventory investments have been growing and their current average weeks of supply (WOS) for the externally sourced medical devices is at ~38 weeks. Hence, at 38 weeks of supply, MedCo has enough inventories on hand to cover 38 weeks of customer demand. In addition, the expectation from their customers is to receive products within 24-48 hours after they place their orders which makes having products in inventory essential for fulfilling demand. Furthermore, there is a constant introduction of new products with very few items being discontinued, hence this increases the number of stock keeping units (SKU) maintained. As a result, MedCo aims to identify the appropriate inventory level targets for each medical device product in order to reduce inventory levels while maintaining high customer service.

1.5. Key Questions and Scope of the Study

Due to MedCo's desire to reduce inventory while still maintaining high customer service levels, our primary research focus was to determine the appropriate inventory modeling approaches for 137 externally sourced medical device SKUs. This involved understanding the inventory challenges specific to the medical device industry, unique characteristics of each product, the inventory modeling approaches that exist, and the current inventory modeling process at MedCo. Key questions explored during this process include: (1) What inventory management strategy is appropriate for each SKU? (2) How are safety stock service targets defined and measured? (3) What synergies exist between products and how can these synergies be leveraged?

Finally, additional research was conducted to understand the impact of different inventory drivers and determine which parameters could enable MedCo to reduce inventory while maintaining satisfactory customer service levels. This analysis allowed us to compare MedCo's current inventory levels with those we propose as a result of our research. Other subsidiaries and medical device companies will be able to leverage these findings in order to improve inventory levels and reduce costs.

2. Literature Review

Limited research currently exists relevant to inventory management in the medical device industry. Published literature often is not centered on inventory management specific to the medical device industry and instead focuses on topics such as supply chain collaboration. However, resources are abundant on inventory management strategies in other industries that are universally applicable.

In this literature review, we document the inventory management techniques and concepts that have been proven effective in other industries and that are relevant to the medical device supply chain. First, we discuss the medical device supply chain and the importance of inventory management. Next, we examine traditional aspects of inventory management such as inventory classification methods, SKU rationalization, safety stock calculations, and base-stock inventory models. Finally, we present the impact of service level measurement on inventories. This information sets the stage for determining appropriate inventory management strategies and inventory levels for a set of externally sourced medical device products.

2.1. Medical Device Supply Chain

Supply chain efficiency in the medical device industry continues to gain importance due to factors such as new medical device excise taxes, pricing pressures in the industry, and fluctuations in the economy. In addition, healthcare providers are receiving declining reimbursements as a result of healthcare reforms and at the same time are expected to continue delivering high quality patient care. Suppliers are also facing stiff challenges as selling, general, and administrative (SG&A) expenses cause their margins to decline. The SG&A expenses in the medical-surgical supplies industries are nearly twice that of other industries. These expenses impact both manufacturers and distributors. Therefore, the industry as a whole has the opportunity to initiate and embrace large scale changes and transformations to their supply chains. Organizations that have done this have had success increasing the efficiency of their business and controlling costs. This behavior is necessary for the future of the healthcare industry (Global Healthcare Exchange, 2012).

2.2. Managing Inventory Effectively

Effective inventory management across a supply chain is universally important despite the industry in which a company operates. According to the Aberdeen Group (2004):

> Inventory is one of the most valuable assets a company has, yet benchmark results show that most companies fail to manage it effectively. The majority of manufacturer and distributors rely on out-of-date, too simplistic, or overly localized inventory policies. By doing so, companies tie up working capital, harm customer retention, and hurt shareholder value. Faced with lengthening supply chain channels and tighter service-level demands from customers, many companies are now wholesale reexamining how to flow inventory across their supply chains and how to set inventory policies.

To effectively manage inventory, management must leverage improvement opportunities that exist throughout the supply chain. Many of today's inventory challenges relate to information flows, operational issues, and strategic issues (Billington & Lee, 1992).

Challenges relating to information flow include a lack of supply chain metrics, insufficient definitions of customer service, delivery data that is not accurate, and information systems that are inefficient. Supply chain metrics that are unaligned between entities in a supply chain result in objectives and missions that conflict or have little to do with the overall performance of the supply chain. Many companies do not have performance measures that monitor the complete supply chain, and if measures do exist the measures often lack metrics related to customer satisfaction. A company's definition of customer service is often insufficient as well. It is important for companies to determine whether line item fill rate or complete order fill rate should be measured based on expectations from customers. In addition, fill rate measures do not explain order delays and the magnitude of these delays. All of these aforementioned issues can be compounded as a result of a lack of integrated information systems between the facilities in a supply chain that participate in producing and delivering products to end users (Billington & Lee, 1992).

Challenges that relate to operational issues include not acknowledging the impact uncertainties will have on the supply chain and utilizing overly simplistic inventory stocking policies (Billington & Lee, 1992). According to the Aberdeen Group (2004), companies that use simplistic inventory management techniques have excess inventory of 15-30% and lower customer service levels. Several sources of uncertainty exist in a supply chain including lead time from suppliers, supplier delivery performance, incoming part quality, and demand. The lack of documentation and tracking of these variables makes it impossible to understand the sources of variation that exist and their magnitude. This can lead to insufficient inventory, excess inventory, and an inaccurate understanding of actual lead times (Billington & Lee, 1992). Many companies also set inventory policies that are too simplistic. "Despite companies' aspirations, Aberdeen estimates that fewer than 5% of companies today are effectively factoring in variability across the supply chain when setting inventory policies. Companies commonly use absolute lead times and monthly demand variation into their safety stock calculations (Aberdeen Group, 2004)."

Finally, an inaccurate measurement of inventory costs can impact strategic investments. Most organizations consider warehousing costs, storage costs, and costs associated with the opportunity cost of capital; however, they often ignore obsolescence costs and inventory reworking costs, both of which can significantly increase holding costs (Billington & Lee, 1992).

In order to leverage all of these opportunities, managers should consider the entire supply chain when making decisions, share integrated information across parties in the supply chain, make inventory decisions that benefit each site, and implement appropriate supply chain performance measures (Billington & Lee, 1992). "Companies that try to reduce inventory across the supply chain are twice as likely to have below-average inventory carrying costs as their industry peers (Aberdeen Group, 2004)."

2.3. Inventory Classification of SKUs

Inventory is a key cost driver in the medical device supply chain. In order to set inventory levels, companies often segment SKUs into characteristic-based groups. These groupings allow for the allocation of resources to SKUs that generate the most sales volume and ensure that resources are not over allocated to SKUs that have minimal impact on the bottom line of an organization. A traditional method for segmenting individual SKUs is A-B-C classification. The inputs to this classification method include the value of a SKU in dollars (v) and the annual demand for a SKU (D). A-B-C classification involves ranking SKUs in descending order, from highest to lowest, by D*v value. According to Silver, Pyke, and Peterson (1998), "it is common to use three priority ratings: A (most important), B (intermediate importance) and C (least important)" to group the results. The groupings are meant to correspond to the priority management gives to the SKUs in each group in terms of time and monetary resources. At times it is appropriate to have more than three categories, provided each receives unique treatment.

In an analyzed sample, Class A SKUs typically comprise 20% of SKUs and correspond to ~80% of the total annual dollar movement. Class B SKUs typically comprise 30% of SKUs and correspond to ~15% of the total annual dollar movement. Class C SKUs include the remaining 50% of SKUs and contribute to ~5% of the total annual dollar movement (Silver, 1998). Currently MedCo's classification of SKUs as either slow or fast movers based on demand results in ~78% of SKUs being classified as fast movers and ~22% of SKUs being classified as slow movers. The fast moving SKUs contribute to ~90% of the dollar movement over a six month period and the slow moving SKUs contribute to ~2% of the dollar movement over six months.

2.4. SKU Rationalization Process

Each product in a product portfolio has an impact on service level, revenue, and profit. As a result, it is important to analyze all products, including those with low volumes. "As contradictory as it may seem, eliminating product offerings-even though they are sources of revenue-can actually lead to increased revenue and better company performance" (Gilliland, 2011). However, before eliminating a SKU, one should verify that it is not newly released or commonly purchased with a much larger collection of products as this could result in the loss of customer(s). In addition, although revenue can be lost from removing items from a company's offerings, this can often be made up by slight increases in order fill rate on products that remain or customers buying potential substitute products to replace the item that has been discontinued. Overall, not all low volume items needs to be eliminated; however, their existence should be justified (Gilliland, 2011).

2.5. Calculation of Safety Stock

Following segmentation and SKU rationalization, safety stocks can be determined. According to Silver, Pyke and Peterson (1998) safety stock is not necessary when demand variability is absent and supply lead time is certain. Safety stock mitigates both the variability in actual demand against the expected demand as well as the difference between the observed and projected replenishment times. According to Chopra and Meindl, the appropriate level of safety stock considers the desired service level of product availability and the variability of both the demand and the supply (Chopra & Meindl, 2007). Demand uncertainty is measured as the forecast error for a given period. Silver, et al. presents a safety stock calculation, expressed as the product of the safety factor, k and the standard deviation of forecast error, σ_L (Silver, 1998).

$$SS = k * \sigma_L \tag{1}$$

When both demand and supply are uncertain, the safety stock formula is extended to account for the significant role of supply uncertainty (Chopra & Meindl, 2007):

$$SS = k * \sqrt{(E[L]\sigma_D^2) + ((E[D])^2\sigma_L^2)} \tag{2}$$

Where k is the safety factor, E[L] is the expected lead time, E[D] is the expected demand, and σ_D and σ_L are the standard deviation of demand and lead time respectively. Dimensional consistency is necessary across these parameters and a period of time must be defined over which the standard deviations are measured. For example, if the base time period is in months, then E[L] will be in months, σ_D and E[D] will be expressed for a one month period, and σ_L will be the standard deviation of lead time over a month.

In a base stock ordering policy, the equation is revised to include the review period (R). That is, the lead time will be replaced by lead time plus review period. Equations (1) and (2) are revised to reflect the safety stock calculations in a base stock model.

$$SS = k * \sigma_{Leadtime} \tag{3}$$

$$\sigma_{Leadtime} = \sqrt{\left([L+R]\sigma_D^2\right) + \left([D]^2\sigma_L^2\right)} \tag{4}$$

Choosing the appropriate level of safety stock involves making a trade-off between the inventory holding costs and the costs of stockout. The safety stock formula is typically used on products with high demand, which are referred to as fast-moving items. However, items with low demand are often characterized with a high coefficient of variation (Chopra & Meindl, 2007) and as such; the result of the safety stock formula corresponds to a high percentage of demand. Correspondingly, safety stocks must be allocated to slow-moving items in a different manner.

2.6. Base-Stock Inventory Model

MedCo's inventory levels are reviewed periodically over weekly intervals. This periodic review inventory policy is known as a base-stock inventory model. In the base-stock model, the inventory level is evaluated at each review period and replenished to a pre-determined order up-to level (Simchi-Levi, 2008). For each periodic review and lead time period, the inventory position is checked and an order is placed up to an order level that is enough to cover the time interval between orders and the lead time. Figure 1 illustrates the base-stock inventory model where inventory position is inventory on hand plus inventory on order, L is lead time, and R is the review period. This illustration shows the case where R is greater than L; however, it can also be applied to scenarios where L is greater than R. If L is greater than R, multiple orders will potentially exist in the system at the same time and the inventory position is evaluated based on inventory hand and in the pipeline.

The order-up to level, S can be calculated as the mean demand over lead time and review period plus the safety stock quantity. Equation (5) shows the order up-to calculation if lead time is deterministic and equation (6) shows the same calculation when lead time is stochastic (Silver, 1998).

$$S = \mu_{L+R} + k * \sigma_{Leadtime} \tag{5}$$

$$S = \mu_{L+R} + k * \sqrt{([L+R]\sigma_D^2) + ([D]^2\sigma_L^2)} \tag{6}$$

Orders are generally placed when the inventory position falls to the safety stock level, signifying the lowest theoretical level of inventory. The lowest level of inventory is a point just before receiving an order, whereas the highest level of inventory is achieved just after receiving an order (Simchi-Levi, 2008). Thus, the average inventory on hand is the average between the lowest and highest inventory levels. Mathematically it can be expressed as:

$$\textit{Expected Inventory High}, E[I^+] = S - \mu * L = \mu * r + k * \sigma * \sqrt{r+L} \tag{7}$$

$$\textit{Expected Inventory Low}, E[I^-] = S - \mu * (r+L) = k * \sigma * \sqrt{r+L} \tag{8}$$

$$\textit{Expected Inventory Average}, E[I^{ave}] = \frac{E[I^+] + E[I^-]}{2} \tag{9}$$

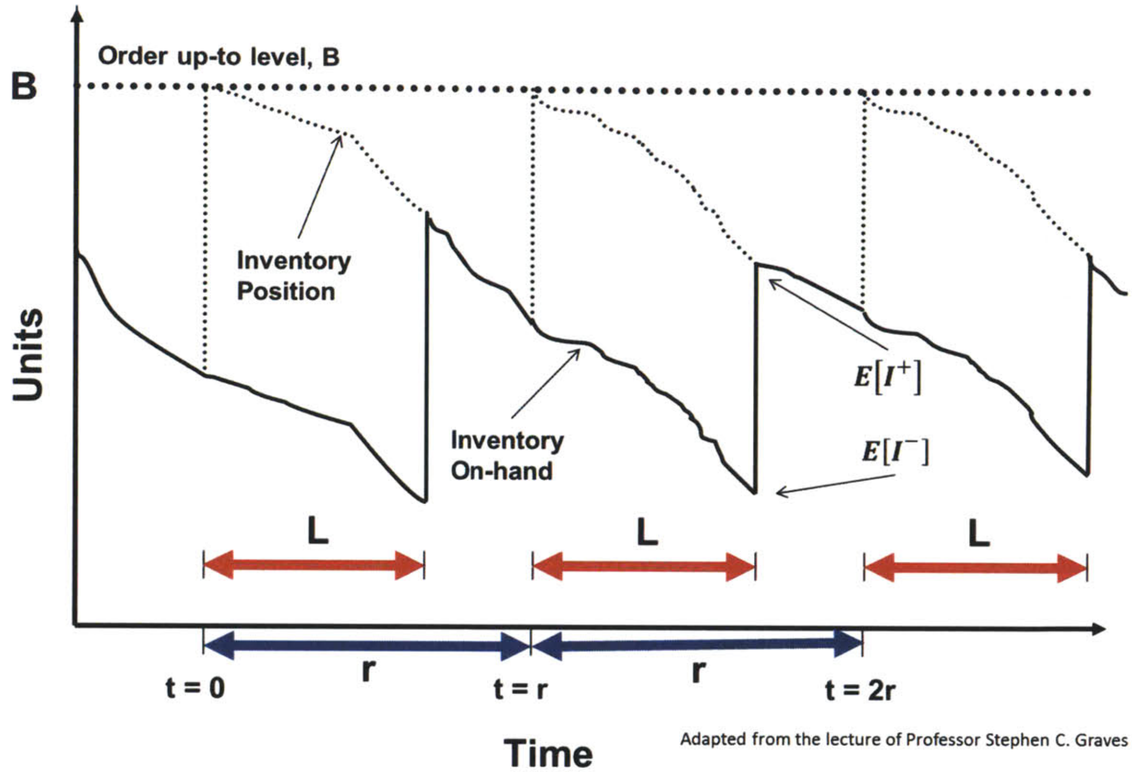

Figure 1: Base-stock Inventory Model

2.7. Measuring Customer Service

A company's customer service is tied to the satisfaction of customer demand through product availability. According to Simchi-Levi (2008), all else being equal, the higher the desired service level the larger the requirement for inventory investment. Two common service measures of product availability are item fill rate and cycle service level. According to Silver, Pyke, and Peterson (1998), cycle service level is the ratio of replenishment cycles without a stockout to the total number of replenishment cycles over a pre-defined period. Fill rate is the ratio of satisfied customer demand to total demand over a pre-defined period.

Fill rate can be further categorized as line fill rate, unit fill rate, and order fill rate. "The line fill rate (LFR) is the ratio of the number of order lines completely satisfied (LS) to the total order lines requested (LR) over a pre-defined time period. For example, if in March there was 1000 lines over 600 orders and we filled 850 lines completely a LFR of 85% would result. This has the potential to result in some orders that were not filled at all. The order fill rate (OFR) is the ratio of the number of orders completely satisfied (LS) without substitution or backorder to the number of orders requested (OR). For example, if in March there were 600 orders and 400 of them were able to be filled completely, then an OFR of 66.7% would result. The unit fill rate (UFR) is the ratio of the total units shipped (TUS) to the total units requested (TUR) (Frazelle, 2002). For example, if 100,000 units are ordered across 600 orders and 1,000 lines a unit fill rate of 50% will result if 50,000 units are shipped even if these 50,000 units appeared in only 850 lines and 400 orders.

$$\mathbf{LFR = LS / LR} \tag{10}$$

$$\mathbf{OFR = OS/OR} \tag{11}$$

$$\mathbf{UFR = TUS/TUR} \tag{12}$$

If one of these three types of fill rates is measured, it is possible to estimate the other two. An estimate of the LFR is the UFR raised to the average units per line (upl) and an estimate of the OFR is the LFR raised to the average lines per order (lpo) over a pre-defined period of time (Frazelle, 2002). For example, if a unit fill rate of 80% exists and the average units per line are five, the expected line fill rate is ~33%. In addition, if the line fill rate is ~33% and the lines per order are on average 5 then the order fill rate is ~.13%.

$$\mathbf{LFR = UFR^{upl}} \tag{13}$$

$$\mathbf{OFR = LFR^{lpo}} \tag{14}$$

In addition, unit fill rate can be converted to a cycle service level and vice versa. A unit fill rate can be converted to a cycle service level (CSL) using the unit normal distribution table (see Appendix Table 1) and the following equations:

$$G_u(k) = \frac{(1-F)*\mu*R}{\sigma\sqrt{R+L}} \tag{15}$$

$$CSL = 1 - p_{u\geq}(k) \tag{16}$$

Where $G_u(k)$ is the expected units short per cycle, F is the fill rate, μ is the average demand over a period, R is the review period, σ is the standard deviation of demand over a period, L is the lead time, and $p_{u\geq}(k)$ is the probability of stock out. First, $G_u(k)$ is calculated and the value is found in the unit normal distribution table. Next, the corresponding value for $p_{u\geq}(k)$ and k is found in the table and used to calculate the CSL. Finally, the corresponding k value is plugged into the safety stock formula (equation (3)) to achieve the desired item fill rate / customer service level.

A cycle service level can also be converted to a unit fill rate using the unit normal distribution table and the equations above. First, $p_{u\geq}(k)$ is found by subtracting the cycle service level from one. Next, this value is referenced in the unit normal distribution table and the corresponding $G_u(k)$ value is identified. Finally, equation (15) is used to calculate the unit fill rate. The following logic, displayed in Figures 2 and 3, can be used to perform the conversions between cycle service level and item fill rate in excel. For the same cycle service level, parts will have varying item fill rates due to differences in key parameters such as average demand and standard deviation of demand.

$$\phi(k) = \frac{1}{\sqrt{2\pi}} e^{-.5k^2} \qquad \Phi(k) = CSL$$

$$G(k) = \phi(k) - k * (1 - \Phi(k))$$

Norm.s.inv(CSL) | or Table Lookup | $IFR = 1 - \frac{\sigma_{L+R} * G_u(k)}{D * R}$

	Cycle Service Level Today (CSL)	k (safety factor)	G(k)	Item Fill Rate Generated	Average Monthly Demand	Demand Standard Deviation	Lead Time (in Months)	Review Period (in Months)
Part 1	99.51%	2.58	0.001563	99.91%	290,833	41,484	0.87	0.25
Part 2	99.51%	2.58	0.001563	99.95%	14,218	1,386	0.30	0.25
Part 3	99.51%	2.58	0.001563	99.81%	1,067	330	0.67	0.25
Part 4	99.51%	2.58	0.001563	99.96%	918	65	0.50	0.25
Part 5	99.51%	2.58	0.001563	99.93%	796	88	0.67	0.25

Figure 2: Cycle Service Level to k and Item Fill Rate in Excel

$G_u(k) = \frac{(1 - IFR) * D * R}{\sigma_{L+R}}$ | Table Lookup | Norm.s.inv(CSL)

	Desired Item Fill Rate	G(k)	Cycle Service Level (CSL)	k (safety factor)	Average Monthly Demand	Demand Standard Deviation	Lead Time (in Months)	Review Period (in Months)
Part 1	99.51%	0.0081934	98%	2.01	290,833	41,484	0.87	0.25
Part 2	99.51%	0.0170837	96%	1.73	14,218	1,386	0.30	0.25
Part 3	99.51%	0.0041743	99%	2.26	1,067	330	0.67	0.25
Part 4	100%	0.020259	95%	1.66	918	65	0.50	0.25
Part 5	100%	0.0117018	97%	1.88	796	88	0.67	0.25

Figure 3: Item Fill Rate to Cycle Service Level and k in Excel

Insight:

The primary scope of this research is to determine the optimal inventory modeling approach for externally sourced medical device products. The focal points of our research are to understand the inventory challenges specific to the medical device industry, to identify the various factors that affect inventory levels and to analyze the impact of each driver in order to determine which inventory parameters can be adjusted to drive efficiencies. A specific focus will be placed on product segmentation by exploring the unique characteristics of each product, such as velocity, lead time, costs and criticality. Each segment will warrant a different inventory management strategy to optimize inventory levels while maintaining the desired customer service levels and considering substitution opportunities.

3. Methodology

In order to assess and improve MedCo's inventory levels, we focused on the impact of key inventory drivers. Our methodology comprised four steps: understanding the company's inventory management approaches, identifying the key inventory drivers, segmenting parts into groups requiring similar inventory management strategies, and finally, outlining a strategy for measuring the potential inventory reduction opportunities as well as the impact of each driver on SKU levels.

The research scope involved approximately one hundred thirty externally sourced medical device SKUs. A snapshot of safety stock inventory in October of 2012 showed a total inventory for these products of ~$3.1 Million. Based on the company's inventory model, the company's goal at this time was to have a safety stock of ~$1.5 Million. In addition, the company desired to decrease inventory further through the modification of key inventory drivers.

3.1. Assess Current Inventory Management Practices

The company model, called the "inventory entitlement model", calculates safety stock levels. The model uses a formula comprising the following "If" statements:

- If a target customer service level = 0%, then safety stock level = zero

- If the product has a 6 month past demand and 6 month future forecast, where each month has a demand <= 5, then the inventory level is determined based on a grid (see explanation of grid in Figure 4, below)
- If the product's

  [service level * maximum(standard deviation demand, standard deviation

  forecast)* $\frac{\sqrt{\frac{Lead\ Time}{30}}}{Maximum(\frac{Average\ (6\ month\ demand)}{4}, \frac{Average(6\ month\ forecast)}{4}, 1)}$] <= 2 ,

  then safety stock is determined as

  $Maximum(\frac{Average\ (6\ month\ demand)}{4}, \frac{Average(6\ month\ forecast)}{4})*2$
- Otherwise, the safety stock is determined by:

  [service level * max(standard deviation demand, standard deviation forecast)* $\sqrt{\frac{Lead\ Time}{30}}$]

	1 & 2	Forecast					
	A	0	1	2	3	4	5
Demand	0	0	1	1	2	3	4
	1	1	1	1	2	3	4
	2	1	1	2	3	3	4
	3	1	2	2	3	4	5
	4	2	2	3	3	4	5
	5	2	3	3	4	4	5

	3 & 4	Forecast					
	B	0	1	2	3	4	5
Demand	0	0	1	1	1	2	3
	1	0	1	1	1	2	3
	2	1	1	1	2	2	3
	3	1	1	1	2	3	4
	4	1	1	2	2	3	4
	5	1	2	2	3	4	4

Figure 4: Grid for Slow Moving SKUs

The grid shown in Figure 4 is used to determine the inventory of slow moving parts. It is based on the maximum monthly demand over the past six months, the maximum monthly forecast for the next six months and the service level of the part. The service level is based on the cycle service level that is desired. A cycle service level is determined by the probability of not stocking out during an ordering cycle. An ordering cycle is defined as the time between when an order is placed and when it arrives. If a part has a desired cycle service level of 1 (90%) or 2 (95%), the first grid is used, and if a part has a desired customer service level of 3 (97%) or 4 (99.5%), the second grid is used. The maximum monthly demand over the previous six month period appears on the left side of the grid, and the maximum monthly forecast appears in the top of the grid. Where the two values intersect is the quantity at which the safety stock inventory is set for these slow moving parts.

In addition to the use of this formula there is also an option to override the safety stock value in special scenarios or modify it based on events that have taken place. For example, if a large special order creates a demand spike that is not representative of its potential future demand pattern. However, neither of these practices is currently being utilized. As a result, a one-time bump in demand will result in extra inventory that is not necessary.

We identified several gaps in this inventory entitlement model. First, when calculating safety stock levels, lead time variability is not considered. Second, setting five as the cut off for slow moving items was arbitrarily decided upon. Third, there are several buffers in the safety stock formula which include adjusting parts with less than two weeks of inventory to two weeks, rounding up all calculated figures, and taking the max of the demand or forecast for different calculations. Finally, the slow moving SKU grid does not take lead time in to account. These gaps need to be addressed and appropriate inventory drivers analyzed in order to reduce inventory levels.

3.2. Identification of Key Inventory Drivers

Inventory decisions in a complex medical device industry are governed by inventory drivers. In order to determine the appropriate inventory management strategies, an understanding of these key variables is necessary. As outlined in the literature review, there are specific drivers that influence the level of inventories. We analyzed the safety stock formula (equation (3)) on the basis of these drivers, which include product lead time, variability in demand and lead time, and criticality. In addition, we examined the impact of product costs, demand velocity, product substitutes and synergies.

3.2.1. Lead Time

The posted product lead time was used in the analysis. The accuracy of the product lead time information was verbally verified by the inventory managers; however, this was not confirmed mathematically due to the unavailability of inbound delivery data for the products in scope.

3.2.2. Demand

Aggregated monthly data from the previous 12 months was utilized. In addition, more granular line by line order data was extracted for synergy analysis. Furthermore, the forecast for the next 12 months was employed and compared with historical demand data.

3.2.3. Variability of Lead Time

Lead time variability information was not available. The variability of lead times can be determined by comparing the posted lead time with the elapsed time from the purchase order execution date to the product arrival date.

3.2.4. Variability of Demand

The variability of demand was extracted by assuming that the demand is normally distributed and taking the standard deviation of the aggregated monthly demand data. In addition, the mean absolute percent error (MAPE) and root mean squared error (RMSE) were calculated as a measure of forecast accuracy against actual demand.

3.2.5. Cost

The posted standard costs of the products were used. For simplicity, price changes were not factored into the analysis under the assumption that the current values will be representative of future costs.

3.2.6. Criticality

The criticality of the product was evaluated as the type 1 service level. That is, the probability that a stockout will occur for every replenishment cycle, as assigned by the inventory managers. Type 2 service, which is the item fill rate for any given product, was utilized in the synergy analysis of order data. With the given service levels, a normal distribution service factor was generated, which was used in the safety stock formula for inventory buffers.

3.3. Review of SKU Classification

The first step in developing a SKU classification system is to identify the key inventory drivers. Using the safety stock formula, we identified these key drivers: desired customer service level, lead time, demand, demand variability, and lead time variability. In addition, we considered the cost of each part an important factor as it directly influences the dollar value of inventory on hand.

Next, several of these key drivers were utilized in order to group the parts in scope. A part was identified as either slow or fast moving, having a long lead time or a short lead time, having a low criticality or a high criticality, and having a low cost or a high cost. Lead time variability was disregarded at this point, as the information was not available and currently was not used to calculate inventory levels.

Following the identification of the drivers that would be utilized during the SKU segmentation process, a determination of what was considered "low" and "high" was made. For service level (criticality), we divided the four service levels in to two groups. A low service level corresponded to anything at or below 95% and a high service level was at or above 97%. For demand, a low demand was determined as a SKU with an average monthly demand of less than or equal to ten. This constituted around 57% of SKUs and included parts that would soon be obsolete. Therefore, 57% of parts would be classified as low and 43% of parts would be classified as high. For lead time, a split of 31 days was selected as the review period for the parts in one month. This resulted in 50% of parts with a low lead time and 50% of parts with a high lead time. Finally, we looked at cost, with the top 20% of parts being over $600 and the remaining 80% of parts being below $600. A summary of the segmentation breakpoints can be found in Table 1.

Table 1: Segmentation Break Points

	Service Level	Demand	Lead Time	Cost
Low	74% SKUs Service Level 3= 95% or Service Level 4 = 90%	57% SKUs <= 10 /month	50% SKUs < 31 days	80% SKUs < $600
High	26% SKUs Service Level 1= 99.5% or Service Level 2 = 97%	43% SKUs > 10 / month	50% SKUs >=31 days	20% SKUs >= $600

After determining which SKUs had which characteristics, inventory strategies were devised for each group. One strategy was to utilize a simulation to determine target inventory levels for slow moving SKUs. The simulation implied that a low level of inventory should be held for these parts. Another strategy, used for fast moving parts, is determining safety stocks through the use of the safety stock formula. In addition, any parts with lead times below the customer requested lead times can be ordered from the supplier when a customer order is received. The strategies are displayed in Figure 5.

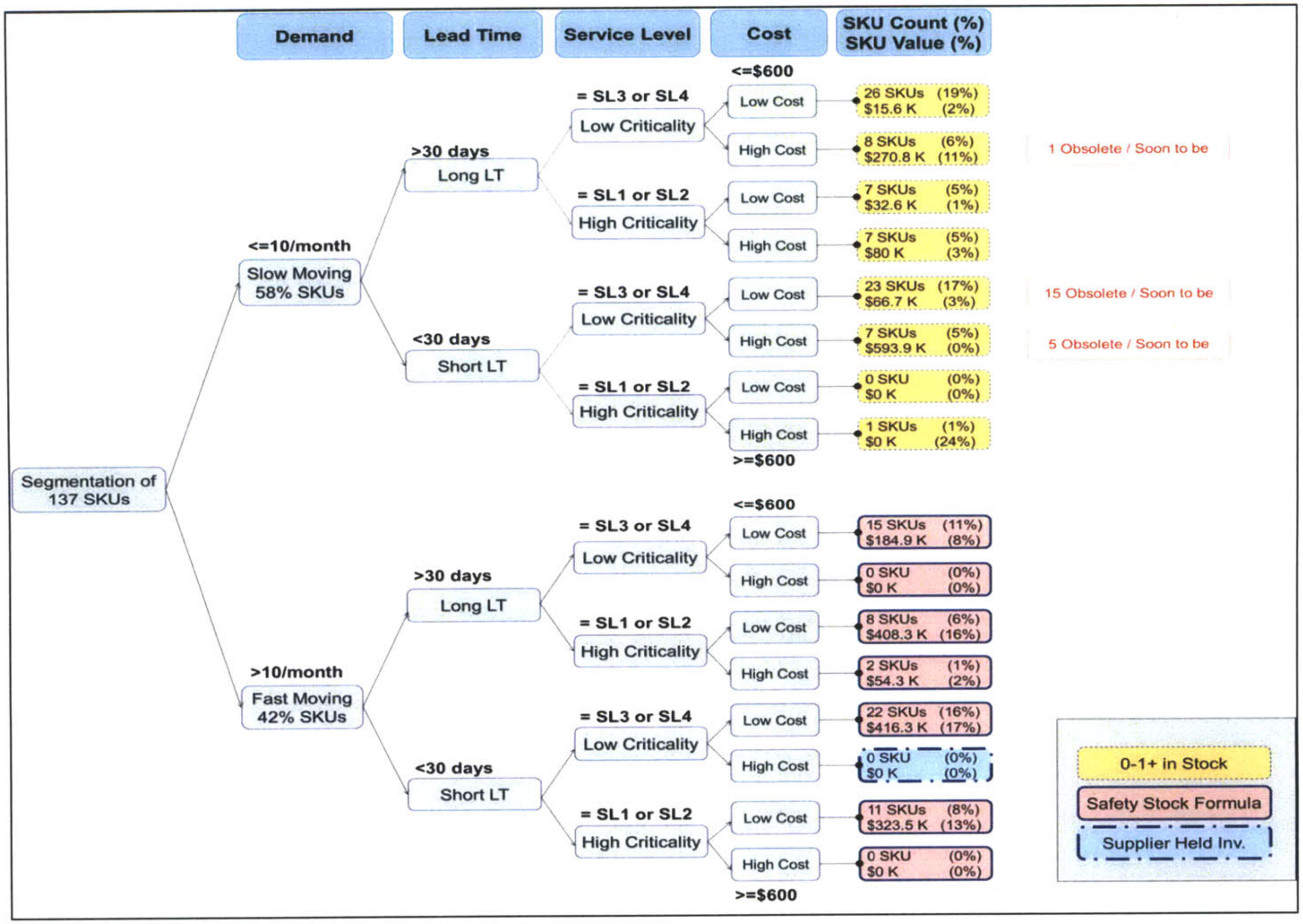

Figure 5: Inventory Management Strategies based on SKU Characteristics

3.4. Determination of Appropriate Inventory Management Strategies

Product segmentation and the analysis of the various drivers that influence inventory levels showcased that unique strategies for each product classification are required for an inventory management initiative to be effective. As outlined above, a decision tree was constructed using the identified product characteristics to come up with the various segments with each category analyzed to determine the appropriate inventory management strategy. Three inventory management strategies were considered: The first uses a safety stock formula (equation (3) from literature review), which factors product criticality, demand, and lead time, variability of demand and variability of lead time and is effective for products with high demand velocity. The second implements an order-to-order strategy where no inventory will be kept in stock. This strategy is appropriate for slow-moving products with short lead times. The third strategy, based on a simulation tool, keeps a limited number of units in stock to efficiently minimize the inventory holding costs. This strategy is suitable for slow-moving items.

In addition, synergies among each product were explored. To facilitate such analysis, custom-built proprietary software was used. This software analyzed order line details and prioritized each product by putting a premium on which items, when available, will yield a higher number of fulfilled orders. This analysis provided an insight on the relationship between products that would otherwise be uncorrelated. The findings from such analysis will influence the service level assignment of the products within our scope.

Following segmentation and synergy analysis, the impact of the various inventory drivers on inventory levels is investigated. This is done through a sensitivity analysis of the key drivers. The values of each parameter were systematically changed and compared to the current scenario to highlight the financial impact of each driver to inventory costs. To facilitate prioritizing of opportunities, each product was sorted according to the most savings yielded. The list of products was then further examined with the inventory managers to determine the feasibility of pursuing inventory reduction initiatives without sacrificing service levels.

4. Data Analysis

4.1. Measures of Customer Service

MedCo measures customer service through line item fill rate and sets safety stock using cycle service level. The customer service metric should match the customer service factor in the safety stock calculation. The reasoning behind this and impact of this disconnect can be seen through the following examples.

MedCo currently sets safety stock using a cycle service level (CSL). Each SKU is assigned a CSL of 90% (k = 1.28), 95% (k=1.64), 97% (k=2.33), or 99.5% (k=2.58), depending on its judged criticality. Since a SKU's item fill rate is dependent on the average demand and standard deviation of the SKU, varying item fill rates are generated for the same CSL. When demand variability and incoming supply lead time variability are stable, the fill rate is typically higher than the cycle service level. However, when lead time variability or demand variability is high, the fill rate is lower than the cycle service level (King, 2011). This is demonstrated in Figure 6. In this figure, each blue triangle corresponds to the Cycle Service level set for one of sixty eight individual SKUs and the red dot directly above or below each blue triangle represents the item fill rate generated for the same SKU. For example, SKU A has a desired cycle service level of 90% and an item fill rate of 96.3% and SKU B has a desired cycle service level of 90% and an item fill rate of 52%. The conversion between cycle service level and item fill rate is in section 2.7 of the literature review.

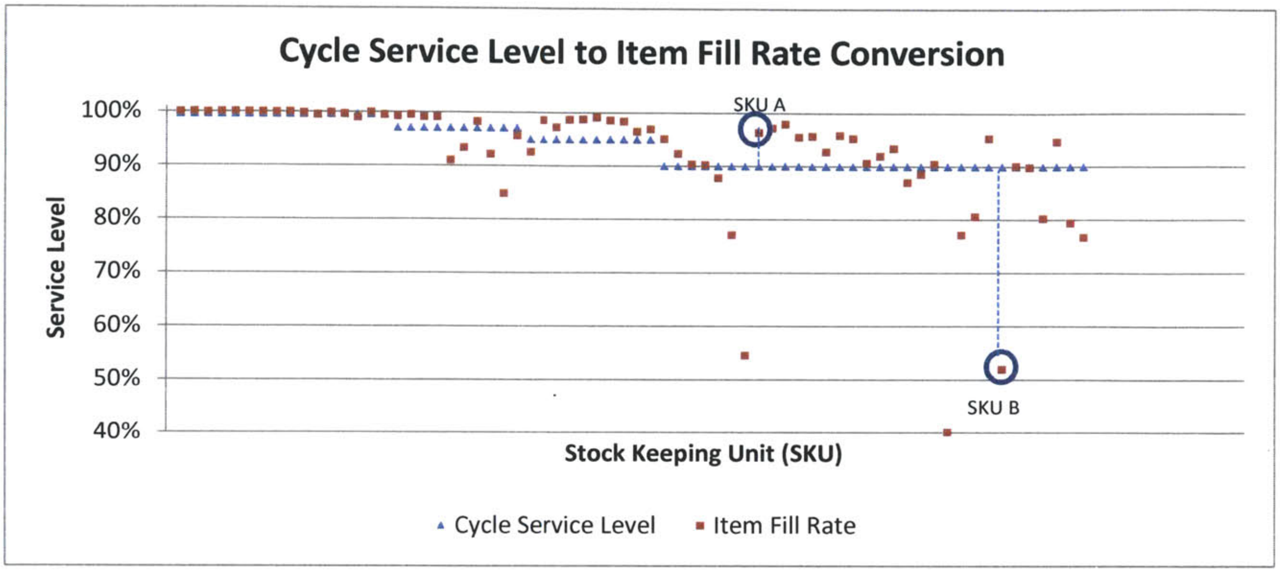

Figure 6: Cycle Service Level to Item Fill Rate

Reviewing these SKUs in further detail in Table 2, it is seen that the unique fill rates stem from the differences in lead time, demand, and standard deviation of demand for SKU A and SKU B. SKU B has a longer lead time (4.03 months verse .2 months) and a higher ratio of standard deviation to demand (1.2 units verse .3 units). Hence, these two factors contribute to the lower overall fill rate for SKU B.

Table 2: Fill Rate Comparison

SKU	Z	Cycle Service Level Today	Review Period (in Months)	Lead Time (in Months)	Average Demand (Monthly)	Standard Deviation (Monthly)	G(k)	Item Fill Rate Generated
A	1.28	90%	0.25	0.20	344.17	100.97	0.047543	**96.26%**
B	1.28	90%	0.25	4.03	12.67	15.50	0.047543	**51.84%**

Improvements to MedCo's customer service metric performance are possible through the alignment of the measure MedCo tracks (item fill rate) with the measure Medco uses in the safety stock formula (cycle service level). In reality, MedCo desires item fill rates, instead of cycle service levels, of 90%, 95%, 97%, or 99.5% and must adjust the k value in the safety stock formula accordingly to achieve this.

Analyzing the effect of this adjustment across the 68 externally sourced medical device SKUs with average monthly demand greater than 10 units, a savings of $7,070 can be realized. While, these savings are relatively small compared to the ~$1 Million currently held in inventory for these 68 parts, they are significant as this practice is currently applied to externally sourced products in this division of the company as well as in the other divisions. In addition, this analysis shows that enough inventories are not being held for some parts in order to hit the desired fill rates. Therefore, it is recommended that inventory be optimized and not necessarily just reduced.

Several factors influence how much safety stock must be held to hit a desired unit fill rate. These factors include review period, lead time, standard deviation, and demand. Holding all other variables constant, increasing the review period will decrease the required safety stock required to hit the same item fill rate and increasing the lead time, standard deviation, or demand will increase the required safety stock required to hit the same fill rate. Each of these impacts is demonstrated in Tables 3-6 where μ is average monthly demand in units, R is the review period in months, σ is the standard deviation of demand in units over a month, L is the lead time in months, G(k) is the unit normal loss function, and k is the safety factor used in the safety stock equation.

Table 3: Impact of Review Period

	Monthly										
Item Fill Rate	μ	R	σ	L	G(k)	k	Cycle Service Level	Safety Stock	Cycle Stock	Total Inventory	Weeks of Supply
95.00%	100	0.25	75	1	0.0149	1.78	96%	149	125	274	12
95.00%	100	0.5	75	1	0.0272	1.53	94%	141	150	291	13
95.00%	100	1	75	1	0.0471	1.28	90%	136	200	336	15
95.00%	100	2	75	1	0.0770	1.04	85%	135	300	435	19
95.00%	100	3	75	1	0.1000	0.9	82%	135	400	535	23
95.00%	100	4	75	1	0.1193	0.8	79%	134	500	634	27

The same fill rate is achieved with slightly less safety stock as the review period (R) increases. This does not yield an overall reduction in inventory, however, as additional cycle stock, in fact, much more, must be held to cover the review period. The impact of safety stock reduction is dwarfed by the increase in cycle stock.

Table 4: Impact of Lead Time

	Monthly										
Item Fill Rate	μ	R	σ	L	G(k)	k	Cycle Service Level	Safety Stock	Cycle Stock	Total Inventory	Weeks of Supply
95.00%	100	0.25	75	0.25	0.0236	1.59	94%	84	50	134	6
95.00%	100	0.25	75	0.5	0.0192	1.68	95%	109	75	184	8
95.00%	100	0.25	75	1	0.0149	1.78	96%	149	125	274	12
95.00%	100	0.25	75	2	0.0111	1.9	97%	214	225	439	19
95.00%	100	0.25	75	3	0.0092	1.97	98%	266	325	591	26
95.00%	100	0.25	75	4	0.0081	2.02	98%	312	425	737	32

As the lead time of a part increases, additional safety stock and cycle stock are required to hit the same item fill rate target. Therefore, working with suppliers to drive down lead times can generate significant inventory savings. Lead time is the most powerful factor influencing total inventory levels. For example, the part with a lead time of 3 months in the table above requires 266 units of safety stock and 325 units of cycle stock whereas the part with a lead time of .25 months requires a safety stock of only 84 units and a safety stock of only 50 units.

Table 5: Impact of Standard Deviation of Monthly Demand

	Monthly										
Item Fill Rate	μ	R	σ	L	G(k)	k	Cycle Service Level	Safety Stock	Cycle Stock	Total Inventory	Weeks of Supply
95.00%	100	0.25	5	1	0.2236	0.42	66%	2	125	127	6
95.00%	100	0.25	25	1	0.0447	1.31	90%	37	125	162	7
95.00%	100	0.25	50	1	0.0224	1.62	95%	91	125	216	9
95.00%	100	0.25	75	1	0.0149	1.78	96%	149	125	274	12
95.00%	100	0.25	100	1	0.0112	1.9	97%	212	125	337	15
95.00%	100	0.25	125	1	0.0089	1.98	98%	277	125	402	17

As the standard deviation of monthly demand increases, additional safety stock is required to hit the same item fill rate target. Therefore, working with customers to smooth out orders / prevent spikes in demand can generate significant inventory savings. Looking at past order data, the customers creating these spikes can be identified. Discussions can then occur with the customer to see if all of the product demand creating these spikes is truly needed at the time it is ordered or if the order can be delivered over a period in the future, hence smoothing out demand. In addition, MedCo currently promises deliveries to customers in 24-48 hours. If customers willing to accept longer delivery lead times are identified, this can also assist in smoothing out the demand delivered to the customer since a longer time window for delivery is available.

Table 6: Impact of Demand

	Monthly										
Item Fill Rate	μ	R	σ	L	G(k)	k	Cycle Service Level	Safety Stock	Cycle Stock	Total Inventory	Weeks of Supply
95.00%	25	0.25	18.75	1	0.0149	1.78	96%	37	31.25	69	12
95.00%	50	0.25	37.5	1	0.0149	1.78	96%	75	62.5	137	12
95.00%	75	0.25	56.25	1	0.0149	1.78	96%	112	93.75	206	12
95.00%	100	0.25	75	1	0.0149	1.78	96%	149	125	274	12
95.00%	125	0.25	93.75	1	0.0149	1.78	96%	187	156.25	343	12
95.00%	150	0.25	112.5	1	0.0149	1.78	96%	224	187.5	411	12

Finally, holding the coefficient of variation $(\frac{\sigma}{\mu})$ constant at 75%, as demand increases the safety stock and cycle stock will both increase in order to hit the same target fill rate. The weeks of supply, however, will remain the same in each scenario.

4.2. Expected Inventory Levels On Hand

The expected inventory on hand is the mid-point between the theoretical lowest point and the highest point immediately preceding delivery of products. The lowest point is typically the safety stock quantity with the highest point expressed as the demand over the review period plus the safety stock quantity. Equation (9) can be used to determine the expected inventory on hand for any given product in a periodic review model. The calculated expected inventory on hand was compared with MedCo's snap shot of actual inventory on hand. It was observed that the total expected inventory on hand was \$1,624,101 while the actual inventory on hand was \$3,057,159 for the externally sourced products within our scope. Table 7 illustrates the top 10 parts in terms of overstock cost variance between the theoretical expected and actual observed. In addition, Appendix Table 2 shows the part by part comparison between the expected and actual inventories on hand.

Table 7: Top 10 Parts with Inventory Variance

PART ID	UNIT COSTS (\$)	SAFETY STOCK (units)	AVG. WEEKLY DEMAND (units)	REVIEW PERIOD (Weeks)	EXPECTED MINIMUM ON HAND (units)	EXPECTED MAXIMUM ON HAND (units)	EXPECTED MINIMUM ON HAND (\$)	EXPECTED MAXIMUM ON HAND (\$)	EXPECTED AVERAGE ON HAND (units)	EXPECTED AVERAGE ON HAND (\$)	CURRENT ON HAND (units)	CURRENT ON HAND (\$)	DIFFERENCE (units)	DIFFERENCE (\$)
A	\$ 6,284.25	3	1	1	3	4	\$ 18,852.75	\$ 25,137.00	3.5	\$ 21,994.88	85	\$ 534,161.25	81.5	\$ 512,166.38
B	\$ 137.14	291	124	1	291	415	\$ 39,906.40	\$ 56,911.19	353	\$ 48,408.80	2050	\$ 281,127.57	1697	\$ 232,718.77
C	\$ 9,162.36	2	0	1	2	2	\$ 18,324.72	\$ 18,324.72	2	\$ 18,324.72	14	\$ 128,273.04	12	\$ 109,948.32
D	\$ 7,037.10	1	0	1	1	1	\$ 7,037.10	\$ 7,037.10	1	\$ 7,037.10	16	\$ 112,593.60	15	\$ 105,556.50
E	\$ 336.90	200	10	1	200	210	\$ 67,380.00	\$ 70,749.00	205	\$ 69,064.50	514	\$ 173,166.60	309	\$ 104,102.10
F	\$ 72.15	311	111	1	311	422	\$ 22,438.65	\$ 30,447.30	366.5	\$ 26,442.98	1669	\$ 120,418.35	1302.5	\$ 93,975.38
G	\$ 3,447.15	9	2	1	9	11	\$ 31,024.35	\$ 37,918.65	10	\$ 34,471.50	36	\$ 124,097.40	26	\$ 89,625.90
H	\$ 23.98	889	246	1	889	1135	\$ 21,314.13	\$ 27,212.08	1012	\$ 24,263.10	3795	\$ 90,986.64	2783	\$ 66,723.54
I	\$ 155.79	73	19	1	73	92	\$ 11,372.67	\$ 14,332.68	82.5	\$ 12,852.68	384	\$ 59,823.36	301.5	\$ 46,970.69
J	\$ 373.20	16	1	1	16	17	\$ 5,971.20	\$ 6,344.40	16.5	\$ 6,157.80	142	\$ 52,994.40	125.5	\$ 46,836.60

4.3. Added Safety Stock Buffers

MedCo's current entitlement model includes several additional "buffers" when calculating safety stock. Using the basic safety stock formula, equation (1) the recommended safety stock for the 58 fast moving parts is $480,892. However, MedCo's inventory model currently shows a recommended safety stock of $712,581. This gap is a result of two buffers: a two week minimum and a maximum standard deviation. If the recommended safety stock covers less than two weeks of the maximum of average weekly demand and average weekly forecast, then the recommended safety stock is two times the maximum of average weekly demand and average weekly forecast. Across the 58 parts this led to an extra $190,548 of recommended inventory. If the recommended safety stock covers more than two weeks, then the safety stock is determined in part by using the maximum standard deviation of demand or forecast. Since forecasts are estimates, this also has the potential to drive up inventory based on a number that is not very sound. Considering forecasts, instead of merely past demand, results in an additional $41,141 in inventory. Overall, the "buffers" add an additional $231,689 which is approximately 48% of the base level.

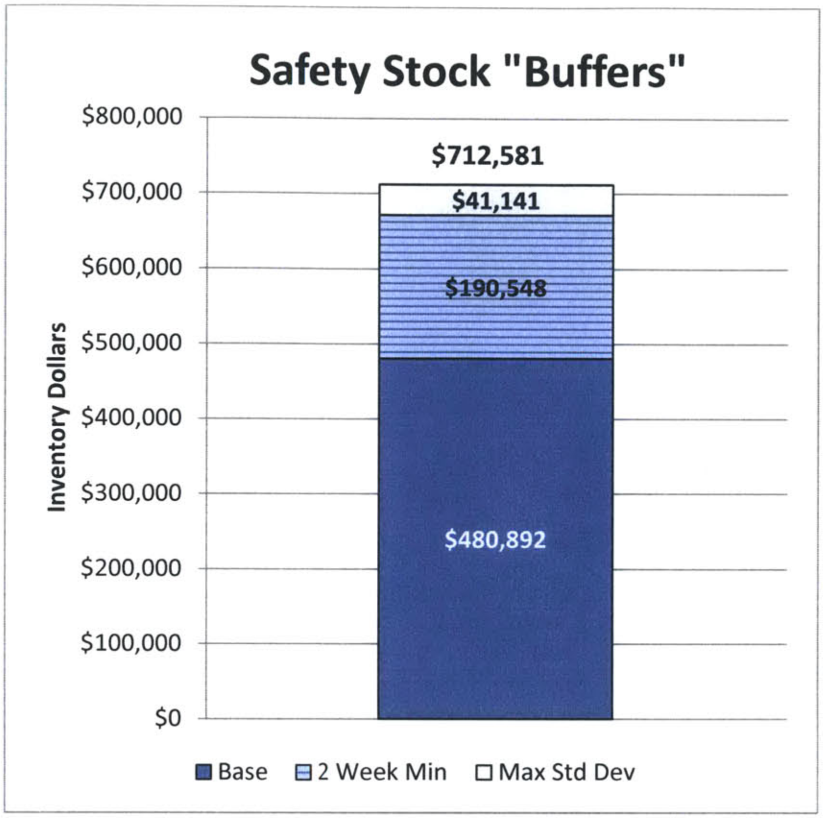

Figure 7: Buffers Added to Safety Stock

4.4. Simulation Analysis

A simulation model that represents the characteristics of the inventory system at MedCo was developed for the purpose of testing the effects and relationships of the various inventory drivers. In the simulation, the values of the probabilistic demand were randomly generated based on pre-determined demand distributions - Normal, Poisson or user defined entries. The outputs of the simulation are the type 1 cycle service levels and type 2 item fill rates. The controllable inputs are the mean and standard deviation of demand, lead time, safety stock, re-order point, minimum order quantity and review period.

The simulation model was also used to determine the breakpoint in categorizing the velocity of demand as fast or slow moving. The inventory strategies between a fast and slow moving product are materially different in that a slow mover will be managed through purchase to order or through the maintenance of a minimum level of safety inventories. The safety stock formula is not appropriate to use for slow moving products as the standard deviation is high compared to its mean as represented in the coefficient of variation. In contrast, a fast moving product requires the application of the safety stock formula. The use of the safety stock formula necessitates that the demand is normally distributed and thus the simulation was used to determine the mean demand to which the demand distribution becomes normally distributed.

As a result of the simulation, it was determined that the break point between slow and fast moving parts would be those with an average demand of 11 units per month. This is the point at which a strategy of keeping 0 or 1 unit of safety stock yielded a cycle service level greater than 95%. Moreover, the simulation tool was used to replace MedCo's current management of slow movers through the "Grid" by combining the effects of the various parameters mentioned (especially lead time) above to generate the expected service levels. Appendix Tables 3-13 outline the expected cycle service levels based on 35 runs of 1080 daily simulations of demand for slow movers with mean monthly demand of 11 units or less.

4.5. Obsolete Parts

Slow moving parts are often discontinued as the cost to provide them outweighs the revenues MedCo receives from offering them. Currently, ~$122 K in safety stock is held for 17 parts that have been identified as obsolete or soon to be obsolete parts. This safety stock level corresponds to 5% of the current on hand inventory.

4.6. Inventory Driver Impact

For parts that are not categorized as obsolete or soon to be obsolete, inventory drivers can be leveraged to reduce inventory levels. For slow movers this involves both cycle and safety stock and for fast movers a concentration is placed on safety stock levels.

4.6.1. Inventory driver analysis using the simulation

The objective of the inventory simulation is to determine the smallest inventory levels that will satisfy the target customer service levels. The inventory simulation model allows the simultaneous experimentation with the different drivers. For each controllable input, a random demand is generated and the resulting type 1 and type 2 service levels are calculated. With the simulation model in place, inventory managers can explore the sensitivity of their decisions with respect to controllable parameter inputs. For instance, an average monthly demand of 8 units, lead time of 30 days, order quantity of 10 units, review period of 7 days, safety stock of 3 units and simulated over a span of 1,080 days will yield a type 1 cycle service level of 92.9% and type 2 item fill rate of 99.3%. A summary of the simulation results for the different safety stock quantities is shown in Table 8.

Safety Stock	Type 1 Cycle Service Level	Type 2 Item Fill Rate
0	71.4%	95.0%
1	85.2%	96.3%
2	90.3%	98.0%
3	92.9%	99.3%
4	96.6%	99.7%
5	100.0%	100.0%

Table 8: Simulation Results

4.6.2. *Inventory driver analysis using safety stock formula*

Determining the impact of the key inventory drivers in the safety stock formula (customer service, lead time, demand variability, and lead time variability), requires manipulation of the safety stock formula. MedCo currently calculates inventory levels with several buffers built in. For example, the minimum safety stock level of two maximum weeks that is required regardless of the calculated inventory level (see section 4.3 Added Safety Stock Buffers). Removing all of these extra buffers drops the recommended inventory level of the 58 parts which the safety stock formula is appropriate for from $716 K to $481 K (a $235 K reduction). Currently safety stock for these 58 parts is at $1.6 Million, significantly higher than the recommended level.

4.6.2.1. Lead Time / Parts with High Lead Time

Lead Time is a critical driver of inventory levels. Reducing lead time allows for a reduction in both cycle stock and pipeline stock. This reduction results because when a part is ordered, a replacement part will arrive sooner from the supplier and thus, the inventory level requirements to satisfy target service levels were also reduced.

MedCo SKU lead times for fast moving SKUs range from 6-132 days. Focusing on the starting inventory level of ~$481 K for the 58 SKUs where the safety stock formula applies, it can be seen in Figure 8 below that reducing the lead time of each part by ten percent would reduce inventory to $456 K. Since MedCo currently bases safety stock on only the standard deviation of the lead time, instantaneous replenishment would eliminate safety stock needs. However, the review period must be factored into the calculation of the safety stock and thus, inventory levels will be higher than zero even when the lead time is set at zero.

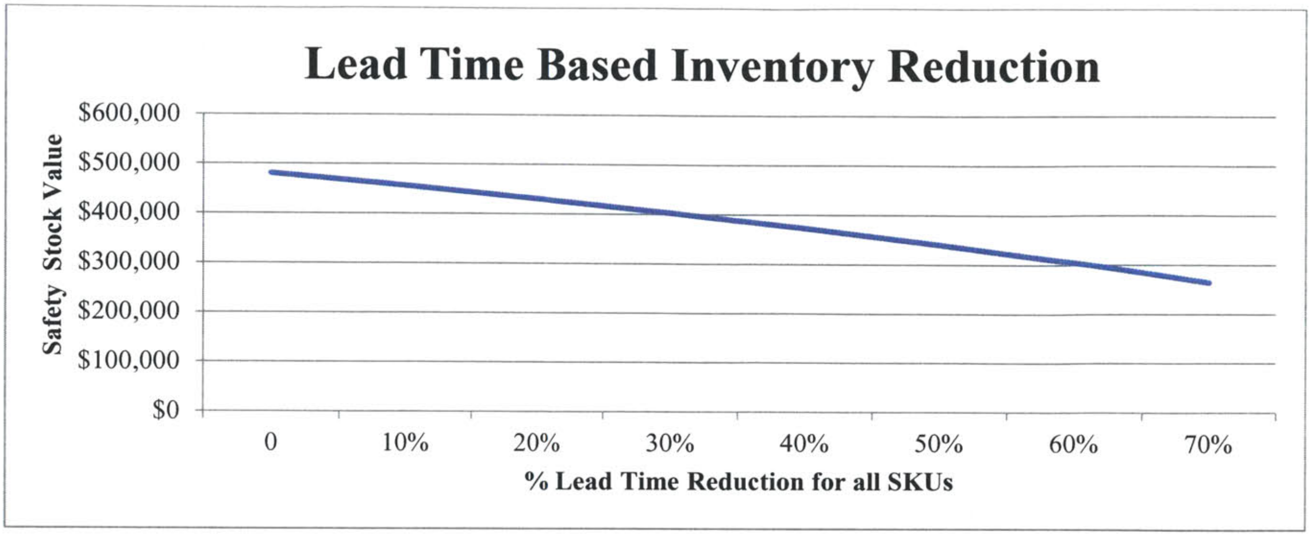

Figure 8: Lead Time Reduction Results in Reduced Inventory Levels

Next, we looked at each fast moving part group that resulted from our segmentation and labeled each group in Figure 9. Each of the five buckets corresponds to a graph in Figure 10. Groups 4-5 contain parts with short lead times and therefore will not generate large savings from inventory reduction. Group 1 also will not generate significant savings because even though the parts have long lead times, the dollar value of the parts are relatively low. Therefore, it is recommended that select parts from group 2 and parts from group 3 be targeted for lead time reduction. Group 2 contains several parts with long lead times, so even though the dollar value of the SKUS are lower these savings can grow if large reductions in lead time are possible. Group 3 contains long lead time and high dollar SKUs so reducing lead times in this group will generate the largest benefits. When deciding on the group 2 and group 3 parts to target suppliers should be taken into consideration. If there are several parts that belong to one supplier it makes the most sense to work with that supplier first as there will likely be added cost associated with working with each additional supplier to reduce lead times. These parts can be targeted by working with the suppliers of these parts to identify opportunities to drive down lead times.

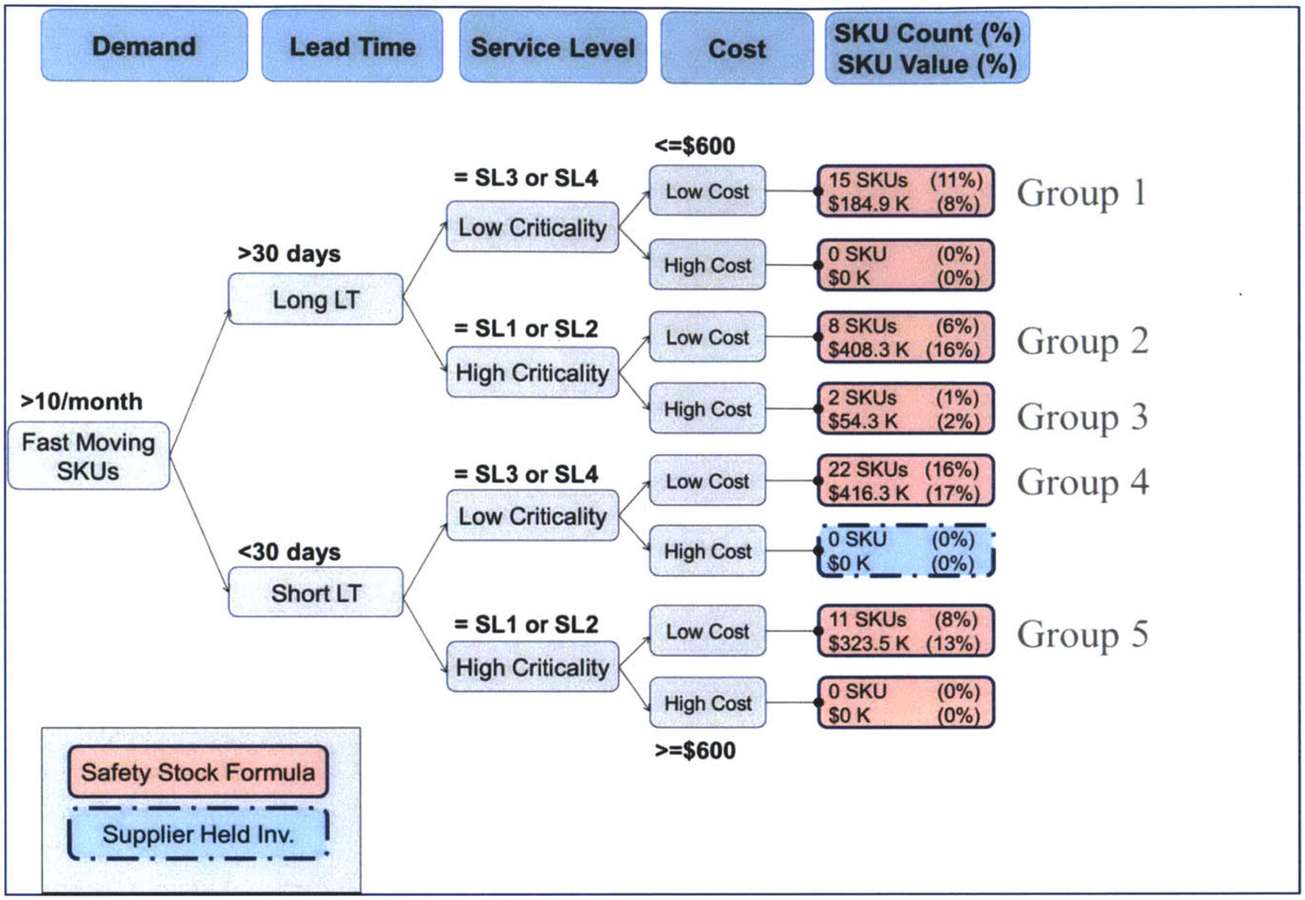

Figure 9: Fast Moving Group Segments

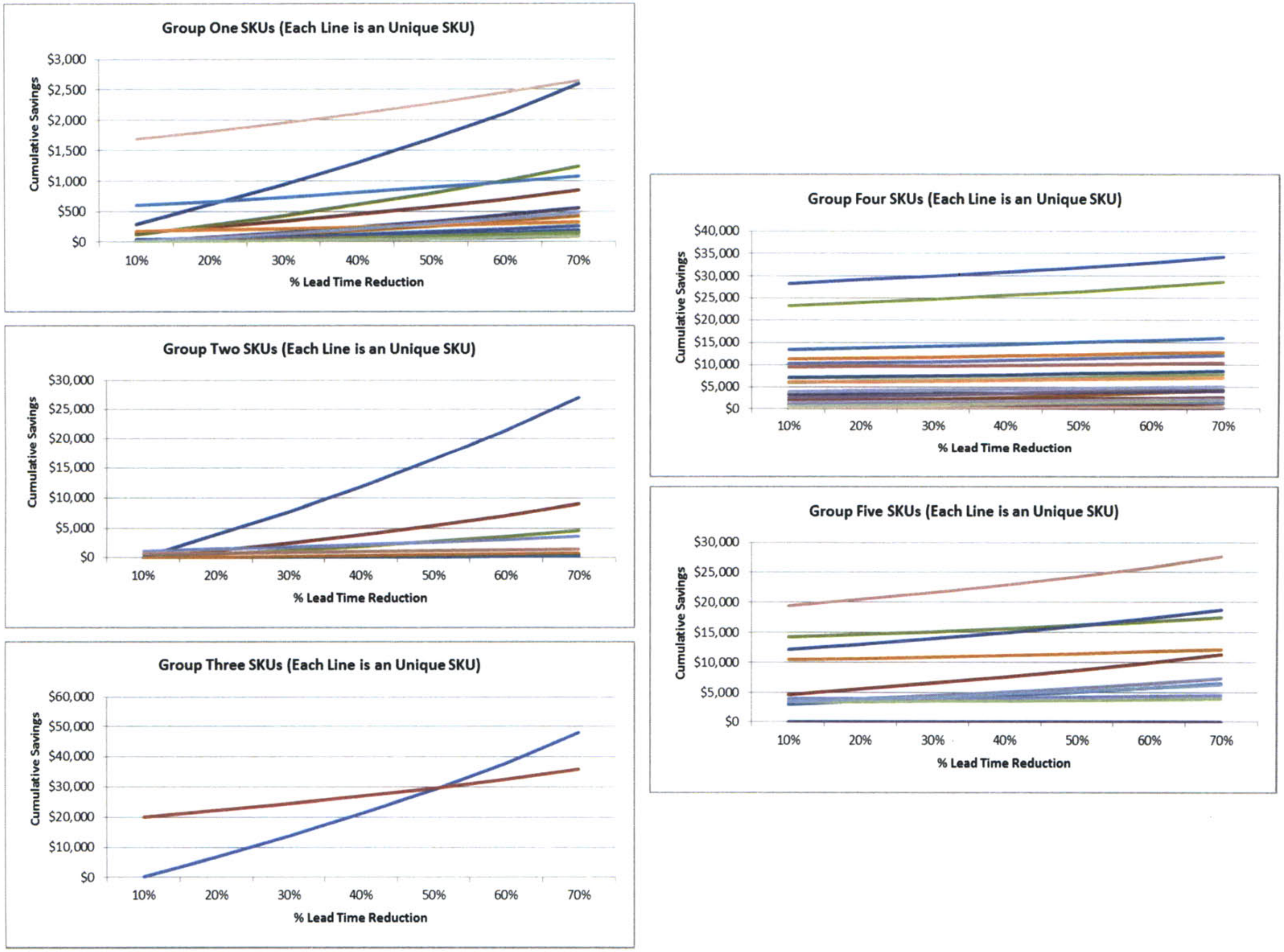

Figure 10: Lead Time Reduction by Group

4.6.2.2. Demand Variability

Demand variability is expected to be higher in the biomedical device industry due to the highly probabilistic nature of demand in the hospitals. The variability of demand in our analysis is represented by the coefficient of variation, which is the ratio of the standard deviation to the mean. All else being equal, the more variable the demand, the more safety inventory is required to meet the target service levels. Using the externally sourced parts within the scope of this research, it was observed that a 1% reduction in the coefficient of variation will yield an inventory savings of $35,801. Furthermore, the effects of demand variability to inventory value exponentially increase as the demand variability increases. A 25% increase in the coefficient of variation will equate to an increase in inventory cost by $377,474 and a 50% increase requires an additional inventory investment of $882,567. Figure 11 summarizes the effects of demand variability to inventory value across all parts. Reduction in the coefficient of variation for the high value, high variable products will yield the most savings. Despite the probabilistic nature of demand, MedCo should attempt to minimize demand variability by identifying the key customers of the highly variable products and partnering with them to improve forward looking indicators of demand. In addition, more robust sales and operations planning with internal departments involving shared assumptions and information may result in improved forecasts and reduced variability.

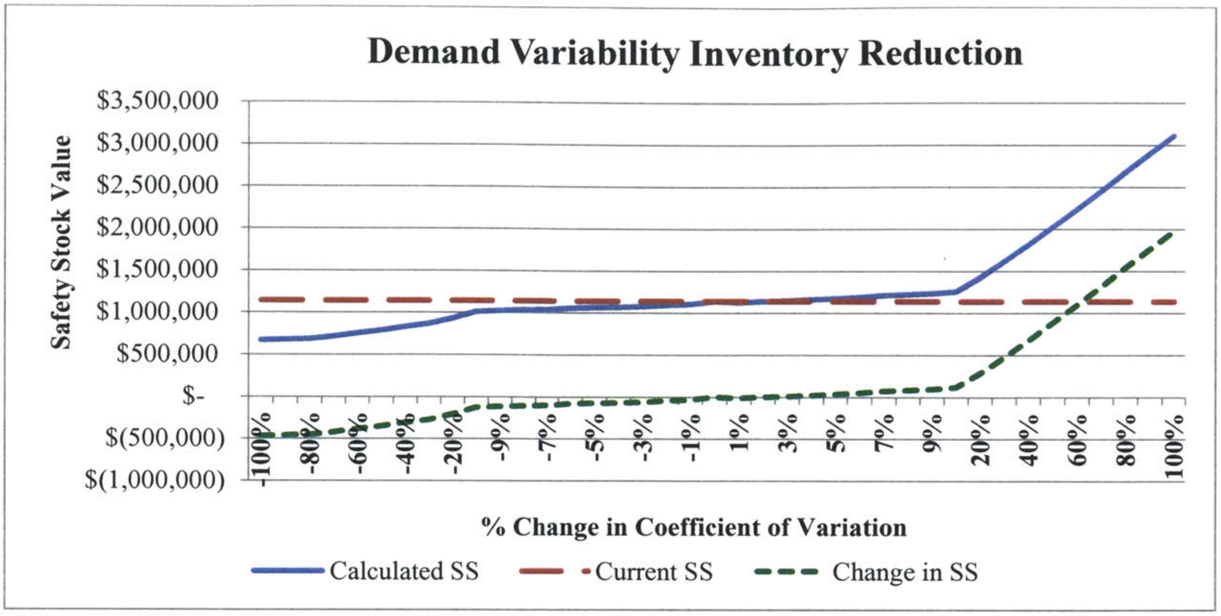

Figure 11: Coefficient of Variation Sensitivity Analysis

4.6.2.3. Customer Service Target

For fast moving parts, another key inventory driver is the desired customer service level. MedCo focuses on high customer service and delivers product within 24-48 hours of customer orders. However, a reduction in customer service would result in inventory savings.

Currently, all of MedCo's parts fall under one of four target customer service levels based on cycle service level: 99.5%, 97%, 95%, and 90%. The safety stock formula is applicable to these parts. These 58 SKUs currently contribute to ~$1.6 Million in inventory. According to MedCo's inventory entitlement model, safety stock inventory levels should be ~$716 K and removing the buffers in this formula, the recommended inventory level is $481 K.

Figure 12 below shows the impact on inventory value should MedCo leverage customer service targets as a driver for inventory reduction and is based on the 58 SKUs which were determined as fast moving. The baseline shows that there would be $481 K in inventory based on the customer service levels currently defined by MedCo. The subsequent points show the impact on inventory if the cycle service level (CSL) is decreased by 1% for each part until the part falls to 90%. For example, if the customer service level of each part is decreased by 1% inventory can be reduced by $37 K. Overall, if all parts are lowered to a customer service level of 90% the safety stock level can be decreased to ~$290 K from $481 K, resulting in inventory savings of $191 K which is a 40% reduction. Although, reducing all service levels may not be realistic, parts with the highest impact and those with substitutes could be considered.

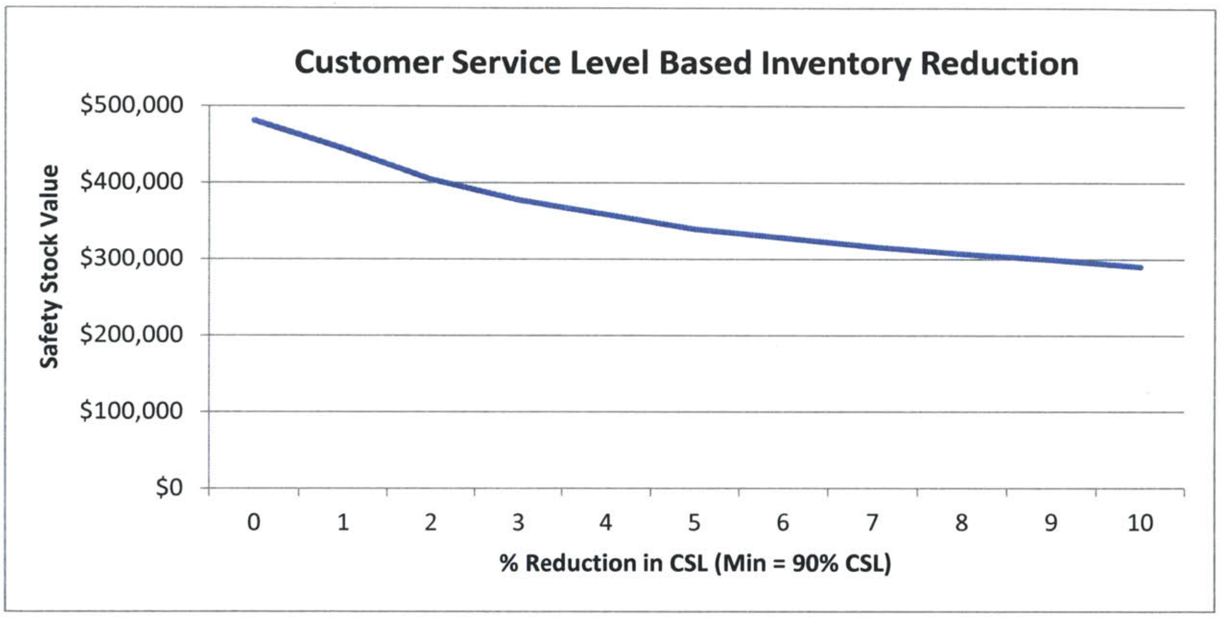

Figure 12: Cycle Service Level Impact on Inventory

The CSL can also be analyzed on a SKU group basis. The fast moving SKUs were broken down into five unique buckets through the development of the inventory management tree. The graphs on the right depict the parts in each of these groups and the cumulative savings from reducing CSL for each part by 1%. Groups two, three, and four show the largest opportunities for savings, whereas groups one and five show minimal opportunity since a majority of the SKUs already had an assigned CSL of 90% and we are assuming that it is undesirable to drop below this level.

Therefore, it should be decided if there are opportunities to provide different service levels to different customers or decrease the overall service levels for these parts as it makes sense from a business perspective.

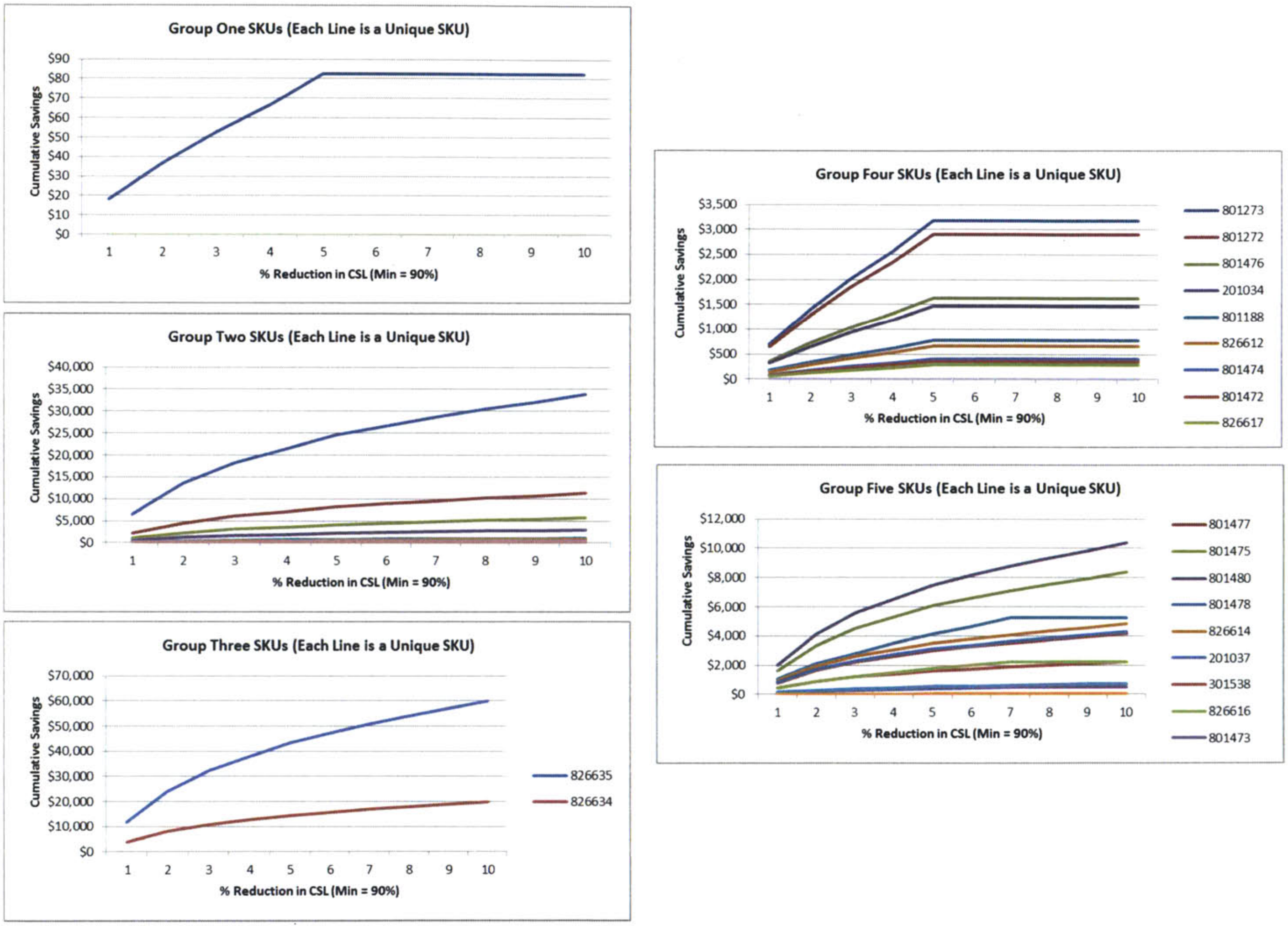

Figure 13: Cycle Service Level Reduction by Group

4.7. Synergy Analysis

Order data was reviewed for the period of January through November 2012. First, the SKU that could independently fulfill the largest number of orders was identified. This SKU, 301538, fulfills 17.3% of orders. Next, parts were added one by one in the order that fulfilled the largest percentage of orders. Figure 13 below shows that with just 26 of the 132 parts (20%), 80% of orders can be fulfilled. This analysis identifies key SKUs to stock in order to fulfill the most complete orders. The percent increase in order fulfillment by part is displayed in Appendix Table 14.

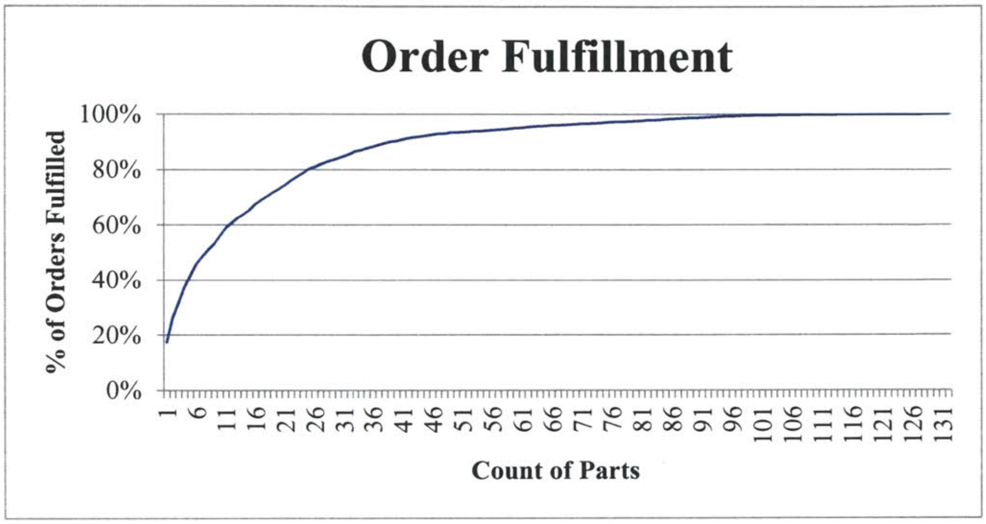

Figure 14: Cumulative Order Fulfillment Based on January – November 2012 Order Data

In addition to identifying key parts for stocking, this analysis identifies parts that travel together in clusters which are listed in Figure 14. All of these parts must be in stock in order to fulfill additional orders. For example, parts Q, R, S and T display a history of being ordered together. If part Q is not in stock then additional orders cannot be fulfilled even if the other three parts are available. This type of analysis is extremely useful in deciding safety stock levels to hold for parts and what to store in different warehouses that fulfill orders.

Clusters		
Cluster 1: Q R S T	**Cluster 2:** AB AC AD	**Cluster 3:** AF AG
Cluster 4: AI AJ	**Cluster 5:** AR AS	**Cluster 6:** BC BD
Cluster 7: BH BI	**Cluster 8:** BJ BK BL	**Cluster 9:** BN BO
Cluster 10: BQ BR BS	**Cluster 11:** CB CC CD	**Cluster 12:** CH CI CJ CK
Cluster 13: CL CM	**Cluster 14:** CO CP CQ CR	**Cluster 15:** DD DE
Cluster 16: DI	**Cluster 17:** DK DL DM	**Cluster 18:** DN DO
Cluster 19: DQ DR	**Cluster 20:** DS DT	

Figure 15: Part Clusters (Based on Part Numbers in Appendix Table 14)

5. Conclusion

5.1. Recommendations

5.1.1. Recalibrate Supply Chain Concepts

MedCo has the ability to set inventory levels more appropriately through the use of several supply chain concepts: inventory position against inventory on hand, the distinction between type 1 and type 2 service levels, and the components of the safety stock formula.

5.1.1.1. Inventory Position vs. Inventory On-hand

The decision of whether or not to replenish should be governed by the total inventory position. Total inventory position is the sum of orders in transit and inventory on hand. Inventory investments are influenced by contractual agreements. If pipeline inventory is owned by a company, the average inventory holding cost is based on the sum of the average pipeline inventory and average inventory on hand. In contrast if pipeline inventory is owned by the supplier, the average inventory holding cost is simply based on the average on hand inventory cost. Typically, companies take ownership of the products upon delivery of the materials as in the case of MedCo. Thus, MedCo.'s average inventory on hand using equation (9) is the midpoint between the safety stock and demand over the review period plus safety stock. Similarly, MedCo's inventory position is the sum of the inventory on hand and the pipeline inventory. MedCo currently sets a target for inventory position, however, MedCo compares average inventory on hand to the target resulting in higher inventory levels than necessary.

5.1.1.2. *Service Levels*

MedCo should align the service factor in the safety stock formula with what is measured in the organization. The company should use cycle service level or item fill rate to both set safety stock and measure performance. This alignment will optimize inventory levels. Since this alignment does not exist today some parts are overstocked and some are under-stocked. Based on our analysis of slow moving SKUs, MedCo is holding an extra ~$7 K in inventory for just 58 SKUs. Over the companies entire portfolio this impact will be seen at a much larger scale.

5.1.1.3. Safety Stock Calculation

At MedCo, instead of using the type 1 cycle service level safety factor in the calculation of the safety stock, MedCo uses the line item fill rate as if it was the cycle service level in the assignment of the safety factor. As shown in section 4.1, this error generated inconsistencies on the intended target service levels and the calculated safety stock. Moreover, MedCo does not factor the variability of lead time in the safety stock calculation. As a result, the calculated safety stock levels are understated to meet the intended target service levels. Furthermore, MedCo uses the maximum values of either the standard deviation of demand or the standard deviation of forecast in assigning the variability used in the safety stock calculation. When the standard deviation of demand is used in the safety stock calculation, the variation is measured from the average of the demand. This will be effective if the replenishment uses the average demand and not the maximum demand or the maximum forecast. Similarly, if the standard deviation of the forecast is used, the underlying assumption is that replenishment is performed using the average forecast and that the forecast is highly reliable that resembles actual demand. Instead, we recommend the use of the root mean squared error between the forecast and actual demand to be used in the safety stock calculation since MedCo uses a generated forecast to trigger replenishment. This is consistent with the current practice of replenishment using forecast as the safety stock is intended to buffer for the forecast error.

5.1.2. Refine the Entitlement Model

MedCo's inventory entitlement model is an analytic tool for inventory management that guides inventory planners in their decision to replenish inventory. Through the inventory entitlement tool, MedCo demonstrates their preference to use inventory analytics to compliment the business intuition of MedCo's inventory managers. The implementation of the inventory entitlement model had been effective to efficiently manage inventories across MedCo's global subsidiaries. However, the inventory entitlement model must be refined to address a number of deficiencies in the calculation of safety stocks. We identified several gaps in this inventory entitlement model. First, when calculating safety stock levels, lead time variability is not considered. Furthermore, the lead time variability data is not captured or was not made available in the calculation of the safety stock. Second, there were several buffers in the safety stock formula which include adjusting parts with less than two weeks of safety inventory to a minimum of two weeks demand as safety stock, rounding up all calculated figures, and taking the max of the demand or forecast for different calculations. Third, setting five as the cut off for slow moving items was arbitrarily decided upon. Finally, the slow moving SKU grid does not take lead time in to account. These gaps need to be addressed and appropriate inventory drivers analyzed in order to reduce inventory levels.

Lead time variability is an important element in the calculation of the safety stock and thus should not be excluded. The current calculation assumes that the replenishment lead time is exact but in actual practice, the arrival of externally sourced product from the suppliers varies. To protect from the supply variability, equation (2) must be used for safety stock calculation. Moreover, the extra buffers that are embedded in the entitlement model safety stock formula, unnecessarily over pads the safety stock in the system which then results to a much higher service level than originally targeted at the expense of increasing the risks of obsolescence, shortening of product shelf life and raising inventory holding costs. Furthermore, the arbitrary assignment of a monthly demand of five along with the use of the SKU grid over simplifies the management of slow movers and discounts the effects of other vital parameters such as the aforementioned lead time.

5.1.3. Inventory Management Strategies

Following product segmentation as described in section 3.3, MedCo can employ different inventory management strategies for every identified product segment. The majority of the fast movers will continue to be managed using the safety stock formula except for the fast mover with short lead time, low criticality and high costs which we recommend to hold with the supplier and order only when required. Currently, none of these parts exist in the portfolio of parts we analyzed, however as characteristics of parts change parts might move in to this group. Supplier held parts significantly reduce inventory holding costs without sacrificing service if the suppliers lead time is relatively short.

For slow moving products with a monthly demand of less than 10 per month, we recommend keeping a minimum amount of inventory and to use a simulation tool to guide them in the assignment of the appropriate level of safety stock to match the target service levels. In some cases, there will not be a need to hold safety stock as the cycle stock will be sufficient to satisfy the target fill rates. For the remaining slow moving SKUs, a limited safety stock level will be appropriate to uphold customer service targets.

In addition, MedCo should consider product substitutes and product synergies to complement their inventory strategies. Product substitution is the replacement of a product to fill the demand of another. Chopra and Meindl presented two forms of substitution categorized by who initiated the substitution – Manufacturer-driven and Customer-driven substitutions. In either case, the value of substitution lies in the supply chain's ability to satisfy orders by aggregating demand or reducing safety inventories without sacrificing customer service levels. In a Manufacturer-driven substitution, the total inventory requirement is reduced through aggregation of demand. Similarly, in a Customer-driven substitution, the reduction of safety inventories is enabled by the joint management of substitutable products (Chopra & Meindl, 2007). Additionally, Chopra and Meindl argued that both demand uncertainty and correlation between the substitute products influence the benefits that can be gained from substitution. Generally, the greater the demand uncertainty, the greater is the benefit of substitution. Likewise, the lower the correlation of demand between interchangeable products, the greater is the advantage of implementing substitution (Chopra & Meindl, 2007). For products with known substitutes, MedCo can aggregate demands to maximize the risk pooling of demand variability. Furthermore, MedCo can identify substitutes and strategically hold higher levels of inventory of the lower cost product, hence reducing inventory holding costs.

In addition to looking at product substitutes, the synergy analysis in section 4.7, demonstrates the importance of holding certain SKUs. For example, holding only 26 SKUs in inventory would have allowed for an order fill rate of 80% over a one year period. In addition, MedCo should investigate the stocking levels of the identified clusters to raise service levels even further. The synergy analysis was conducted with only the externally sourced products within our scope. However, the value of the synergy analysis can be magnified by increasing the scope of the analysis to all parts within MedCo. Moreover, the synergy analysis can be expanded to other subsidiaries with the intention to highlight the relationship of products that may intuitively otherwise be uncorrelated.

The other methodologies used in analyzing inventory strategies for externally sourced medical devices, namely product segmentation, inventory driver sensitivity analysis, and simulation analysis can likewise be expanded to a broader range of parts and to other subsidiaries of MedCo's parent company.

5.1.4. Inventory Efficiencies

5.1.4.1. *Reduction of Lead Time*

As shown in section 4.6.2.1, lead time is a critical factor in determining the appropriate inventory levels. As such, a reduction in lead time will result in lower cycle and pipeline inventories and ultimately lower total inventory levels. At the forefront, MedCo should validate the accuracy of lead time data. Definitions of the beginning and ending parameters of the lead time must be consistent across the entire company. In addition, rounding to the nearest month or week is discouraged as this practice will add additional buffers that were already factored into the safety stock calculations. Furthermore, continuous measurement and periodic validation is advisable. After validating lead time data, MedCo should explore opportunities to reduce lead time, focusing on parts with high value and long lead time as this product segment will drive the most significant inventory savings. To achieve lead time reduction, MedCo can identify key suppliers through supplier segmentation and collaborate with them to attain the reduction of lead time without sacrificing quality of the product and service to customers.

5.1.4.2. Measurement of Lead Time Variability

Knowing the variability of lead time is essential to guard against the uncertainty of supply. If lead time variability data is available, equation (2) can be used to calculate the appropriate safety stock for a given target cycle service level and ensure that enough safety stock exists in the system. Currently, MedCo does not measure lead time variability. Likewise, MedCo's safety stock calculation does not account for supply variability. A way to measure lead time variability for externally sourced medical devices is to compare the expected lead time with the time elapsed between the purchase order initiation and the receipt date for a particular product. We recommend that MedCo establish a measure of lead time variability and refine the safety stock calculation to factor lead time variability as shown in equation (2).

5.1.4.3. Measurement of Demand Variability

As discussed in section 4.6.2.2, demand variability is high in the biomedical device industry due to the unexpected nature of customer demand. Moreover, customers such as hospitals at times fill their shelves with quantities higher than their actual needs causing significant noise to demand patterns. In addition, the rising trunk stocks in the possession of the sales representatives masks the actual demand which also contributes to the variability in demand. In order to dampen demand variability, visibility of inventory across downstream customers is fundamental. MedCo must improve their knowledge of actual product usage at the hospitals to supplement the known order patterns. This information can be utilized to improve their forecasts and inventory management. Furthermore, the demand for products that will be used to re-stock hospital shelves can be smoothened by refining order fulfillment policies. MedCo should investigate the feasibility of changing order rules such as fulfilling "X" number of units within 24-48 hours with orders above “X” units to be completed in “Y” days. A change in fulfillment policy will allow MedCo’s supply chain to recover from unexpected demand patterns. Also, the feasibility of vendor managed inventory should be investigated by MedCo to regulate volatile demand patterns. Critical to success of these initiatives that reduces demand variability is partnership with key customers. MedCo should segment their customer base and identify the key customers to collaborate with in order to increase visibility of demand, understand their ordering patterns and negotiate fulfillment terms, all of which will ultimately result to reduced inventory levels and higher service levels.

6. Suggested Future Research

Our research provided a detailed strategic analysis of the inventory management strategies that can be applied for externally sourced medical devices. However, there were limitations to our study which can be the focus of future research. One area of future research as discussed in section 4.7 is the expansion of the synergy analysis to an increased number of stock keeping units beyond those in our scope. By doing this, the value of the synergy analysis will be magnified and the relationship of products that may otherwise be uncorrelated may surface. Another area of future research is an expansion of the analysis to include lead time variability. The exclusion of lead time variability is primarily due to the absence of tangible data. As suggested in section 5.1.4.2, it is highly advisable the MedCo begin collecting lead time variability data. This will predicate further analysis on its impact on the safety stock calculation, the overall inventory levels and inventory holding costs. In addition, lead time variability can be added as another key parameter to the simulation tool, further increasing the accuracy of expected customer service levels. This could be expanded to a broader scope of SKUs across MedCo’s parent company.

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8. Appendix

Appendix Table 1: Unit Normal Loss Table

Note: These values were calculated in excel and contain only a small snapshot of the unit normal loss table.

Z	CSL	p_u>=(k)	$G_u(k)$
0.000	50%	0.500000	0.399043
0.260	60%	0.397432	0.282449
0.530	70%	0.298056	0.188786
0.850	80%	0.197663	0.110042
1.040	85%	0.149170	0.077219
1.090	86%	0.137857	0.070043
1.130	87%	0.129238	0.064700
1.180	88%	0.119000	0.058493
1.230	89%	0.109349	0.052784
1.290	90%	0.098525	0.046549
1.350	91%	0.088508	0.040938
1.410	92%	0.079270	0.035905
1.480	93%	0.069437	0.030703
1.560	94%	0.059380	0.025555
1.650	95%	0.049471	0.020663
1.760	96%	0.039204	0.015799
1.890	97%	0.029379	0.011362
2.060	98%	0.019699	0.007231
2.070	98%	0.019226	0.007036
2.080	98%	0.018763	0.006846
2.330	99%	0.009903	0.003359
3.900	100%	0.000048	0.000011

Appendix Table 2: Calculated Inventory on Hand

PART ID	UNIT COSTS ($)	SAFETY STOCK (units)	AVG. WEEKLY DEMAND (units)	REVIEW PERIOD (Weeks)	EXPECTED MINIMUM ON HAND (units)	EXPECTED MAXIMUM ON HAND (units)	EXPECTED MINIMUM ON HAND ($)	EXPECTED MAXIMUM ON HAND ($)	EXPECTED AVERAGE ON HAND (units)	EXPECTED AVERAGE ON HAND ($)	CURRENT ON HAND (units)	CURRENT ON HAND ($)	DIFFERENCE (units)	DIFFERENCE ($)
A	$ 6,284.25	3	1	1	3	4	$ 18,852.75	$ 25,137.00	3.5	$ 21,994.88	85	$ 534,161.25	81.5	$ 512,166.38
B	$ 137.14	291	124	1	291	415	$ 39,906.40	$ 56,911.19	353	$ 48,408.80	2050	$ 281,127.57	1697	$ 232,718.77
C	$ 9,162.36	2	0	1	2	2	$ 18,324.72	$ 18,324.72	2	$ 18,324.72	14	$ 128,273.04	12	$ 109,948.32
D	$ 7,037.10	1	0	1	1	1	$ 7,037.10	$ 7,037.10	1	$ 7,037.10	16	$ 112,593.60	15	$ 105,556.50
E	$ 336.90	200	10	1	200	210	$ 67,380.00	$ 70,749.00	205	$ 69,064.50	514	$ 173,166.60	309	$ 104,102.10
F	$ 72.15	311	111	1	311	422	$ 22,438.65	$ 30,447.30	366.5	$ 26,442.98	1669	$ 120,418.35	1302.5	$ 93,975.38
G	$ 3,447.15	9	2	1	9	11	$ 31,024.35	$ 37,918.65	10	$ 34,471.50	36	$ 124,097.40	26	$ 89,625.90
H	$ 23.98	889	246	1	889	1135	$ 21,314.13	$ 27,212.08	1012	$ 24,263.10	3795	$ 90,986.64	2783	$ 66,723.54
I	$ 155.79	73	19	1	73	92	$ 11,372.67	$ 14,332.68	82.5	$ 12,852.68	384	$ 59,823.36	301.5	$ 46,970.69
J	$ 373.20	16	1	1	16	17	$ 5,971.20	$ 6,344.40	16.5	$ 6,157.80	142	$ 52,994.40	125.5	$ 46,836.60
K	$ 0.21	32,678	5,931	1	32,678	38609	$ 6,698.99	$ 7,914.85	35643.5	$ 7,306.92	264000	$ 54,120.00	228356.5	$ 46,813.08
L	$ 92.05	94	36	1	94	130	$ 8,652.70	$ 11,966.50	112	$ 10,309.60	599	$ 55,137.95	487	$ 44,828.35
M	$ 588.00	7	3	1	7	10	$ 4,116.00	$ 5,880.00	8.5	$ 4,998.00	81	$ 47,628.00	72.5	$ 42,630.00
N	$ 24.27	295	147	1	295	442	$ 7,160.83	$ 10,729.11	368.5	$ 8,944.97	2080	$ 50,489.92	1711.5	$ 41,544.95
O	$ 18.02	283	141	1	283	424	$ 5,099.74	$ 7,640.61	353.5	$ 6,370.18	2460	$ 44,329.94	2106.5	$ 37,959.76
P	$ 43.61	654	280	1	654	934	$ 28,520.16	$ 40,730.62	794	$ 34,625.39	1505	$ 65,631.24	711	$ 31,005.86
Q	$ 7,560.00	1	0	1	1	1	$ 7,560.00	$ 7,560.00	1	$ 7,560.00	5	$ 37,800.00	4	$ 30,240.00
R	$ 210.00	9	3	1	9	12	$ 1,890.00	$ 2,520.00	10.5	$ 2,205.00	152	$ 31,920.00	141.5	$ 29,715.00
S	$ 81.58	129	59	1	129	188	$ 10,523.78	$ 15,336.98	158.5	$ 12,930.38	522	$ 42,584.60	363.5	$ 29,654.22
T	$ 577.50	6	3	1	6	9	$ 3,465.00	$ 5,197.50	7.5	$ 4,331.25	49	$ 28,297.50	41.5	$ 23,966.25
U	$ 11.15	325	148	1	325	473	$ 3,624.82	$ 5,275.51	399	$ 4,450.17	2435	$ 27,158.29	2036	$ 22,708.12
V	$ 7,560.00	2	0	1	2	2	$ 15,120.00	$ 15,120.00	2	$ 15,120.00	5	$ 37,800.00	3	$ 22,680.00
W	$ 7,560.00	1	0	1	1	1	$ 7,560.00	$ 7,560.00	1	$ 7,560.00	4	$ 30,240.00	3	$ 22,680.00
X	$ 0.09	134,231	67,115	1	134,231	201346	$ 11,490.17	$ 17,235.22	167788.5	$ 14,362.70	414800	$ 35,506.88	247011.5	$ 21,144.18
Y	$ 44.68	502	184	1	502	686	$ 22,430.06	$ 30,651.44	594	$ 26,540.75	1058	$ 47,272.92	464	$ 20,732.17
Z	$ 6.49	1,636	482	1	1,636	2118	$ 10,624.18	$ 13,754.29	1877	$ 12,189.24	5050	$ 32,794.70	3173	$ 20,605.46
AA	$ 178.50	9	2	1	9	11	$ 1,606.50	$ 1,963.50	10	$ 1,785.00	104	$ 18,564.00	94	$ 16,779.00
AB	$ 709.50	6	1	1	6	7	$ 4,257.00	$ 4,966.50	6.5	$ 4,611.75	26	$ 18,447.00	19.5	$ 13,835.25
AC	$ 176.00	5	1	1	5	6	$ 880.00	$ 1,056.00	5.5	$ 968.00	82	$ 14,432.00	76.5	$ 13,464.00
AD	$ 195.00	15	5	1	15	20	$ 2,925.00	$ 3,900.00	17.5	$ 3,412.50	86	$ 16,770.00	68.5	$ 13,357.50
AE	$ 0.17	721	123	1	721	844	$ 120.84	$ 141.45	782.5	$ 131.15	80200	$ 13,441.52	79417.5	$ 13,310.37
AF	$ 1,974.00	10	1	1	10	11	$ 19,740.00	$ 21,714.00	10.5	$ 20,727.00	17	$ 33,558.00	6.5	$ 12,831.00
AG	$ 15.34	177	84	1	177	261	$ 2,715.18	$ 4,003.74	219	$ 3,359.46	1000	$ 15,340.00	781	$ 11,980.54
AH	$ 125.00	9	1	1	9	10	$ 1,125.00	$ 1,250.00	9.5	$ 1,187.50	105	$ 13,125.00	95.5	$ 11,937.50

Appendix Table 2: Calculated Inventory on Hand (continued)

PART ID	UNIT COSTS ($)	SAFETY STOCK (units)	AVG. WEEKLY DEMAND (units)	REVIEW PERIOD (Weeks)	EXPECTED MINIMUM ON HAND (units)	EXPECTED MAXIMUM ON HAND (units)	EXPECTED MINIMUM ON HAND ($)	EXPECTED MAXIMUM ON HAND ($)	EXPECTED AVERAGE ON HAND (units)	EXPECTED AVERAGE ON HAND ($)	CURRENT ON HAND (units)	CURRENT ON HAND ($)	DIFFERENCE (units)	DIFFERENCE ($)
AI	$ 41.16	28	9	1	28	37	$ 1,152.56	$ 1,523.03	32.5	$ 1,337.80	310	$ 12,760.53	277.5	$ 11,422.73
AJ	$ 0.16	4,370	1,769	1	4,370	6139	$ 677.35	$ 951.55	5254.5	$ 814.45	74200	$ 11,501.00	68945.5	$ 10,686.55
AK	$ 10,464.00	6	2	1	6	8	$ 62,784.00	$ 83,712.00	7	$ 73,248.00	8	$ 83,712.00	1	$ 10,464.00
AL	$ 378.93	1	0	1	1	1	$ 378.93	$ 378.93	1	$ 378.93	27	$ 10,231.11	26	$ 9,852.18
AM	$ 642.00	7	1	1	7	8	$ 4,494.00	$ 5,136.00	7.5	$ 4,815.00	21	$ 13,482.00	13.5	$ 8,667.00
AN	$ 22.90	384	158	1	384	542	$ 8,794.68	$ 12,413.32	463	$ 10,604.00	820	$ 18,780.30	357	$ 8,176.30
AO	$ 0.05	36,116	18,058	1	36,116	54174	$ 1,805.80	$ 2,708.70	45145	$ 2,257.25	208500	$ 10,425.00	163355	$ 8,167.75
AP	$ 190.00	9	2	1	9	11	$ 1,710.00	$ 2,090.00	10	$ 1,900.00	52	$ 9,880.00	42	$ 7,980.00
AQ	$ 180.60	3	1	1	3	4	$ 541.80	$ 722.40	3.5	$ 632.10	44	$ 7,946.40	40.5	$ 7,314.30
AR	$ 114.45	130	46	1	130	176	$ 14,878.50	$ 20,143.20	153	$ 17,510.85	215	$ 24,606.75	62	$ 7,095.90
AS	$ 42.00	26	1	1	26	27	$ 1,092.00	$ 1,134.00	26.5	$ 1,113.00	161	$ 6,762.00	134.5	$ 5,649.00
AT	$ 2.36	602	40	1	602	642	$ 1,420.36	$ 1,514.73	622	$ 1,467.55	2775	$ 6,547.34	2153	$ 5,079.79
AU	$ 194.25	21	10	1	21	31	$ 4,079.25	$ 6,021.75	26	$ 5,050.50	50	$ 9,712.50	24	$ 4,662.00
AV	$ 4.78	440	93	1	440	533	$ 2,103.20	$ 2,547.74	486.5	$ 2,325.47	1438	$ 6,873.64	951.5	$ 4,548.17
AW	$ 0.31	4,739	1,769	1	4,739	6508	$ 1,481.41	$ 2,034.40	5623.5	$ 1,757.91	19000	$ 5,939.40	13376.5	$ 4,181.49
AX	$ 31.02	74	37	1	74	111	$ 2,295.23	$ 3,442.84	92.5	$ 2,869.04	220	$ 6,823.65	127.5	$ 3,954.62
AY	$ 278.52	1	0	1	1	1	$ 278.52	$ 278.52	1	$ 278.52	15	$ 4,177.80	14	$ 3,899.28
AZ	$ 22.07	35	5	1	35	40	$ 772.33	$ 882.66	37.5	$ 827.49	213	$ 4,700.16	175.5	$ 3,872.67
BA	$ 2.36	145	6	1	145	151	$ 342.11	$ 356.27	148	$ 349.19	1767	$ 4,169.06	1619	$ 3,819.87
BB	$ 178.50	3	1	1	3	4	$ 535.50	$ 714.00	3.5	$ 624.75	24	$ 4,284.00	20.5	$ 3,659.25
BC	$ 183.50	0	0	1	0	0	$ -	$ -	0	$ -	19	$ 3,486.50	19	$ 3,486.50
BD	$ 297.55	0	0	1	0	0	$ -	$ -	0	$ -	10	$ 2,975.50	10	$ 2,975.50
BE	$ 125.00	0	0	1	0	0	$ -	$ -	0	$ -	23	$ 2,875.00	23	$ 2,875.00
BF	$ 42.08	29	8	1	29	37	$ 1,220.32	$ 1,556.96	33	$ 1,388.64	100	$ 4,208.00	67	$ 2,819.36
BG	$ 27.76	24	8	1	24	32	$ 666.24	$ 888.32	28	$ 777.28	112	$ 3,109.12	84	$ 2,331.84
BH	$ 42.81	16	1	1	16	17	$ 684.96	$ 727.77	16.5	$ 706.37	70	$ 2,996.70	53.5	$ 2,290.34
BI	$ 131.25	1	0	1	1	1	$ 131.25	$ 131.25	1	$ 131.25	17	$ 2,231.25	16	$ 2,100.00
BJ	$ 114.45	77	30	1	77	107	$ 8,812.65	$ 12,246.15	92	$ 10,529.40	110	$ 12,589.50	18	$ 2,060.10
BK	$ 199.50	1	0	1	1	1	$ 199.50	$ 199.50	1	$ 199.50	11	$ 2,194.50	10	$ 1,995.00
BL	$ 114.17	0	0	1	0	0	$ -	$ -	0	$ -	17	$ 1,940.89	17	$ 1,940.89
BM	$ 17.50	20	4	1	20	24	$ 350.00	$ 420.00	22	$ 385.00	130	$ 2,275.00	108	$ 1,890.00
BN	$ 89.60	0	0	1	0	0	$ -	$ -	0	$ -	21	$ 1,881.60	21	$ 1,881.60
BO	$ 58.77	52	22	1	52	74	$ 3,055.89	$ 4,348.77	63	$ 3,702.33	92	$ 5,406.58	29	$ 1,704.25
BP	$ 15.80	8	1	1	8	9	$ 126.40	$ 142.20	8.5	$ 134.30	100	$ 1,580.04	91.5	$ 1,445.74

Appendix Table 2: Calculated Inventory on Hand (continued)

PART ID	UNIT COSTS ($)	SAFETY STOCK (units)	AVG. WEEKLY DEMAND (units)	REVIEW PERIOD (Weeks)	EXPECTED MINIMUM ON HAND (units)	EXPECTED MAXIMUM ON HAND (units)	EXPECTED MINIMUM ON HAND ($)	EXPECTED MAXIMUM ON HAND ($)	EXPECTED AVERAGE ON HAND (units)	EXPECTED AVERAGE ON HAND ($)	CURRENT ON HAND (units)	CURRENT ON HAND ($)	DIFFERENCE (units)	DIFFERENCE ($)
BQ	$ 17.24	7	1	1	7	8	$ 120.66	$ 137.89	7.5	$ 129.28	90	$ 1,551.31	82.5	$ 1,422.04
BR	$ 4.72	22	2	1	22	24	$ 103.84	$ 113.28	23	$ 108.56	320	$ 1,510.40	297	$ 1,401.84
BS	$ 13.61	16	3	1	16	19	$ 217.73	$ 258.55	17.5	$ 238.14	108	$ 1,469.66	90.5	$ 1,231.52
BT	$ 3.36	33	13	1	33	46	$ 110.88	$ 154.56	39.5	$ 132.72	402	$ 1,350.72	362.5	$ 1,218.00
BU	$ 15.80	15	3	1	15	18	$ 237.01	$ 284.41	16.5	$ 260.71	89	$ 1,406.24	72.5	$ 1,145.53
BV	$ 367.50	1	0	1	1	1	$ 367.50	$ 367.50	1	$ 367.50	4	$ 1,470.00	3	$ 1,102.50
BW	$ 17.24	17	2	1	17	19	$ 293.08	$ 327.56	18	$ 310.32	81	$ 1,396.44	63	$ 1,086.12
BX	$ 48.77	1	0	1	1	1	$ 48.77	$ 48.77	1	$ 48.77	23	$ 1,121.71	22	$ 1,072.94
BY	$ 121.37	0	0	1	0	0	$ -	$ -	0	$ -	7	$ 849.59	7	$ 849.59
BZ	$ 776.96	0	0	1	0	0	$ -	$ -	0	$ -	1	$ 776.96	1	$ 776.96
CA	$ 17.24	9	2	1	9	11	$ 155.13	$ 189.60	10	$ 172.37	54	$ 930.79	44	$ 758.42
CB	$ 1.83	1,426	121	1	1,426	1547	$ 2,605.30	$ 2,826.37	1486.5	$ 2,715.84	1900	$ 3,471.30	413.5	$ 755.46
CC	$ 13.61	9	1	1	9	10	$ 122.47	$ 136.08	9.5	$ 129.28	60	$ 816.48	50.5	$ 687.20
CD	$ 13.61	27	4	1	27	31	$ 367.42	$ 421.85	29	$ 394.63	68	$ 925.34	39	$ 530.71
CE	$ 200.00	1	0	1	1	1	$ 200.00	$ 200.00	1	$ 200.00	3	$ 600.00	2	$ 400.00
CF	$ 44.19	5	1	1	5	6	$ 220.95	$ 265.14	5.5	$ 243.05	14	$ 618.66	8.5	$ 375.62
CG	$ 5.61	100	23	1	100	123	$ 561.00	$ 690.03	111.5	$ 625.52	171	$ 959.31	59.5	$ 333.80
CH	$ 0.11	2,859	865	1	2,859	3724	$ 309.06	$ 402.56	3291.5	$ 355.81	6000	$ 648.60	2708.5	$ 292.79
CI	$ 5.34	0	0	1	0	0	$ -	$ -	0	$ -	45	$ 240.48	45	$ 240.48
CJ	$ 14.83	0	0	1	0	0	$ -	$ -	0	$ -	15	$ 222.51	15	$ 222.51
CK	$ 30.11	5	1	1	5	6	$ 150.55	$ 180.66	5.5	$ 165.61	11	$ 331.21	5.5	$ 165.61
CL	$ 35.80	1	1	1	1	2	$ 35.80	$ 71.60	1.5	$ 53.70	5	$ 179.00	3.5	$ 125.30
CM	$ 3.86	10	1	1	10	11	$ 38.60	$ 42.46	10.5	$ 40.53	16	$ 61.76	5.5	$ 21.23
CN	$ 1,007.40	1	0	1	1	1	$ 1,007.40	$ 1,007.40	1	$ 1,007.40	1	$ 1,007.40	0	$ -
CO	$ 170.80	0	0	1	0	0	$ -	$ -	0	$ -	0	$ -	0	$ -
CP	$ 105.00	1	0	1	1	1	$ 105.00	$ 105.00	1	$ 105.00	0	$ -	-1	$ (105.00)
CQ	$ 4.59	103	8	1	103	111	$ 473.18	$ 509.93	107	$ 491.56	15	$ 68.91	-92	$ (422.65)
CR	$ 46.59	9	3	1	9	12	$ 419.31	$ 559.08	10.5	$ 489.20	0	$ -	-10.5	$ (489.20)
CS	$ 175.00	3	0	1	3	3	$ 525.00	$ 525.00	3	$ 525.00	0	$ -	-3	$ (525.00)
CT	$ 17.38	25	12	1	25	37	$ 434.58	$ 643.17	31	$ 538.88	0	$ -	-31	$ (538.88)
CU	$ 13.61	79	5	1	79	84	$ 1,075.03	$ 1,143.07	81.5	$ 1,109.05	37	$ 503.50	-44.5	$ (605.56)
CV	$ 18.00	46	16	1	46	62	$ 828.00	$ 1,116.00	54	$ 972.00	16	$ 288.00	-38	$ (684.00)
CW	$ 24.27	209	20	1	209	229	$ 5,073.27	$ 5,558.75	219	$ 5,316.01	190	$ 4,612.06	-29	$ (703.95)
CX	$ 2.53	270	24	1	270	294	$ 682.21	$ 742.85	282	$ 712.53	0	$ -	-282	$ (712.53)

Appendix Table 2: Calculated Inventory on Hand (continued)

PART ID	UNIT COSTS ($)	SAFETY STOCK (units)	AVG. WEEKLY DEMAND (units)	REVIEW PERIOD (Weeks)	EXPECTED MINIMUM ON HAND (units)	EXPECTED MAXIMUM ON HAND (units)	EXPECTED MINIMUM ON HAND ($)	EXPECTED MAXIMUM ON HAND ($)	EXPECTED AVERAGE ON HAND (units)	EXPECTED AVERAGE ON HAND ($)	CURRENT ON HAND (units)	CURRENT ON HAND ($)	DIFFERENCE (units)	DIFFERENCE ($)
CY	$ 114.45	103	48	1	103	151	$ 11,788.35	$ 17,281.95	127	$ 14,535.15	120	$ 13,734.00	-7	$ (801.15)
CZ	$ 24.27	33	3	1	33	36	$ 801.04	$ 873.86	34.5	$ 837.45	0	$ -	-34.5	$ (837.45)
DA	$ 19.09	253	96	1	253	349	$ 4,830.50	$ 6,663.42	301	$ 5,746.96	251	$ 4,792.32	-50	$ (954.65)
DB	$ 0.17	8,263	3,923	1	8,263	12186	$ 1,400.58	$ 2,065.53	10224.5	$ 1,733.05	0	$ -	-10224.5	$ (1,733.05)
DC	$ 155.00	12	1	1	12	13	$ 1,860.00	$ 2,015.00	12.5	$ 1,937.50	0	$ -	-12.5	$ (1,937.50)
DD	$ 114.45	58	25	1	58	83	$ 6,638.10	$ 9,499.35	70.5	$ 8,068.73	45	$ 5,150.25	-25.5	$ (2,918.48)
DE	$ 114.45	91	45	1	91	136	$ 10,414.95	$ 15,565.20	113.5	$ 12,990.08	85	$ 9,728.25	-28.5	$ (3,261.83)
DF	$ 588.00	13	1	1	13	14	$ 7,644.00	$ 8,232.00	13.5	$ 7,938.00	6	$ 3,528.00	-7.5	$ (4,410.00)
DG	$ 12.47	427	212	1	427	639	$ 5,324.56	$ 7,968.14	533	$ 6,646.35	64	$ 798.06	-469	$ (5,848.29)
DH	$ 1,107.00	13	1	1	13	14	$ 14,391.00	$ 15,498.00	13.5	$ 14,944.50	5	$ 5,535.00	-8.5	$ (9,409.50)
DI	$ 1,107.00	54	2	1	54	56	$ 59,778.00	$ 61,992.00	55	$ 60,885.00	45	$ 49,815.00	-10	$ (11,070.00)
DJ	$ 114.45	133	60	1	133	193	$ 15,221.85	$ 22,088.85	163	$ 18,655.35	32	$ 3,662.40	-131	$ (14,992.95)
DK	$ 7,560.00	2	0	1	2	2	$ 15,120.00	$ 15,120.00	2	$ 15,120.00	0	$ -	-2	$ (15,120.00)
DL	$ 58.95	221	106	1	221	327	$ 13,027.33	$ 19,275.73	274	$ 16,151.53	3	$ 176.84	-271	$ (15,974.69)
DM	$ 2.26	6,563	3,281	1	6,563	9844	$ 14,842.88	$ 22,263.19	8203.5	$ 18,553.04	20	$ 45.23	-8183.5	$ (18,507.80)
DN	$ 114.45	175	79	1	175	254	$ 20,028.75	$ 29,070.30	214.5	$ 24,549.53	21	$ 2,403.45	-193.5	$ (22,146.08)
DO	$ 114.45	319	135	1	319	454	$ 36,509.55	$ 51,960.30	386.5	$ 44,234.93	80	$ 9,156.00	-306.5	$ (35,078.93)
DP	$ 114.45	374	157	1	374	531	$ 42,804.30	$ 60,772.95	452.5	$ 51,788.63	70	$ 8,011.50	-382.5	$ (43,777.13)
DQ	$ 1,974.00	40	3	1	40	43	$ 78,960.00	$ 84,882.00	41.5	$ 81,921.00	19	$ 37,506.00	-22.5	$ (44,415.00)
DR	$ 1,107.00	108	14	1	108	122	$ 119,556.00	$ 135,054.00	115	$ 127,305.00	16	$ 17,712.00	-99	$ (109,593.00)
DS	$ 7,560.00	14	1	1	14	15	$ 105,840.00	$ 113,400.00	14.5	$ 109,620.00	0	$ -	-14.5	$ (109,620.00)
DT	$ 7,560.00	16	1	1	16	17	$ 120,960.00	$ 128,520.00	16.5	$ 124,740.00	0	$ -	-16.5	$ (124,740.00)
DU	$ 7,560.00	26	2	1	26	28	$ 196,560.00	$ 211,680.00	27	$ 204,120.00	7	$ 52,920.00	-20	$ (151,200.00)
									TOTAL	$ 1,624,101.48		$ 3,057,159.14		$ 1,433,057.65

Appendix Table 3: Slow-movers Expected Cycle Service Level Simulation Results (μ= 1 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	99.84%	96.85%
2	100.00%	100.00%	100.00%	100.00%	99.73%	93.74%
3	100.00%	100.00%	100.00%	100.00%	99.70%	90.65%
4	100.00%	100.00%	100.00%	100.00%	98.73%	85.16%
5	100.00%	100.00%	100.00%	100.00%	98.81%	83.58%
6	100.00%	100.00%	100.00%	99.86%	98.29%	83.35%
7	100.00%	100.00%	99.88%	99.85%	96.97%	81.04%
8	100.00%	100.00%	100.00%	100.00%	99.89%	97.57%
9	100.00%	100.00%	100.00%	100.00%	99.51%	96.51%
10	100.00%	100.00%	100.00%	100.00%	99.45%	96.47%
11	100.00%	100.00%	100.00%	100.00%	98.98%	95.68%
12	100.00%	100.00%	100.00%	100.00%	99.84%	94.09%
13	100.00%	100.00%	100.00%	100.00%	99.13%	93.90%
14	100.00%	100.00%	100.00%	99.84%	98.68%	93.01%
15	100.00%	100.00%	100.00%	99.85%	98.35%	91.72%
16	100.00%	100.00%	99.70%	99.76%	98.16%	90.87%
17	100.00%	100.00%	100.00%	99.86%	97.79%	89.02%
18	100.00%	100.00%	100.00%	99.73%	97.40%	86.39%
19	100.00%	100.00%	100.00%	99.07%	95.70%	88.41%
20	100.00%	100.00%	99.90%	99.52%	95.98%	82.97%
21	100.00%	100.00%	99.89%	99.88%	97.13%	82.84%
22	100.00%	100.00%	99.88%	98.75%	96.07%	81.49%
23	100.00%	100.00%	99.74%	99.10%	97.05%	86.45%
24	100.00%	100.00%	100.00%	99.06%	95.94%	81.31%
25	100.00%	100.00%	100.00%	99.18%	95.65%	79.21%
26	100.00%	100.00%	99.61%	99.42%	95.12%	77.69%
27	100.00%	100.00%	99.69%	98.52%	92.24%	77.19%
28	100.00%	100.00%	99.82%	98.95%	94.48%	75.15%
29	100.00%	99.88%	99.25%	98.75%	93.76%	75.17%
30	100.00%	100.00%	99.55%	98.92%	92.19%	73.88%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 4: Slow-movers Expected Cycle Service Level Simulation Results (μ= 2 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	100.00%	99.92%
2	100.00%	100.00%	100.00%	100.00%	99.85%	99.00%
3	100.00%	100.00%	100.00%	100.00%	99.70%	97.32%
4	100.00%	100.00%	100.00%	100.00%	99.70%	96.05%
5	100.00%	100.00%	100.00%	100.00%	99.70%	95.30%
6	100.00%	100.00%	100.00%	99.91%	98.76%	91.67%
7	100.00%	100.00%	100.00%	99.85%	98.87%	90.54%
8	100.00%	100.00%	99.93%	99.73%	97.44%	89.41%
9	100.00%	99.93%	100.00%	99.53%	97.19%	86.58%
10	100.00%	100.00%	99.94%	99.44%	97.23%	84.78%
11	99.93%	99.92%	99.93%	99.29%	95.73%	82.64%
12	99.92%	100.00%	100.00%	98.40%	95.15%	78.27%
13	100.00%	99.91%	99.79%	98.85%	93.66%	78.99%
14	100.00%	100.00%	99.94%	98.98%	92.62%	73.01%
15	99.93%	100.00%	99.55%	97.57%	92.13%	72.29%
16	99.92%	100.00%	99.87%	99.28%	97.64%	92.00%
17	100.00%	100.00%	99.84%	99.31%	97.54%	89.93%
18	100.00%	99.93%	99.93%	98.93%	96.02%	87.78%
19	99.85%	100.00%	99.74%	98.21%	94.75%	85.88%
20	100.00%	100.00%	99.62%	98.79%	94.87%	85.49%
21	99.93%	100.00%	99.52%	98.39%	94.62%	84.44%
22	99.86%	99.92%	99.79%	98.13%	95.00%	82.58%
23	100.00%	99.84%	99.68%	97.70%	92.39%	80.47%
24	99.93%	99.93%	99.77%	97.50%	90.45%	77.08%
25	99.94%	99.94%	99.63%	98.00%	92.32%	79.22%
26	99.94%	99.73%	99.17%	96.96%	89.21%	74.20%
27	99.65%	99.75%	98.59%	95.46%	87.12%	76.37%
28	99.56%	99.58%	99.01%	95.42%	88.55%	70.16%
29	99.52%	99.69%	97.98%	95.54%	87.07%	72.32%
30	100.00%	100.00%	97.49%	94.28%	84.73%	70.73%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 5: Slow-movers Expected Cycle Service Level Simulation Results (μ= 3 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	99.95%	99.17%
2	100.00%	100.00%	100.00%	100.00%	99.81%	97.45%
3	100.00%	100.00%	100.00%	99.90%	99.49%	94.71%
4	100.00%	100.00%	100.00%	99.78%	98.74%	92.62%
5	100.00%	100.00%	100.00%	99.69%	97.89%	90.09%
6	100.00%	100.00%	99.95%	99.61%	97.63%	86.60%
7	100.00%	100.00%	99.84%	99.46%	96.15%	83.56%
8	100.00%	99.95%	100.00%	99.76%	99.30%	94.35%
9	100.00%	100.00%	99.95%	99.84%	98.62%	93.37%
10	100.00%	100.00%	99.95%	99.24%	98.33%	92.70%
11	100.00%	99.96%	99.95%	99.34%	97.21%	88.50%
12	100.00%	100.00%	99.84%	98.87%	96.60%	86.82%
13	99.85%	100.00%	100.00%	99.24%	94.27%	85.49%
14	100.00%	100.00%	99.76%	97.62%	94.40%	82.99%
15	99.73%	99.85%	99.53%	98.81%	93.25%	80.37%
16	99.70%	99.95%	99.15%	96.85%	91.47%	77.34%
17	99.56%	99.95%	99.01%	96.84%	89.65%	73.74%
18	100.00%	99.91%	99.71%	98.96%	96.19%	88.05%
19	100.00%	99.92%	99.78%	98.25%	94.86%	86.72%
20	100.00%	100.00%	99.77%	97.85%	94.26%	85.49%
21	99.93%	99.92%	99.19%	97.81%	93.25%	84.64%
22	99.66%	99.54%	99.03%	97.85%	90.57%	82.10%
23	99.77%	99.67%	98.98%	97.10%	91.09%	79.25%
24	99.68%	99.56%	98.69%	96.96%	89.79%	77.58%
25	99.69%	99.50%	98.48%	95.70%	88.10%	75.62%
26	99.50%	99.64%	98.49%	94.90%	87.66%	71.64%
27	98.91%	99.63%	98.01%	94.51%	85.42%	70.34%
28	99.81%	99.73%	99.47%	97.70%	93.60%	84.76%
29	99.39%	99.69%	99.13%	95.86%	92.62%	84.16%
30	99.82%	99.38%	98.97%	97.02%	91.40%	82.07%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 6: Slow-movers Expected Cycle Service Level Simulation Results (μ= 4 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	99.92%	98.02%
2	100.00%	100.00%	100.00%	99.95%	99.50%	95.62%
3	100.00%	100.00%	99.97%	99.80%	99.00%	91.34%
4	100.00%	100.00%	99.97%	99.89%	97.63%	87.84%
5	100.00%	100.00%	100.00%	99.89%	99.29%	96.09%
6	100.00%	100.00%	99.88%	99.71%	98.96%	94.62%
7	100.00%	100.00%	99.92%	99.65%	97.80%	92.33%
8	99.96%	99.96%	99.88%	99.44%	97.57%	89.74%
9	99.93%	99.96%	99.83%	98.75%	96.97%	87.47%
10	99.88%	99.93%	99.84%	98.50%	95.40%	82.48%
11	99.96%	99.89%	99.27%	98.35%	94.01%	79.85%
12	100.00%	99.94%	99.95%	99.16%	97.19%	90.69%
13	99.95%	100.00%	99.72%	99.10%	95.96%	88.95%
14	99.89%	99.94%	99.27%	99.02%	95.50%	86.70%
15	100.00%	99.89%	99.60%	98.12%	93.86%	84.46%
16	99.71%	99.71%	99.16%	97.64%	92.85%	82.13%
17	99.59%	99.89%	99.10%	97.25%	90.50%	78.56%
18	99.63%	99.95%	98.61%	95.58%	88.67%	76.39%
19	99.31%	99.28%	97.78%	95.21%	86.88%	73.63%
20	99.92%	99.78%	99.32%	97.25%	94.55%	85.55%
21	99.70%	99.79%	98.96%	97.09%	93.43%	83.87%
22	99.64%	99.76%	99.19%	98.18%	91.22%	82.38%
23	99.55%	99.20%	98.23%	96.68%	90.03%	81.01%
24	99.39%	99.00%	98.30%	95.61%	89.09%	77.39%
25	99.58%	99.71%	97.77%	94.34%	87.50%	74.11%
26	99.01%	99.04%	97.92%	92.72%	88.10%	73.30%
27	99.91%	99.43%	98.98%	96.45%	93.07%	82.10%
28	99.45%	99.73%	98.71%	95.67%	92.15%	82.91%
29	99.24%	98.65%	99.06%	95.55%	90.98%	82.51%
30	99.72%	98.84%	97.41%	94.37%	88.19%	77.93%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 7: Slow-movers Expected Cycle Service Level Simulation Results (μ= 5 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	99.77%	97.47%
2	100.00%	100.00%	100.00%	100.00%	99.84%	98.99%
3	100.00%	100.00%	100.00%	99.97%	99.76%	97.55%
4	100.00%	100.00%	100.00%	99.91%	99.32%	96.02%
5	99.97%	100.00%	100.00%	99.78%	98.67%	93.01%
6	100.00%	100.00%	99.91%	99.49%	97.77%	89.74%
7	99.90%	99.97%	99.82%	98.91%	96.55%	86.40%
8	100.00%	100.00%	99.96%	99.72%	98.88%	95.02%
9	100.00%	99.96%	99.90%	99.52%	98.11%	92.68%
10	99.96%	99.90%	99.91%	98.92%	96.57%	88.78%
11	99.91%	99.91%	99.69%	98.77%	95.72%	87.61%
12	99.91%	99.82%	99.52%	97.60%	93.51%	84.44%
13	99.82%	99.72%	99.40%	96.73%	91.59%	80.37%
14	99.94%	99.95%	99.57%	98.71%	96.54%	90.58%
15	99.88%	99.77%	99.60%	98.10%	95.63%	88.62%
16	99.62%	99.59%	99.51%	98.70%	93.84%	85.74%
17	99.61%	99.71%	98.87%	97.29%	91.59%	83.05%
18	99.88%	99.82%	98.89%	96.97%	91.78%	81.15%
19	99.11%	99.88%	97.63%	96.19%	88.65%	78.50%
20	99.47%	99.56%	99.15%	97.87%	94.39%	85.30%
21	99.70%	99.84%	98.90%	97.19%	91.91%	85.92%
22	99.29%	99.39%	98.39%	97.18%	91.00%	82.18%
23	99.30%	99.20%	98.39%	96.62%	89.17%	80.23%
24	98.59%	99.07%	97.83%	94.41%	87.16%	79.72%
25	98.98%	99.24%	96.65%	92.94%	85.73%	74.80%
26	99.25%	99.18%	98.39%	95.79%	91.62%	86.11%
27	99.16%	99.45%	98.29%	96.32%	88.81%	81.72%
28	99.47%	99.22%	98.18%	95.27%	90.83%	80.35%
29	99.02%	98.46%	97.56%	93.78%	88.06%	79.52%
30	99.82%	98.66%	96.55%	93.73%	86.48%	75.66%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 8: Slow-movers Expected Cycle Service Level Simulation Results (μ= 6 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	99.95%	99.61%
2	100.00%	100.00%	100.00%	99.97%	99.82%	98.37%
3	100.00%	100.00%	100.00%	99.97%	99.46%	96.55%
4	100.00%	100.00%	100.00%	99.78%	98.54%	93.61%
5	99.92%	99.95%	99.89%	99.51%	97.45%	90.23%
6	99.96%	99.96%	99.96%	99.96%	99.19%	95.91%
7	100.00%	100.00%	99.73%	99.48%	97.60%	94.03%
8	99.80%	100.00%	99.93%	99.44%	97.02%	90.02%
9	99.97%	99.93%	99.50%	98.50%	94.95%	88.13%
10	99.80%	100.00%	99.01%	98.24%	92.98%	83.07%
11	99.90%	99.95%	99.90%	99.12%	97.22%	91.28%
12	99.85%	99.91%	99.79%	98.62%	95.98%	89.25%
13	99.80%	99.85%	99.33%	97.59%	94.19%	87.14%
14	99.41%	99.90%	99.23%	97.01%	92.95%	83.03%
15	99.80%	99.38%	98.37%	96.36%	90.65%	79.84%
16	99.64%	99.75%	99.46%	98.20%	95.04%	88.84%
17	99.80%	99.49%	99.43%	97.74%	94.55%	86.07%
18	99.30%	99.87%	99.10%	96.39%	92.26%	81.70%
19	99.17%	99.17%	97.69%	95.54%	90.00%	81.72%
20	98.77%	99.08%	97.34%	94.46%	88.52%	76.50%
21	99.41%	99.46%	97.95%	96.72%	94.98%	86.04%
22	98.93%	99.62%	98.31%	95.57%	91.91%	84.44%
23	99.01%	98.85%	97.31%	95.29%	89.43%	81.55%
24	99.30%	98.71%	98.09%	94.73%	88.19%	78.76%
25	98.23%	98.85%	96.66%	93.93%	84.75%	74.85%
26	99.82%	99.11%	98.18%	94.89%	93.44%	83.01%
27	99.28%	98.04%	96.37%	94.68%	91.21%	83.74%
28	99.46%	98.64%	97.40%	94.85%	86.93%	79.22%
29	99.13%	98.31%	96.98%	92.17%	86.30%	75.58%
30	98.75%	98.31%	95.90%	91.85%	84.99%	72.08%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 9: Slow-movers Expected Cycle Service Level Simulation Results (μ= 7 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	99.91%	99.32%
2	100.00%	100.00%	100.00%	99.91%	99.66%	98.07%
3	100.00%	100.00%	100.00%	99.95%	99.27%	95.20%
4	100.00%	100.00%	100.00%	99.97%	99.80%	98.02%
5	100.00%	100.00%	99.93%	99.79%	99.09%	95.54%
6	100.00%	99.97%	99.93%	99.64%	97.99%	93.53%
7	99.97%	99.97%	99.63%	98.96%	97.28%	90.66%
8	100.00%	100.00%	99.91%	99.43%	98.24%	95.29%
9	100.00%	100.00%	99.86%	99.40%	97.64%	91.59%
10	100.00%	100.00%	99.70%	98.78%	96.41%	90.26%
11	99.87%	99.70%	99.49%	98.14%	93.83%	86.69%
12	99.69%	99.71%	98.78%	96.89%	92.92%	83.36%
13	99.94%	99.95%	99.46%	98.42%	95.59%	89.61%
14	99.56%	99.78%	99.02%	97.86%	93.88%	87.70%
15	99.78%	99.45%	99.33%	97.37%	93.22%	84.03%
16	99.44%	99.40%	98.32%	95.49%	89.61%	79.12%
17	99.61%	99.75%	99.28%	98.03%	93.66%	87.64%
18	99.60%	99.62%	98.45%	96.64%	92.43%	86.64%
19	99.35%	99.17%	98.56%	94.94%	90.67%	82.56%
20	99.60%	99.22%	97.71%	94.73%	88.82%	82.18%
21	99.47%	99.03%	98.36%	97.00%	93.04%	86.09%
22	99.24%	98.94%	97.57%	96.25%	92.11%	84.13%
23	99.07%	98.97%	97.57%	95.07%	89.16%	81.90%
24	98.69%	98.67%	96.41%	93.81%	87.89%	78.13%
25	97.73%	98.62%	96.11%	92.66%	83.26%	77.44%
26	98.10%	99.22%	98.09%	94.88%	90.77%	85.06%
27	98.96%	98.45%	95.84%	95.35%	87.31%	80.89%
28	98.36%	98.49%	95.68%	93.45%	88.13%	79.49%
29	97.04%	98.41%	95.73%	92.54%	83.64%	75.57%
30	99.62%	98.58%	97.01%	95.21%	87.87%	81.20%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 10: Slow-movers Expected Cycle Service Level Simulation Results (μ= 8 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	99.83%	99.22%
2	100.00%	99.98%	100.00%	99.88%	99.30%	96.66%
3	100.00%	100.00%	100.00%	99.94%	99.64%	98.50%
4	100.00%	100.00%	99.97%	99.94%	99.11%	97.08%
5	100.00%	100.00%	99.95%	99.58%	97.74%	94.33%
6	99.89%	99.91%	99.73%	99.23%	97.27%	89.58%
7	100.00%	99.92%	99.96%	99.41%	98.53%	94.70%
8	99.96%	99.92%	99.92%	99.13%	96.90%	92.32%
9	100.00%	99.93%	99.66%	98.78%	95.07%	88.80%
10	100.00%	99.95%	99.62%	99.42%	97.80%	94.12%
11	99.85%	99.95%	99.75%	98.88%	96.42%	90.52%
12	99.67%	99.75%	99.41%	98.12%	95.55%	87.96%
13	99.62%	99.85%	98.95%	96.40%	93.08%	84.42%
14	99.84%	99.83%	99.48%	98.22%	96.46%	90.97%
15	99.59%	99.65%	99.20%	97.17%	94.00%	87.72%
16	99.71%	99.26%	98.11%	96.23%	92.76%	84.42%
17	99.36%	99.05%	97.68%	95.15%	91.10%	83.49%
18	99.53%	99.17%	98.52%	97.04%	92.81%	88.67%
19	99.41%	99.54%	98.15%	96.28%	92.89%	83.64%
20	98.92%	98.92%	96.92%	94.57%	90.35%	82.39%
21	98.37%	98.48%	97.39%	94.02%	88.37%	78.54%
22	99.47%	98.92%	97.83%	96.12%	92.58%	83.74%
23	98.68%	98.55%	97.23%	94.50%	90.36%	80.73%
24	98.45%	98.37%	97.31%	93.80%	88.47%	78.55%
25	99.08%	98.88%	97.10%	96.18%	92.12%	85.71%
26	98.36%	99.00%	97.52%	93.85%	90.03%	83.52%
27	97.47%	98.01%	96.51%	93.02%	86.90%	79.82%
28	98.00%	97.94%	96.12%	92.14%	86.42%	78.37%
29	99.08%	98.67%	96.08%	93.78%	89.77%	83.47%
30	99.13%	98.67%	97.25%	92.76%	86.82%	80.05%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 11: Slow-movers Expected Cycle Service Level Simulation Results (μ= 9 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	99.98%	99.83%	98.73%
2	100.00%	100.00%	100.00%	100.00%	99.92%	99.27%
3	100.00%	100.00%	100.00%	99.85%	99.58%	98.11%
4	100.00%	99.97%	100.00%	99.77%	98.42%	95.56%
5	99.97%	100.00%	99.97%	99.85%	99.27%	97.08%
6	100.00%	99.97%	99.84%	99.39%	98.46%	95.86%
7	100.00%	99.92%	99.70%	99.13%	97.41%	92.47%
8	99.96%	100.00%	99.88%	99.44%	98.54%	95.50%
9	99.96%	99.87%	99.75%	98.73%	97.07%	93.17%
10	99.91%	99.83%	99.39%	98.17%	95.98%	90.51%
11	99.82%	99.83%	98.97%	97.70%	94.21%	86.55%
12	99.74%	99.90%	99.38%	98.59%	96.74%	91.65%
13	99.89%	99.73%	99.36%	97.53%	95.50%	89.00%
14	99.85%	99.24%	98.78%	95.88%	92.41%	85.25%
15	99.88%	99.79%	99.52%	97.71%	96.06%	89.46%
16	99.77%	99.34%	98.82%	96.81%	93.41%	87.85%
17	99.35%	99.45%	98.06%	96.45%	90.75%	83.41%
18	99.52%	99.65%	98.40%	96.64%	95.40%	89.61%
19	98.92%	99.53%	98.80%	95.87%	92.74%	86.54%
20	99.06%	98.35%	97.42%	94.04%	90.24%	83.86%
21	98.85%	98.69%	97.77%	93.95%	88.04%	79.64%
22	99.07%	99.02%	97.81%	95.20%	91.80%	85.47%
23	98.23%	98.23%	98.36%	94.92%	89.01%	81.54%
24	98.31%	98.02%	96.61%	92.61%	89.46%	81.57%
25	98.38%	99.31%	97.69%	95.03%	91.37%	87.11%
26	98.15%	98.65%	96.36%	94.17%	88.98%	81.70%
27	97.58%	97.61%	96.51%	92.55%	86.91%	80.38%
28	98.51%	98.26%	97.15%	94.87%	90.53%	85.98%
29	98.05%	98.03%	96.63%	93.80%	90.41%	82.32%
30	98.46%	97.30%	96.77%	92.58%	85.03%	80.22%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 12: Slow-movers Expected Cycle Service Level Simulation Results (μ= 10 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	100.00%	99.75%
2	100.00%	100.00%	100.00%	99.95%	99.81%	98.90%
3	99.98%	100.00%	100.00%	99.91%	99.13%	96.81%
4	100.00%	100.00%	99.97%	99.91%	99.66%	98.66%
5	99.97%	100.00%	99.90%	99.66%	98.91%	96.23%
6	99.94%	99.94%	99.91%	98.96%	97.79%	91.99%
7	99.96%	99.88%	99.85%	99.53%	98.79%	95.10%
8	99.96%	99.92%	99.66%	99.02%	96.90%	93.09%
9	99.81%	99.77%	99.53%	98.50%	95.69%	89.32%
10	99.87%	99.85%	99.91%	98.44%	97.73%	93.67%
11	99.77%	99.65%	99.35%	98.15%	95.58%	90.20%
12	99.90%	99.62%	98.62%	97.60%	94.69%	87.39%
13	99.82%	99.73%	99.31%	99.01%	96.00%	91.79%
14	99.63%	99.41%	98.94%	97.89%	94.59%	88.20%
15	99.41%	99.67%	98.55%	96.29%	92.77%	85.92%
16	99.77%	99.68%	98.72%	98.04%	95.30%	90.17%
17	99.07%	99.45%	98.13%	95.38%	92.74%	86.40%
18	98.83%	99.13%	97.78%	94.94%	90.96%	82.56%
19	99.17%	99.44%	98.39%	97.13%	93.09%	87.52%
20	99.10%	98.30%	97.81%	95.30%	91.50%	87.44%
21	98.76%	98.34%	96.01%	93.46%	87.92%	83.61%
22	98.96%	98.91%	97.62%	96.45%	92.36%	85.50%
23	98.56%	98.00%	97.44%	94.54%	90.64%	84.48%
24	98.33%	98.48%	96.68%	92.75%	88.44%	81.13%
25	99.10%	98.20%	96.79%	95.05%	90.81%	84.84%
26	98.76%	98.49%	97.45%	94.86%	89.20%	83.07%
27	98.21%	97.36%	96.31%	91.64%	86.65%	78.73%
28	98.70%	98.34%	97.35%	94.59%	91.03%	83.64%
29	98.08%	98.10%	96.09%	93.00%	87.96%	81.74%
30	97.51%	96.30%	95.13%	90.45%	85.79%	78.95%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 13: Slow-movers Expected Cycle Service Level Simulation Results (μ= 11 / month)

SAFETY STOCK	5	4	3	2	1	0
LEAD TIME						
1	100.00%	100.00%	100.00%	100.00%	100.00%	99.67%
2	100.00%	100.00%	100.00%	99.96%	99.75%	98.22%
3	100.00%	100.00%	100.00%	100.00%	99.83%	98.56%
4	100.00%	100.00%	99.97%	99.71%	99.27%	97.35%
5	100.00%	100.00%	99.91%	99.64%	98.11%	94.91%
6	100.00%	100.00%	99.82%	99.96%	98.98%	96.68%
7	99.96%	99.86%	99.79%	99.22%	97.45%	94.01%
8	100.00%	99.92%	99.96%	99.41%	98.36%	96.80%
9	99.88%	99.87%	99.83%	98.77%	97.73%	94.29%
10	99.82%	99.82%	99.24%	98.04%	95.96%	90.53%
11	99.70%	99.90%	99.28%	98.42%	97.57%	93.34%
12	99.71%	99.71%	98.97%	97.83%	95.84%	90.51%
13	99.51%	99.17%	98.97%	97.74%	93.49%	87.52%
14	99.57%	99.77%	99.32%	97.68%	95.31%	92.65%
15	99.71%	99.38%	98.94%	96.61%	93.38%	88.52%
16	99.21%	99.02%	97.67%	95.76%	92.16%	83.64%
17	99.30%	99.63%	98.63%	96.00%	93.94%	87.88%
18	99.38%	98.90%	97.44%	96.01%	92.10%	84.59%
19	99.10%	98.87%	99.08%	97.39%	92.94%	89.33%
20	99.10%	99.24%	97.87%	95.81%	92.39%	85.85%
21	98.76%	98.68%	96.41%	94.88%	88.66%	81.37%
22	98.88%	99.21%	97.86%	96.02%	93.50%	87.25%
23	98.34%	98.91%	97.45%	94.48%	90.09%	84.27%
24	98.03%	97.14%	96.60%	92.94%	87.19%	80.83%
25	98.73%	98.76%	97.66%	94.77%	91.30%	84.98%
26	98.35%	97.95%	96.12%	93.27%	89.26%	81.95%
27	98.30%	97.57%	95.13%	92.90%	87.20%	79.87%
28	98.01%	97.66%	96.46%	94.46%	87.70%	82.60%
29	97.74%	97.69%	94.96%	91.88%	90.09%	77.48%
30	98.56%	97.59%	96.99%	94.01%	91.32%	85.65%

Heat Map Legend:			
>99 %	95% - 99%	90% - 95%	<90%

Appendix Table 14: Synergy Analysis Results

Part Number	Orders	Total Orders	Penetration	Iteration	Count
Part	Additional orders now able to be filled by the addition of this part to the stockroom.	Cumulative orders able to be filled by the set of parts from here to the top of the list.	Cumulative Percentage of all orders able to be filled by the set of part from here to the top of the list.	Cumulative number of clusters in the stockroom	Cumulative number of part numbers in the stockroom
A	4598	4598	17.26%	1	1
B	2296	6894	25.88%	2	2
C	1466	8360	31.38%	3	3
D	1456	9816	36.84%	4	4
E	1203	11019	41.36%	5	5
F	1073	12092	45.39%	6	6
G	819	12911	48.46%	7	7
H	737	13648	51.23%	8	8
I	731	14379	53.97%	9	9
J	630	15009	56.34%	10	10
K	603	15612	58.60%	11	11
L	587	16199	60.80%	12	12
M	475	16674	62.59%	13	13
N	453	17127	64.29%	14	14
O	441	17568	65.94%	15	15
P	398	17966	67.44%	16	16
Q	379	18345	68.86%	17	17
R	379	18724	70.28%	17	18
S	379	19102	71.70%	17	19
T	379	19481	73.12%	17	20
U	365	19846	74.49%	18	21
V	352	20198	75.81%	19	22
W	350	20548	77.13%	20	23
X	338	20886	78.40%	21	24
Y	325	21211	79.62%	22	25
Z	271	21482	80.63%	23	26
AA	254	21736	81.59%	24	27
AB	217	21953	82.40%	25	28

Appendix Table 14: Synergy Analysis Results (continued)

Part Number	Orders	Total Orders	Penetration	Iteration	Count
Part	Additional orders now able to be filled by the addition of this part to the stockroom.	Cumulative orders able to be filled by the set of parts from here to the top of the list.	Cumulative Percentage of all orders able to be filled by the set of part from here to the top of the list.	Cumulative number of clusters in the stockroom	Cumulative number of part numbers in the stockroom
AC	217	22170	83.21%	25	29
AD	217	22387	84.03%	25	30
AE	191	22578	84.75%	26	31
AF	186	22764	85.44%	27	32
AG	186	22950	86.14%	27	33
AH	183	23133	86.83%	28	34
AI	167	23300	87.45%	29	35
AJ	167	23466	88.08%	29	36
AK	157	23623	88.67%	30	37
AL	155	23778	89.25%	31	38
AM	151	23929	89.82%	32	39
AN	119	24048	90.26%	33	40
AO	116	24164	90.70%	34	41
AP	98	24262	91.07%	35	42
AQ	88	24350	91.40%	36	43
AR	85	24435	91.72%	37	44
AS	85	24520	92.04%	37	45
AT	84	24604	92.35%	38	46
AU	81	24685	92.65%	39	47
AV	71	24756	92.92%	40	48
AW	69	24825	93.18%	41	49
AY	63	24888	93.42%	42	50
AZ	61	24949	93.65%	43	51
BA	58	25007	93.86%	44	52
BB	51	25058	94.06%	45	53

Appendix Table 14: Synergy Analysis Results (continued)

Part Number	Orders	Total Orders	Penetration	Iteration	Count
Part	Additional orders now able to be filled by the addition of this part to the stockroom.	Cumulative orders able to be filled by the set of parts from here to the top of the list.	Cumulative Percentage of all orders able to be filled by the set of part from here to the top of the list.	Cumulative number of clusters in the stockroom	Cumulative number of part numbers in the stockroom
BC	41	25195	94.57%	48	56
BD	41	25236	94.72%	48	57
BE	41	25277	94.88%	49	58
BF	39	25316	95.02%	50	59
BG	38	25354	95.17%	51	60
BH	38	25392	95.31%	52	61
BI	38	25429	95.45%	52	62
BJ	39	25468	95.59%	53	63
BK	39	25506	95.74%	53	64
BL	39	25545	95.88%	53	65
BM	37	25582	96.02%	54	66
BN	37	25619	96.16%	55	67
BO	37	25656	96.30%	55	68
BP	37	25693	96.44%	56	69
BQ	37	25730	96.58%	57	70
BR	37	25767	96.72%	57	71
BS	37	25804	96.86%	57	72
BT	35	25839	96.99%	58	73
BU	35	25874	97.12%	59	74
BV	34	25908	97.25%	60	75
BW	34	25942	97.37%	61	76
BX	34	25976	97.50%	62	77
BY	31	26007	97.62%	63	78
BZ	29	26036	97.73%	64	79
CA	26	26062	97.82%	65	80
CB	25	26087	97.92%	66	81
CC	25	26112	98.01%	66	82
CD	25	26137	98.10%	66	83

Appendix Table 14: Synergy Analysis Results (continued)

Part Number	Orders	Total Orders	Penetration	Iteration	Count
Part	Additional orders now able to be filled by the addition of this part to the stockroom.	Cumulative orders able to be filled by the set of parts from here to the top of the list.	Cumulative Percentage of all orders able to be filled by the set of part from here to the top of the list.	Cumulative number of clusters in the stockroom	Cumulative number of part numbers in the stockroom
CE	25	26162	98.20%	67	84
CF	25	26187	98.29%	68	85
CG	24	26211	98.38%	69	86
CH	23	26234	98.47%	70	87
CI	23	26258	98.56%	70	88
CJ	23	26281	98.64%	70	89
CK	23	26304	98.73%	70	90
CL	26	26330	98.83%	71	91
CM	26	26356	98.93%	71	92
CN	23	26379	99.01%	72	93
CO	21	26400	99.09%	73	94
CP	21	26421	99.17%	73	95
CQ	21	26442	99.25%	73	96
CR	21	26463	99.33%	73	97
CS	22	26485	99.41%	74	98
CT	15	26500	99.47%	75	99
CU	10	26510	99.51%	76	100
CV	10	26520	99.54%	77	101
CW	9	26529	99.58%	78	102
CX	9	26538	99.61%	79	103
CY	8	26546	99.64%	80	104
CZ	7	26553	99.67%	81	105
DA	7	26560	99.69%	82	106
DB	7	26567	99.72%	83	107
DC	7	26574	99.75%	84	108
DD	7	26581	99.77%	85	109
DE	7	26587	99.79%	85	110
DF	6	26593	99.82%	86	111
DG	5	26598	99.84%	87	112
DH	5	26603	99.85%	88	113

Appendix Table 14: Synergy Analysis Results (continued)

Part Number	Orders	Total Orders	Penetration	Iteration	Count
Part Number	Additional orders now able to be filled by the addition of this part to the stockroom.	Cumulative orders able to be filled by the set of parts from here to the top of the list.	Cumulative Percentage of all orders able to be filled by the set of part from here to the top of the list.	Cumulative number of clusters in the stockroom	Cumulative number of part numbers in the stockroom
DI	3	26613	99.89%	90	116
DJ	3	26616	99.90%	91	117
DK	2	26618	99.91%	92	118
DL	2	26621	99.92%	92	119
DM	2	26623	99.93%	92	120
DN	2	26625	99.94%	93	121
DO	2	26627	99.94%	93	122
DP	3	26630	99.96%	94	123
DQ	2	26632	99.96%	95	124
DR	2	26633	99.97%	95	125
DS	2	26635	99.97%	96	126
DT	2	26636	99.98%	96	127