

Policy Safety Stock Cost Optimization : Xerox Consumable Supply Chain Case Study

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Inventory, cost, and the level of service are three interrelated key metrics that most supply chain organizations are striving to optimize. One way to achieve this goal is to create a simulation model to conduct sensitivity analysis and optimization on several different supply chain policies that can be implemented in actual operation. In this paper, a case of Xerox global supply chain modeling and analysis to assess several “what if” scenarios for the consumable policy safety stock is presented. The simulation model, combined with analytical cost model and optimization module, is used to optimize the policy safety stock level to achieve the lowest total value chain cost. It was shown quantitatively that the policy safety stock can be reduced, but it is offset by the inbound premium transportation cost to expedite supplies in shortage, and the outbound premium transportation cost to send supplies to customers via express shipment, requiring fine balance.

Keywords: Supply Chain Model, Discrete Event Simulation, Policy Safety Stock Optimization

1. Introduction

Supply chain management is playing an important role in the corporate business strategy as the supply chain network in a typical firm is becoming complex, spanning throughout the entire globe. Acquisition of raw materials, supply of parts from part vendors, intra company distribution and stocking infrastructure for finished goods, and outbound distribution network for delivering goods to end customers are all important elements of the supply chain that need to work in harmony for efficient operation of the overall network. Accordingly, active research efforts are being undertaken to pioneer ways to design and implement better supply chain net-

work and corresponding supply chain policies.

One of the most widely used methods to evaluate and assess the impact of a new complex system, such as a supply chain, in an efficient manner is to utilize simulation tools (Iannone *et al.*, 2007). Simulation models allow quick construction of a virtual system with required parameter and performance relationship to observe system performance sensitivity with respect to the user controlled parameters, without going through testing of the actual system (Harrison *et al.*, 2007).

In many instances, supply chain simulation models are created using discrete event simulation (Roy and Arunachalam, 2004; Mele *et al.*, 2006; Yoo, 2010; Tako and Robinson, 2012), due to the time-based dynamic nature of the supply

The work presented in this paper in its entirety was conducted while employed at Xerox Corporation.

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chain itself. Another simulation method that is used in lieu of discrete event simulation are agent based modeling (Hilletoft and Lattila, 2012; Jetly *et al.*, 2012; Rolon and Martinez, 2012; Santa-Eulalia *et al.*, 2012; Li and Chan, 2013; Lim *et al.*, 2013). Agent based modeling overcomes the limitation of the discrete event simulation model that it can model each supplier, distributor and customer as an agent, customizing their behaviors, allowing more accurate in-depth analysis of the supply chain, even if number of suppliers, distributors or customers are in the order of thousands. The system dynamic model is another popular dynamic model that is used for supply chain simulation (Cannella, 2013; Mula *et al.*, 2013; Rand, 2013). System dynamic model allows decision makers to model and observe the supply chain at the top system level.

Simulations are frequently utilized to answer questions in various areas of supply chain management. Models are used to assess the performance of the supply chain system under uncertainties such as demand uncertainty (Vidalakis *et al.*, 2013), the bullwhip effect resulting from forecast errors (Wangphanich *et al.*, 2010; Hussain *et al.*, 2012; Hussain and Saber, 2012; Chatfield, 2013), and production/supply lead time variability (Ruiz-Torres and Mahmoodi; 2010; Finke *et al.*, 2012) to just name a few. Also, supply chain models are frequently utilized to optimize key metrics, such as the level of inventory, overall value chain cost, or the level of service for the end customers (Mele *et al.*, 2006; Bottani and Montanari, 2010; Ruiz-Torres and Mahmoodi, 2010). Sometimes, high fidelity simulation model can be combined with other methodologies, such as six sigma (Kumar *et al.*, 2011) or Taguchi experiments (Hussain and Saber, 2012; Yum *et al.*, 2013) to extract desired performance metrics.

The work presented in this paper contributes to the area of supply chain simulation and analysis through an industrial case study conducted at Xerox Corporation, where the total value chain cost for its global consumable supply chain was optimized using a combination of high fidelity supply chain model and an excel based optimization module. The total value chain consists of Xerox consumable parts supplier, the main company, and consumers who order them. The objective is to minimize the total value chain cost, which consists of premium parts transportation costs for inbound and outbound shipment to and from the company network, and the cash value of consumable parts policy safety stock. In the next section, the detailed case study is presented.

2. Case Study : Xerox Consumable Supply Chain Policy Safety Stock Cost Optimization

2.1 Xerox Consumable Supply Chain Overview

The Xerox consumable supply chain is responsible for

supplying parts that are used in Xerox printing system in regular cadence (e.g. inks, toners, photoreceptors, etc...). <Figure 1> shows the simplified version of Xerox consumable parts supply chain. The consumable supply chain consists of Xerox planning issuing purchase orders (POs) to various suppliers with supplier-specified order lead time and finished goods transit time into the Xerox supply chain network. Consumable parts are stored in several regional distribution centers within the network, and upon receipt of customer order, directly shipped to customers. Once those deployed parts reach end of their lives, they are sent back to returns processing facility for remanufacturing or disposal.

In this paper, an optimization case study conducted for Xerox consumable supply chain is presented. In the next section, the overview of the consumable supply chain case study, modeling process, assumptions, and analysis results are presented and explained in detail.

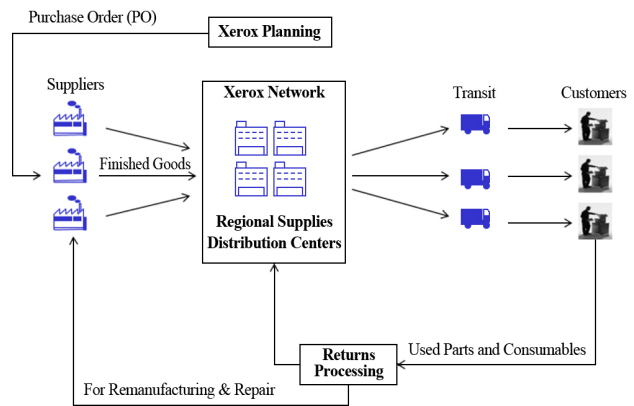


Figure 1. Xerox consumable parts supply chain

2.2 Case Study Overview

One of the key tasks for the supply chain organization is to reduce the amount of holding inventory, while minimizing the premium transportation cost of required inventories and meeting the customer level of service. <Figure 2> shows the relationship between inventory, cost and level of service.

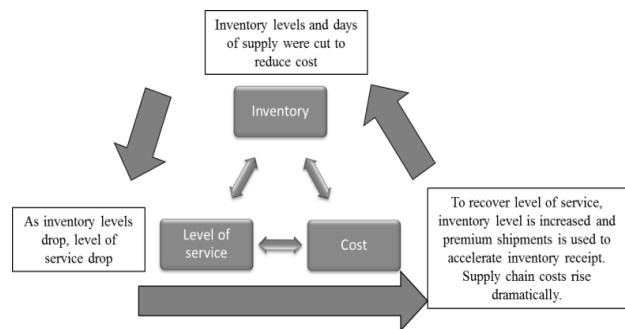


Figure 2. Relationship between inventory, level of service and cost

For example, the organization initiates reduction in its inventory holding to save cash tied to the inventory. This, in turn, triggers drop in level of service due to more frequent stock out of stock keeping units (SKU) required by customers. To remedy the situation, inbound shipments of inventory are accelerated through the use of premium shipments, causing escalation of transportation costs. Also, to satisfy waiting customers, outbound shipment to customers are also shipped using premium shipment. As the cost increases, a decision is made to increase the level of inventory, which brings the inventory level to where it was originally. In order to break this negative cycle, there is a need to create a quantitative framework that will allow systematic optimization of all three metrics, which results in lowest total value chain cost for the corporation.

In order to estimate the total value chain cost for the consumable supply chain as a function of the inventory level, decisions had to be made on 1) type of inventory to reduce; 2) how much to reduce; and 3) type of costs to include when optimizing for the total cost to the corporation.

Consumables Inventory Values (Normalized)

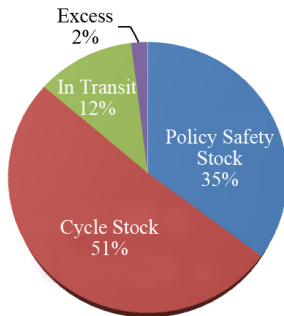


Figure 3. Consumables inventory breakdown (by monetary value)

1) Type of inventory for reduction : <Figure 3> shows the breakdown of consumable inventory into different categories. The inventory shown represents the entire Xerox consumable SKU inventory snapshot at the time of the case study, which was used for the case study analysis. Policy safety stock (PSS) is a buffer inventory to absorb uncertainties in customer demands and other unforeseen circumstances. Cycle stock is necessary inventory to satisfy nominal recurring customer demands. In transit stock is inventory that is either en-route to the company network or in transit to customers. Finally, excess stock is surplus inventory above and beyond required inventory held by Xerox. The decision was made not to pursue the analysis of cycle stock and in-transit stock, due to lack of information regarding the overall cost of altering inventory transit policy and cycle stock shipment and handling policy. For the excess inventory, it can be removed for cost saving, since it is above and beyond officially required inventory determined. As a result, it was decided to focus on the reduction of safety stock and analyze the level of service and total cost consequences.

- 2) Inventory reduction : Through internal inquiry, recommended quantity of safety stock for each and every consumable SKU was obtained. Once the data is collected, it was decided to decrease safety stock in decrements of 10% and obtain stock out sensitivity for SKUs analyzed.
- 3) Costs included : There are three major cost elements which were included in this case study.
 - a. First is the weighted average capital cost (WACC) of the inventory. For example, if \$1,000,000 worth of inventory is reduced and the interest rate is 10% per year, the actual cash equivalent WACC saving is \$100,000 per year. This was done to enable apple to apple comparison between the inventory reduction and the other costs.
 - b. Second cost element is the inbound expedited shipping cost. When there are not enough in-network inventories to satisfy expected demand, necessary quantity is brought into the network via faster premium shipment, which cost more than the equivalent regular shipment.
 - c. The last cost element is the outbound expedited shipping cost to customers. As time to fulfill order increases due to inventory unavailability, it is more likely that aged orders are shipped via premium shipment, which is more expensive than regular shipment.

<Figure 4> shows the consumable supply chain cost optimization framework used for the case study. Inputs include part demand, part inventory, its order lead time from the supplier and supplier’s PO flexibility. The PO flexibility is the ability for Xerox to adjust its original PO within the order lead time. Typically, the flexibility to adjust the order quantity decreases as the final shipment date is near, due to the supplier’s commitment of resources to produce the parts specified in the PO. The outputs include the percentage of total inventory that was shipped via premium shipping and the percentage of orders that had to be shipped out via express shipment due to stock out. Using this, the optimizer module can calculate the total corporate cost, which is the total value chain cost.

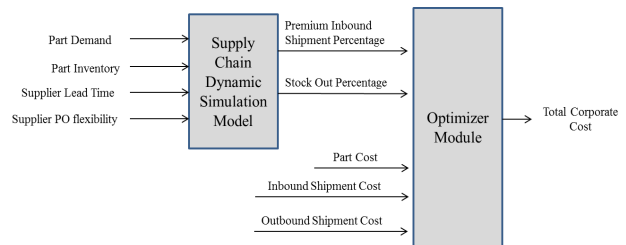


Figure 4. Consumable supply chain cost optimization framework

- Supply Chain Dynamic Simulation Model : For the dynamic simulation of the consumable supply chain, a dis-

crete simulation model constructed with the Anylogic™ simulation software was used. The simulation model simulates consumable inventory flow from the supplier to Xerox regional warehouses, then to customers, according to the Xerox inventory policy and heuristics, such as supplier PO flexibility, rules for premium inbound shipments and inventory replenishments.

- **Optimizer Module** : Once results are obtained from the dynamic simulation model, an Excel based optimizer (Quantum XL™) was used to find the optimal inventory level that will achieve the optimized total value chain cost for the corporation. The optimizer is based on Genetic Algorithm, which is a heuristic optimization method.

2.3 Supply Chain Modeling and Assumptions

Several modeling assumptions were made in order to assure that the simulation reflected the reality of the everyday supply chain operation. These assumptions are explained in this section.

(1) SKU clustering

Consumable parts come from many different suppliers, each with a different supplier lead time and contractual flexibility. These parts were clustered into several categories, as Xerox Supply Chain Business Group defines it. Each category is explained below :

- **Category 1** : These are high usage parts manufactured within the United States. These parts are stocked in regional distribution centers throughout the United States, and customer orders are fulfilled by those regional centers. These parts have very short transit time to regional warehouses than other parts from overseas suppliers.
- **Category 2** : These parts represent low usage parts manufactured within the United States. Since customer orders for these parts are less frequent, these parts are centrally stocked at main warehouse and shipped out to customers as the order arrives.
- **Category 3** : These are high usage parts originating from European suppliers, and have longer transit time than Category 1 and 2 parts. Since these are fast moving parts, they are stocked in regional distribution centers throughout the United States for faster fulfillment.
- **Category 4** : These parts are low usage parts originating from Europe. They are treated as same as Category 2 parts, except requiring longer transportation time.
- **Category 5** : These parts are high usage parts manufactured in North America, outside of United States. These parts are stocked in regional distribution centers throughout United States.
- **Category 6** : These are low usage parts manufactured in North America. They are stored in central warehouse, and are shipped out to customers as the order arrives.
- **Category 7** : These are high volume parts supplied from Asia. These parts are stocked in regional warehouses for customer order fulfillment.
- **Category 8** : These are low volume parts supplied from Asia. In the simulation, they are treated as same as Category 2 parts, except for shorter lead time and longer transit time.

<Table 1> shows lead time, transit time and inventory stocking locations for each category. Note that all the numbers were normalized. The lead time is normalized with respect to the lead time of Category 1 parts, and the transit time is also normalized with respect to the transit time of Category 1 parts. One thing to note is that the manufacturing lead times for the United States and Europe are long, and Asia is short. This is due to the terms of contract with parts manufacturers in those regions, and also due to the availability of manufacturing facility. For this case study, lead times specified in the contract was used.

Table 1. Lead time, transit time and inventory stocking locations for parts

Parts Category	Lead Time	Transit Time	Stocking Locations
Category 1	1.00	1.00	Regional Warehouses
Category 2	1.00	1.00	Central Warehouse
Category 3	1.00	8.57	Regional Warehouses
Category 4	1.00	8.57	Central Warehouse
Category 5	0.60	0.57	Regional Warehouses
Category 6	0.60	1.43	Central Warehouse
Category 7	0.57	8.57	Regional Warehouses
Category 8	0.57	8.57	Central Warehouse

There are several hundred SKUs for the consumable supply chain. Inspecting data for all Xerox consumable SKUs, over 90% of SKU data were deemed fit for the analysis. Parts which were not analyzed either didn't have complete information, or were ramping up parts which would have not fit into our current analysis framework of steady demand parts. For the simulation, SKUs in each cluster were simulated together, since they have same PO lead time and transit time, with identical PO flexibility. Once the simulation for a cluster is finished, simulation for the other cluster is conducted with different lead time, transit time, and PO flexibility.

(2) Regional distribution centers

There are several regional distribution centers throughout the United States that carry consumable inventory and fulfill the regional customer orders. All high volume parts are stocked in these regional centers. Depending on demand for individual parts in each region, the corresponding distribution center carries a certain amount of safety stock as well as cycle stock for regular occurring demands. <Table 2> shows example inventory parameters for one of the parts, listed by individual distribution center.

Table 2. Inventory parameters for an example consumable part

Distribution Center	Re-Order Points	Maximum Inventory Level
A	178	342
B	242	446
C	101	303
D	121	254

In the table, Re-Order Point refers to the inventory level where replenishing order is triggered. This is equivalent to the policy safety stock level. If there are parts available in central warehouse, parts are shipped to the regional center that requested parts until the inventory level at that regional center reaches the maximum inventory level shown above. In case where several regional centers are in parts shortage, but there are not enough to cover the demand within the network, parts are shared proportionally among those centers experiencing shortage. For low volume parts, they are stocked in the main warehouse, and are shipped direct to customer individually as orders arrive.

Due to the limitation on simulation, once the parts arrive in a regional distribution center, it cannot be shipped to any other distribution centers. This means that one center might experience a massive stock out, while another center might have excess inventory at the same time.

(3) Other assumptions

All suppliers send their shipments once a month. When the simulation starts, the month worth of SKU inventory arrives in the network, on top of the safety stock that is already in the network.

- For high volume parts, regional distribution centers are replenished only when their inventory level goes below their re-order point, and will be filled up to their maximum inventory level, given there is sufficient inventory available in the central warehouse.
- The simulation model assumes the last 12 months of historical demand as representative of the next 12 months. Seasonality and part specific growth and decline are not explicit for simplifying purposes.

- Order fulfillment to customers from central location or regional distribution center is first-in-first-out (FIFO) basis. No order can jump in front of other orders in any circumstances.
- Simulation assumed, as a starting point, that all consumable parts are at their current recommended safety stock levels. Any excess inventory above and beyond (as seen in <Figure 3>) becomes saving opportunity.
- Simulation starts with a single SKU with current policy safety stock (PSS) stocked in the network, subject to historical 12 months demand. The simulation then repeats the run with 90% of current PSS level. The simulation run with a single SKU continues with 10% decrement of PSS until there are no safety stocks in the company network. This was repeated for all candidate consumable parts.
- WACC was set at the internal corporate rate for converting inventory reduction into cash savings.
- Inbound premium transportation cost was set at an average value over the entire consumable SKUs.
- For the outbound shipment, it was decided that if an order is aged five days or more, it will be shipped out to customers using premium shipment, as soon as parts become available.
- Outbound premium transportation cost was set at the value provided by the Xerox field service.

(4) Resulting metrics

Once the dynamic supply chain simulation is complete, two key metrics are obtained.

- Premium inbound air shipment percentage : This is the percentage of the total parts shipment into the company network that ended up in expedited shipment, due to a shortage of parts within the network. This metric is especially important for parts coming from Europe and Asia, due to their high transportation cost.
- Stock out percentage : This is the percentage of total parts demand that resulted in stock out, due to a shortage of parts. As the stock out percentage increases, customers wait longer for their order (order aging), which leads to customer dis-satisfaction and additional premium shipment cost to the corporation for sending long waited parts via express shipment.

The optimizer module will take two metrics obtained from the simulation and use premium transportation costs (inbound premium air shipment cost, parts cost, and outbound premium shipment cost) to calculate the total cost to the corporation and attempt to minimize it.

2.4 Simulation and Optimization Results

Using the discrete event simulation model, inbound premium shipment percentage, and stock out percentage for candidate consumable parts for different safety stock level were obtained. <Table 3> shows sample stock out percentage output for one of the parts analyzed. The stock out percentage is calculated at the overall level, and also at the individual distribution center level. Some distribution centers show higher stock out rate than others, due to various reasons, such as higher demand and demand volatility. <Table 4> shows the inbound premium shipment percentage for the same part shown in <Table 3>.

Note that inbound air shipment comes into the main warehouse, thus requiring one overall percentage output. After the simulation results for all parts were acquired, using the parts cost and the average inbound premium shipment cost, plot shown in <Figure 5> was created.

The vertical axis represents total normalized cash value of policy safety stock for evaluated consumable parts. Cash value of policy safety stock was obtained by multiplying the

monetary value of safety stock inventory by WACC, in order to compare directly with the transportation cost. The horizontal axis is the total inbound premium air shipment cost incurred for all evaluated parts at the specified safety stock level. The first point on the left is the total inventory value of current consumable parts policy safety stock, and corresponding inbound premium transportation cost. For the next point, PSS was reduced 10% across the board from the current PSS level, and resulting total PSS value and corresponding premium transportation cost is plotted. The graph shows plots from current PSS level, all the way down to 20% of PSS, or 80% PSS reduction across the board. As expected, as the level of policy safety stock decreases, the average percent of stock out increases, and the cost of inbound transportation for SKUs increase. The plot shown in Figure 5 represents uniform PSS reduction across the board for all parts. To explore other possibilities, several different inventory reduction scenarios were simulated, and plotted in Figure 6. This was done to make sure that the team covered all different scenarios that were brainstormed during PSS reduction strategy meetings, and to see how each scenario will perform.

Table 3. Output for a sample part-stock out percentage

Dist. Center	Policy Safety Stock Level Respect to Current PSS						
	At PSS	-10%	-20%	-30%	...	-90%	-100%
A	12.1%	14.2%	17.7%	21.0%	...	45.1%	52.6%
B	5.7%	6.8%	8.3%	10.5%	...	30.7%	38.8%
C	4.1%	6.0%	8.0%	10.4%	...	29.3%	33.6%
D	1.5%	2.0%	2.4%	3.2%	...	12.5%	14.1%
Part Overall	6.9%	8.5%	10.8%	13.2%	...	32.7%	38.4%

Table 4. Output for a sample part-inbound premium shipment percentage

Shipment Percentage	Policy Safety Stock Level Respect to Current PSS						
	At PSS	-10%	-20%	-30%	...	-90%	-100% (No Safety Stock)
	0.37%	0.68%	0.99%	1.30%	...	2.78%	3.13%

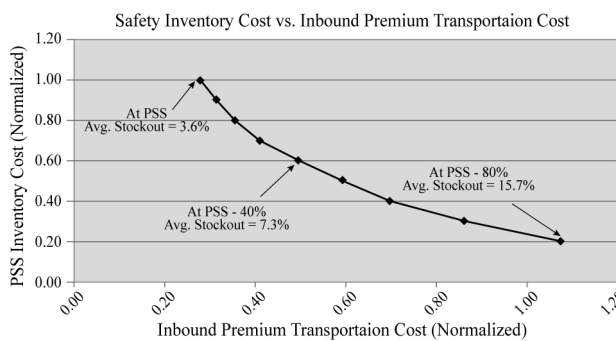


Figure 5. Safety Inventory cost vs. inbound premium transportation cost

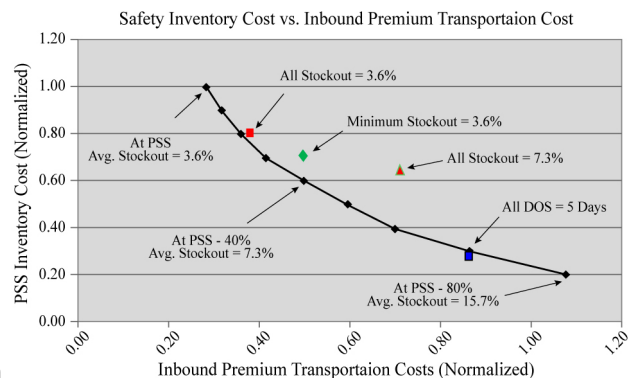


Figure 6. Different scenarios for PSS reduction

- A. **Setting all SKU's stock out percentage to 3.6%** : PSS adjustment was made, so that each and every SKU will have uniform stock out percentage of 3.6%. The resulting plot shows that if we set all SKU's stock out percentage to 3.6%, it will have same inventory reduction impact as if we cut 20% of PSS across the board, but with slightly higher inbound transportation cost.
- B. **Setting minimum stock out percentage to 3.6%** : In this case, all SKU's stock out percentage was set to 3.6% or greater, meaning that if a particular SKU had stock out percentage less than 3.6%, then its PSS was reduced until the stock out percentage was equal to 3.6%. All other SKUs that had stock out percentage greater than 3.6% were left alone. The resulting plot shows that it had same inventory impact as if we cut 30% of PSS across the board, but with a higher inbound transportation cost.
- C. **Setting all SKU's stock out percentage to 7.3%** : The resulting plot shows this to be a very sub-optimal solution, due to high transportation cost.
- D. **All SKU PSS Days of Supply (DOS) set at 5 days** : Safety stock DOS for all SKUs were set to 5 days. The analysis shows that it will have PSS reduction impact close to 70% of total current PSS with roughly equivalent inbound transportation cost as 70% across the board cut scenario.

From all plots shown for various scenarios, it seems that the curve representing the PSS cut across board is a Pareto frontier, where inventory cannot be reduced further without incurring extra shipping cost. <Figure 7> shows the sum of total inbound premium transportation cost and the cash value of the policy safety inventory for varying level of PSS in previous plots.

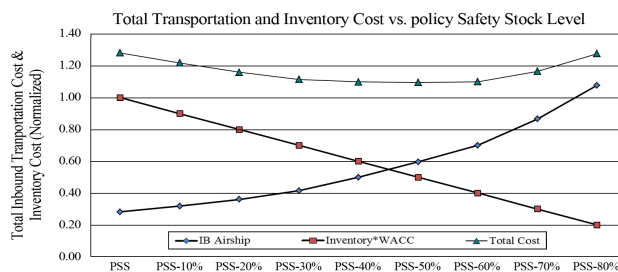


Figure 7. Total Inbound Transportation Cost and Inventory Cost vs. Policy Safety Stock Level

In the plot, there are three curves. The red curve shows the cash value of PSS, which is the total cost of PSS multiplied by WACC. The blue curve represents total inbound premium shipment cost, and finally, the green curve represents the total cost at the specific PSS level. Observing from this graph, if the decision makers were only concerned with inbound transportation cost, up to 50% of current PSS can be eliminated for total optimal cost to the organization.

Up to this point, the analysis was only limited to inbound transportation cost and the inventory cost. However, in order

to see the holistic cost impact on the total corporation level, outbound premium shipping cost for emergency order was added to the total cost. It was assumed that all orders, aged greater than five days, will be shipped out to customers via a premium shipping method with extra cost. One of the challenges was to estimate the portion of total customer demand that would be shipped out as emergency orders. Noting that order aging was a heavily manual step in the modeling work, a design of experiment (DOE) based on seventeen consumable SKUs was constructed. The DOE spanned source (shipping lane) as well as the overall level of stock outs, with the output being the sensitivity of stock out age for a given part to shifts in inventory level. Hence, the DOE could surmise at what point in inventory the stock outs would be significant enough to induce ages beyond five days. First, the order aging profiles of the seventeen parts were modeled, and regression functions constructed. These regressions had R² of approximately 85-90%.

Given these functions, assuming they were representative of the population, estimates of order aging profiles were constructed for the entire set of consumables. These profiles would be a function level of stock out seen over the past twelve months. As a check on the work, six confirmation runs were completed. These parts also spanned part source and stock out level. In all cases tested, the resulting variation was acceptable and it was concluded that the regressions could be used to estimate order age.

Also, based on the deterministic supply chain simulation outputs, simple linear transfer functions for inventory cost and inbound premium transportation costs, as a function of stock out percentage were created for each individual SKU. A similar approach was applied to the outbound premium transportation costs using the DOE model results. With all three cost elements now codified in terms of stock-out percentage, a multiple response optimization was run across all SKU's using the optimization software. The objective of the optimization was the total cost, including inventory and transportation costs. Additionally, the output recommendations from the optimizer could be plotted for the largest financial impact by SKU. This allowed identification of individual SKU for inventory reduction. <Figure 8> shows total value chain cost as function of PSS level.

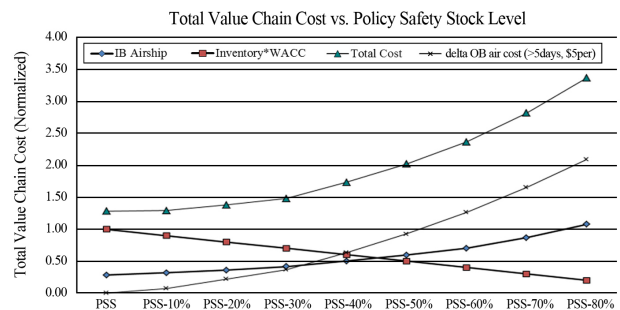


Figure 8. Total Value Chain Cost vs. Policy Safety Stock Level

The plot shows very different results from the one shown in <Figure 7>, due to the addition of outbound premium transportation cost. Decreasing PSS by 50% is no longer a viable option, and from the observation, it is observed that the PSS can be reduced at most 10%, without impacting the level of service.

With all costs in consideration, optimization was performed to find the minimum cost to the total value chain using the optimization module. The algorithm attempted to optimize the PSS level, inbound transportation cost and outbound cost for all SKUs to yield the lowest total cost. <Figure 9> shows the optimized results.

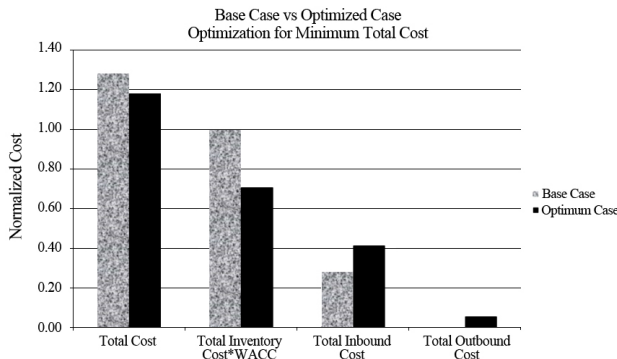


Figure 9. Total Value Chain Cost Optimization Results

The tiled bar represents costs from the base case with a current PSS level. The black bar represents costs from the optimized case. When comparing total costs, the optimized case has slightly more cash savings. This was accomplished by reduction of PSS, while taking on additional cost of inbound premium shipment and outbound premium shipment. One insightful observation of this optimization results can be found in detailed decomposition of cost elements. In the optimized case, PSS is reduced significantly, while inbound and outbound premium transportation cost is increased. This is due to the fact that while the reduction in PSS is 100% guaranteed saving in cost, inbound and outbound transportation cost may or may not reach the level shown in the plot, depending on demand volatility. However, there is downside risk that the transportation cost will be greater than what is shown in the figure, if demand volatility is high.

In order to realize proposed optimized savings, additional analysis was done to identify top impact SKUs that can reduce total inventory cost. <Figure 10> shows top 50 parts, which were identified by the optimization, which can be reduced significantly for inventory cost savings. Y-axis represents the normalized inventory cost savings for each SKU.

The results of this analysis were taken into consideration and identified SKUs shown in Figure 10 were further investigated for inventory reduction action by the supply chain management team at the conclusion of this case study, in order to implement proposed action by the optimization results. One expected difficulty is that the team might have hard time

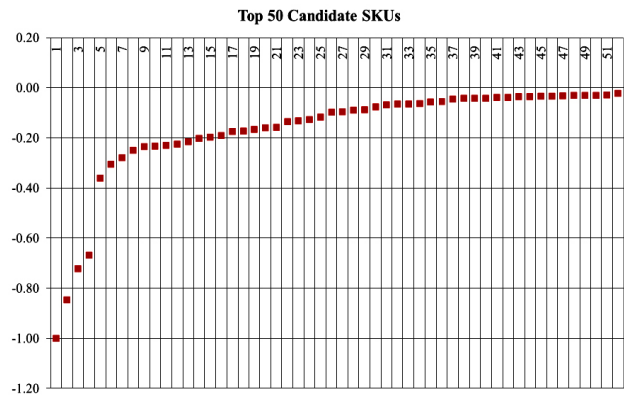


Figure 10. Top Opportunity SKUs for PSS Inventory Reduction

convincing field service engineers who use SKUs which will be reduced for inventory reduction who will be concerned that their outbound transportation cost will increase, even though it will save total cost at the top level.

2.5 Case Study Summary

In this case study, Xerox printing system consumable SKUs were optimized for total value chain cost to the corporation. The cost elements include the total cash value of PSS inventory, inbound premium shipment cost, and outbound premium shipment cost. High fidelity discrete event supply chain simulation model was used to yield stock out percentage and inbound premium shipment percentage for each SKU as a function of its PSS level. Stock out percentage was then used to calculate outbound shipment percentage using DOE derived transfer functions. Using these results, total sum of cost was calculated and optimization was run to determine the minimum cost point for the total supply chain cost to the corporation.

The results showed that the PSS can be reduced, but the high cost of inbound and outbound premium shipment quickly negates the PSS reduction impact. To find the minimum total cost, optimization was performed. The optimization results revealed that the PSS can be reduced with increased transportation cost, while achieving additional savings in total cost. Top opportunity SKUs were identified and are being investigated for PSS reduction opportunities.

3. Conclusions and Future Work

3.1 Conclusions

In this paper, total value chain cost optimization process for Xerox post-sale consumable supply chain was demonstrated with recommendable results. The optimization process utilized validated discrete event supply chain simulation

model, combined with an optimization module to obtain the cost optimal PSS level, considering inbound and outbound premium transportation cost.

It was observed that the PSS can be reduced, but it had to be traded off with increasing inbound and outbound premium transportation cost due to increase in stock out. Also, the optimization results yielded tornado chart for top opportunity parts for their PSS reduction. These parts were recommended for inventory reduction and are currently undergoing assessment for such action.

This case study contributes to Xerox and general academia in its own way. For Xerox, the modeling, simulation and optimization framework developed for this case study was used to simulate many “what if” scenarios for its consumable parts supply chain to identify consequences of PSS reduction and the best way to improve overall value chain cost through reducing identified SKUs. Through use of actual data and simulating current policy with the supply chain model constructed, the team was able to produce results that convinced senior management and were easy to implement. For general practitioners in the supply chain management, this case study provides an actual industry example where modeling and simulation was used to provide quantitative information to supply chain policy decision makers who needs to set the policy.

3.2 Future Work

In order to enhance this framework, a number of improvements can be made. First improvement is the identification of individual SKU's premium inbound and outbound transportation cost for more customized and detailed optimization of PSS level and total cost. Second improvement is the sensitivity of customer to aged orders. In this case study, it was assumed that all orders aged five days or more will automatically shipped out to customers by premium shipment. However, if one can obtain the percentage of orders that are aged five days or more that are shipped out via premium transportation, it would add a more realistic view to the optimization process. Another improvement to the framework would be setting the customer order priority. In reality, when a customer who has been waiting for their order for more than five days will call to complain, the order is elevated and is put on the front of the order list. In this simulation, this was not done. Adding this feature will add more reality to the simulation.

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