Knitting a Fast-Response Apparel Supply Chain

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Summary: This research presents a new insight on inventory management, specifically on strategic safety stock placement within a manufacturing process. The context of this work is a global apparel company. Using segmentation analysis and demand pooling, it was discovered that the optimal safety stock placement was not determined solely by the coefficient of variation (CoV). Other factors, such as lead time and cost of materials, may have an influence on the outcome as well. A sensitivity analysis was also performed to test the impact of our findings.

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KEY INSIGHT

- The best location for safety stock placement may not be at the echelon with the lowest CoV nor at the most upstream stage of a manufacturing process.
- Apparel companies may want to consider establishing a bin of assembled undergarments before the finished goods within its manufacturing process, if not already implemented, as it may be a good strategy.

Introduction

Stylo is a global apparel company that has a wide range of products, such as undergarments and sportwear, listed under several brand names catering to different market segments across the globe. The company adopts a dual sourcing strategy for its raw materials and manufactured goods. This strategy can be divided into two parts of the world: 1) Western Hemisphere and 2) Eastern Hemisphere.

In the Western Hemisphere, the company owns a few facilities in Central America. On the other hand, the Eastern Hemisphere consists of several third-party manufacturers that supports the company and a few company-owned facilities located in Asia and Southeast Asia. Apart from a sound sourcing strategy of shifting its production units to low cost areas of Southeast Asia, Stylo's campaigns have resonated with the company's brand superiority, innovation and low-cost supply chain to provide higher valued products while lowering production costs. To increase its market share and market reach to different geographies, Stylo would acquire other companies in related segments. As an outcome to this strategy, the company' sales grew to approximately USD 6 billion and net income increased to more than USD 0.4 billion in 2016.

Research Objective

Between the year 2009 to 2017, Stylo had relied on a single company-owned facility in Asia for almost all its manufacturing of textiles and cutting of fabrics for the

Eastern Hemisphere market. However, due to issues with the state government, the facility had to be closed. This has affected the company's production performance in terms of the volume of fabrics being manufactured and the time it took to manufacture those fabrics. At the same time, the company also faced issues of increased lead time, demand fluctution and not being able to achive target service levels. Therefore, to overcome these problems, this research aims to determine where would be the optimal location to keep safety stock within the apparel supply chain, for a desired service level?

Literature Review

The topic of determining the safety stock within a manufacturing process is not new and it goes back to several decades. Many researchers and papers have been published from various angles. The earliest literature that has been found was as early as the 1950's. In his brief paper, Simpson (1958) describes each stages of the manufacturing process as "a sequence of operations, separated from each other by inventories" (p. 864).

Sean Willems and Stephen Graves (2000) later built upon Simpson's work and termed the topic as 'strategic inventory placements'. Over the years, these two individuals, either through collaborative work with each other or with other researchers, have extended the strategic inventory placement framework by changing the variable parameters. Some of these variables include nonstationary demand, stochastic lead time, capacity constraints and evolving forecasts.

Besides strategic inventory placement, other reserachers have given it a different name. In his research, Collier (1982) introduced the concept of component commonality and describes it as the degree of Commonality Index, which "reflects the average number of component parent items per average distinct component parts" (p. 1297). Collier had developed a model to identify the relationship and tested it with stochastic simulation experiment.

Another approach is based on the concept of accurate response. Accurate response is a concept of dividing production capacity into two different stages: speculative production and reactive production which was discussed by Fisher, Hammond, Obermeyer and Raman (1997). They contributed to the literature by focusing on possible methods for reducing lead time and exploring the concept of accurate response for an apparel industry by using the case study of the ski wear manufacturer.

Despite the differences in the name of the terms and methods of analysis used by various reserachers, they all have at least one thing in common in which they all address the best location for safety stock placements.

Methodology

Data Collection

Two main documents were used for the research: 1) Histrorical Data for the year 2017; and 2) Bill of Materials (BOM). The 2017 historical data is semi-structured and in the format of Microsoft Excel. It contains demand data for a period of 50 weeks. The structure of the data is shown in Figure 1 below:

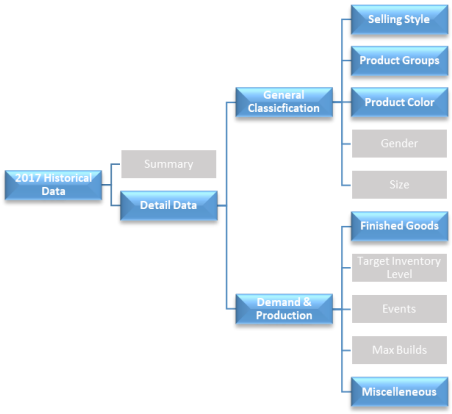

Figure 1: Stylo's 2017 Historical Data Structure

As for the BOM, only partial of the data was given in the format of MS Access. The whole structure of the BOM is shown in the Figure 2 below. However, only those circled in red were the data that was provided.

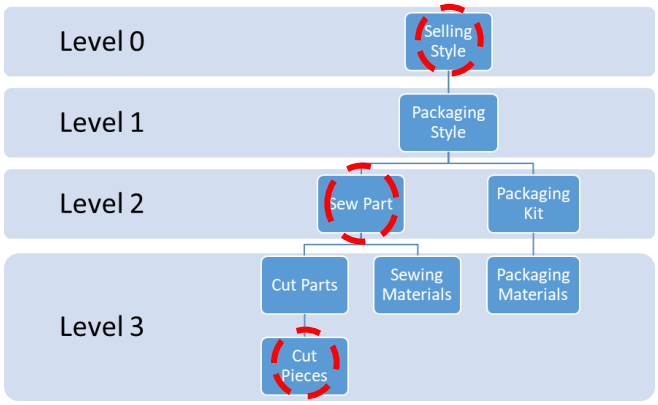

Figure 2: Stylo's Bill of Materials Structure

Apart from the historical data and BOM, data was also gathered by semi-structured interviews and discussions with key representatives from the company.

Segmentation

Before any safety stock calculation could be performed, a segmentation analysis had to be done using the two main documents mentioned earlier. This was meant to identify several key components for the research analysis such as determining the colors of fabrics, SellStyles and safety locations for safety stock calculations.

Initially, the number of Selling Styles had to be narrowed down by comparing the historical data document and the BOM. It was found that there were 2399 SKUs. However, after an analysis was performed based on complete order demand and by replenishment demand only, this was reduced to only 231 Selling Styles. Table 1 shows the breakdown of the Selling Styles.

	2017 Historical Data	BOM Data
No. of Selling Styles	2399	652
No. of Common Selling Style	596	
No. of Common Selling Styles - By Replenishment Only	565	
No. of Selling Styles - By Replenishment and Complete Order Demand	231	

Table 1: Comparison on Number of Selling Styles between 2017 Historical Data and BOM Data

Once the Selling Styles have been narrowed down, the next step was to determine two colors to be used for the safety stock calculations and demand pooling. This was achieved by segmentation of selling styles and undergarment colors in a single selling style. An example of the segmentation is shown in Table 2 below.

	Color1	Color2	Color3	Color4	TOTAL
SellStyle1	1		1		2
SellStyle2		1	1		2
SellStyle3	1				1
SellStyle4				1	1
TOTAL	2	1	2	1	6
Percentage	33.33%	16.67%	33.33%	16.67%	100%

Table 2: Example of Segmentation Table

With the two colors identified, the five SellingStyles and the potential locations for inventory placements had to be determined. The list of the five Selling Styles are shown in the Table 3. For ease of conducting the analysis, the five Selling Style names have been generalised as SellStyle1, SellStyle2, SellStyle3, SellStyle4 and SellStyle 5.

Actual Selling Style Codes	Generic Selling Style Codes
2349C4	SellStyle1
2349B7	SellStyle2
2349Z5	SellStyle3
2349VT	SellStyle4
7460P4	SellStyle5

Table 3: Relationship between Actual Selling Style Codes and Generic Codes

The overall step process to perform the segmentation analysis is shown in Table 4.

Step 1:	Create a table by listing the 'Selling Styles' in rows and the 'Colors' in columns
Step 2:	Match the colors used by each Selling Styles
Step 3:	Sum the usage for each color
Step 4:	Total number of all summation of colors
Step 5:	Calculate the percentage used by each color
Step 6:	Select at least the two highest colors by summation and percentage
Step 7:	Select a few Sell Styles that uses both the selected colors for further analysis on strategic inventory placement

Table 4: Step Process to Perform Segmentation Analysis to Select the Right Selling Styles

Lastly, the final step is the determining the potential locations for inventory placement. This was done based on the data available. A summary of the potential stages is shown in Table 5.

STAGE	PROCESS	COLOR	Lead Time
Stage1	Greige Stage	*Colorless	4 weeks
Stage2	Dyed Fabric Stage	Black or Grey	2 weeks
Stage3	Cut Kit Stage	Black or Grey	3 weeks
Stage4	Piece Undergarment or Underwear Stage	Black or Grey	1 weeks
Stage5	SellingStyle/Finished Goods (FG) Stage	Black & Grey	6 weeks

Table 5: Summary of Potential Stages for Inventory Placement

After all the components for safety stock calculations have been identified, it was now possible to perform the necessary calculations. Several analysis were conducted. First, calculations of the five SellStyles were performed by isolation. This was followed by pooling them at a single stage and at dual stages.

Results

Multiple combination and location of safety stock was evaluated.

Case 1: Safety Stock Results in Isolation: First optimum safety stock location while considering each

Sell Style was investigated. To find this the safety stock of each sell style in isolation was considered in each of the 5 location. From our analysis, it could be conculded that Stage2, which is the greige stage is the cheapest location to hold safety stock to achieve a 95% service level at the US-DC, which is the final echelon of Stylo's supply chain.

Case 2: Safety Stock Result for Single Stage Pooling: If the demand of the five SellStyles are pooled at just one location, results show that Stage2, once again, would be the cheapest location to hold safety stock. The cost amounts to $263,974.

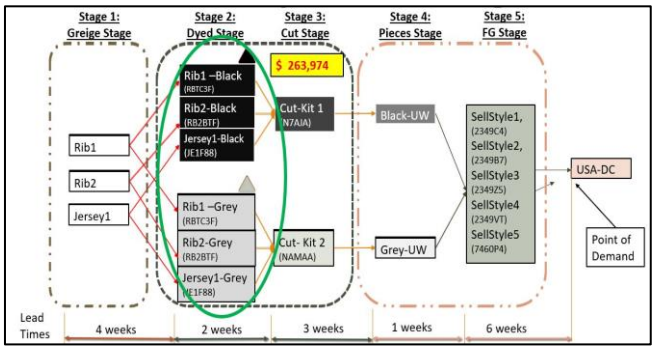

Figure 3: Single Stage Safety Stock Placement at the Greige Stage

Also as we go from Stage 5 to Stage 1 i.e. from downstream to upstream, CoV decreases due to pooling of SKUs. So it can be expected that lowest cost will be at the stage of lowest CoV, however the lowest safety stock cost from our calculation is at the Dyed Fabric Stage (Stage 2). This is because safety stock cost not only depends on standard deviation but also on the cost of holding the safety stock inventory. Figure 4 explicitly shows the safety stock cost and CoV at each stage of Stylo's supply chain and further, shows that though Stage 1 has a lower CoV than Stage 2, the safety stock cost at Stage 2 is the lowest.

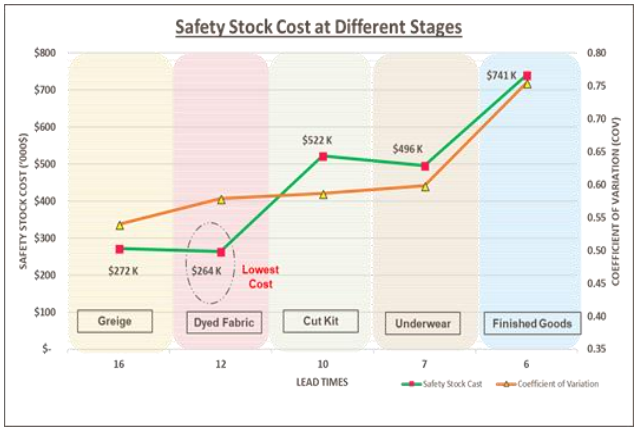

Figure 4: Safety Stock Cost of Single Stage Pooling

Case 3: Safety Stock Result by Pooling at Single Stage: Results show that when SellStyle2,3,4 are pooled at Stage2, and SellStyle1,5 are pooled at Stage1, it gives the low safety stock cost of $286,174. Also, pooling Selling Style at 1,2,3,4 at Dyed stage(Stage 4) and keeping Sell Style 5 in Greige stage (stage 5) has a safety stock cost of $283,068, but single stage pooling at Dyed Fabric stage (Stage 4) has the lowest Safety Stock of $263,974 as shown in Case 2.

Sensitivity Analysis

As there might be fluctuation in lead time in the third-party manufacturing facility, different combinations of lead times at the third party manufacturing stage has been considered to evaluate its effect on safety stock placement.

		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Lowest SS cost	Next Lowest
Scenario 1	LT	6	7	10	12	16		
	Stages	Pkg	UW	cut kit	dyed fabric	greige	$ 263,974	$ 271,879
Scenario 2	LT	6	7	10	12	15		
	Stages	Pkg	UW	cut kit	dyed fabric	greige	$ 263,245	$ 263,974
Scenario 3	LT	6	7	10	13	17		
	Stages	Pkg	UW	cut kit	dyed fabric	greige	$ 274,753	$ 280,246
Scenario 4	LT	6	7	10	13	16		
	Stages	Pkg	UW	cut kit	dyed fabric	greige	$ 271,879	$ 274,753
Scenario 5	LT	6	7	10	-U(12-13)	-U(16-17)		
	Stages	Pkg	UW	cut kit	dyed fabric	greige	$ 273,336	$ 274,753
Scenario 6	LT	6	7	10	-U(12-13.5)	-U(16-17.5)		
	Stages	Pkg	UW	cut kit	dyed fabric	greige	$ 280,438	$ 285,644

LT-Lead Times; UW-Underwear Stage; Pkg-Package Stage; SS-Safety Stock

Table 6: Shows the Lowest Cost Value and Lowest Cost Stage in Four Scenarios of Deterministic Lead Times and Two Scenarios of Variable Lead Time

After investigating multiple scenarios of deterministic and stochastic lead times it can be concluded that if the lead times from Greige to Dyed fabric stage takes 4 weeks at the third-party manufacturer's unit then the outbound warehouse of the third-party manufacturer is the optimum place to pool all the inventory to meet the desired service level of 95%, as shown in Scenarios 1,3,5,6. However, if the lead times from Greige to Dyed fabric stage is reduced to 3 weeks, then it is optimal to pool at the greige stage i.e as greige fabric before dying, as shown in Scenarios 2 and 4.

Conclusion

This research has evaluated different location of safety stock placements. Different pooling strategies were used to decide the lowest cost of safety stock for the desired service level. Also, as third-party manufacturers are outside Stylo's facility, sensitivity analysis for lead times of third-party manufacturers were performed. The following are some of the contributions we have made through our research.

Contribution 1: Location of Safety Stock Placement:
Results showed that the most upstream stage may not be where safety stock cost would be at its lowest. While it may have the lowest coefficient of variation compared to the rest, there may also be other factors, such as lead time and cost of material, that will affect safety stock cost and inventory placements.

Contribution 2: Setting Up a New Stage within the Manufacturing Process:
An outcome from this research shows that it might be a good idea to hold safety stock at the single piece undergarment stage, which is between the cut-kit and packaging process.

Contribution3: Instituting a Lean Supply Chain:
The sponsor company, Stylo, is presently holding inventory at their inbound stage in the form of dyed fabric. Unfortunately, the warehouse does not have optimal inventory for each SKU of the dyed fabric. The analysis conducted in this research can help the company keep optimal amount of inventory at the warehouse in the form of dyed fabric to meet its desired service level.

Limitations

Due to several limitations faced, the research has been simplified to a certain degree. Had these limitations been reduced or removed, the research could have provided a better result. The main limitations include time, software, and data. The inventory optimization was performed manually using MS Excel, MS Access and R programming. Moreover, there were inconsistencies in the data provided by the sponsor company and several components of the data had not been shared.

Future Research

This research has focused using only five out of 231 selling styles and two out of 150 colors. It would be interesting to know if there will be any significant changes to the result of this research if the number was increased. As a start, the company could perform a pilot project at a small scale, similar to what is being done in this research. Then, the model could slowly be expanded by increasing the number of SKUs and colors used in the analysis. At the same time, a projection in terms of financial impact could also be made based on the analysis performed.

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