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QUICK RESPONSE REPLENISHMENT: A CASE STUDY

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ABSTRACT

In this paper we document a case study based upon an on-going analysis for a U.S. fiber/fabric manufacturer who is expanding its operations vertically to include cut and sew operations in Mexico. We will refer to this Vertically Integrated Manufacturer as VIM in this paper. While some of the data have been changed to protect the sources, the story and results themselves are unchanged. More detail on this case can be found in Moon (1999).

1 INTRODUCTION TO THE PROBLEM

VIM is considering providing "full package" service to a "branded" customer (referred to as BC). BC owns the particular garment brands that they sell to retailers, however, they contract out the actual manufacture of the products. Recently, VIM has purchased cut and sew operations in Mexico and plans to partner these plants with its yarn facilities and fabric mills to provide, among other products, the manufacture of a line of jogging shorts for BC. The "full package" product is a relatively new concept to VIM, and thus some analysis is needed in order to weigh the benefits over the traditional practice and to determine how the manufacturer compares to its competitors.

Recent publications (King and Maddalena 1998 and King et al. 1999) have shown the potential benefits of in-season replenishment (Quick Response ordering) and VIM wanted to investigate this possibility. Due to long lead times, the competition is unable to provide this option, and VIM wants to use this fact to its advantage in the negotiation process.

The jogging shorts are offered in 2 styles, 6 colors, and 4 sizes and BC sells the shorts over a sixteen-week period to retailers from its stock inventory held in a distribution center. BC plans to sell the garment for about $9.00/unit. VIM's competitor is believed to offer the product to BC for $3.90/unit.

BC has developed a sales plan several months ahead of the selling season. This plan includes an estimate of: (1) the total demand (scaled to 10,000 units in this case), (2) the assortment mix, and the seasonality of retailer orders (relatively flat over the season). Historically this plan turns out to be on the order of plus/minus 35% in error on the total volume of demand, while the assortment mix error runs about on par with what we believe representative of many retailers (see King and Hunter 1997).

Based upon discussions with VIM it was established that the current lead time to produce and ship the final product (including fabric production and finishing, shipment to Mexico, scheduling backlog time, garment production, and shipment back to the United States) is fourteen weeks. This situation means that there is currently no opportunity for replenishment to BC. As evident from the desire to replenish based on in-season demand, VIM needs to reduce its lead time.

In order for VIM to even consider a Quick Response approach, some changes need to be made to the timing of its product flow. One potential area of improvement is the elimination of lead time that is tied up in production backlog. VIM does not want to run short of orders and risk idling resources so it queues up orders as a buffer. Currently, this buffer leads to a two-week delay to get onto the knitting machine schedule, two weeks for dyeing, and two weeks to get onto the cut-and-sew schedule. Elimination of this backlog is crucial to implementing a Quick Response system for short selling seasons.

No matter the strategy for replenishment, it is believed that at least 65% of the plan must be shipped by VIM prior to the start of the selling season and that there is no minimum for the amount replenished in-season, i.e., if sales are poor, BC can decide not replenish any SKUs.

2 OPERATING STRATEGIES

There are several options that exist for accomplishing the lead time reduction. Each is compared against the current fourteen-week lead time scenario (referred to as

Traditional) where all product is produced prior to the beginning of the selling season. The following is a description of the three strategies considered. Table 1 summarizes the lead times for each strategy.

Table 1: Lead Times for the Strategies

Stage	Traditional	Yarn Stock	Greige Stock	Dyed Reorder
Raw Material	n/a	n/a	3	5
Manufacture	13	7	4	2
Shipping to BC	1	1	1	1

2.1 Yarn Stock

The first option, Yarn Stock, calls for VIM to manufacture finished goods to order where raw materials are held in yarn form and has an eight-week lead time; seven weeks to manufacture (fabric knitting through cut and sew) and one to ship to BC. The yarns used in the product are commonly used across a large number of products and are produced to stock as it is more or less as a commodity. Thus, the supply of yarn is assumed to be "infinite".

2.2 Greige Stock

The second option, Greige Stock, calls for the manufacturer to produce greige (undyed/unfinished) fabric to stock and make to order from that point forward. It has a five-week lead time for finished goods (four weeks to dye, finish, ship to the Mexican cut and sew facility, and then cut/sew the order plus one to ship to BC) and a three-week lead time to restock greige fabric.

In the case of Greige Stock, the fabric is used for other products, however the potential for obsolescence is much greater than yarn. VIM is considering maintaining a stock of greige fabric inventory that can be drawn upon by all products requiring it. In this case, the inventory can be thought of as plentiful and effectively infinite. However, they also want to investigate allocating a portion of the inventory to this program. In this case, a restocking plan is needed.

2.3 Dyed Stock

The third option, Dyed Stock, calls for VIM to produce dyed/finished fabric to stock and make to order from that point forward. It has a three-week lead time for finished goods (two weeks to ship to the Mexican plant and cut/sew the order and then one week to ship to BC) and a five-week lead time to restock dyed fabric. Another option would be to make finished goods to stock, however VIM decided against considering this option.

If they decide on the Dyed Stock option, VIM wants to carefully control the amount of dyed stock inventory as it is the most costly and risky form of raw material.

3 SIMULATION STUDY

The Sourcing Simulator© (http://www.tc2.com) was used to run simulations of these different strategies. This Monte Carlo simulation tool was developed primarily to provide an instructional, hands-on tool for educators and retail buyers wishing to explore the impacts of a wide variety of ordering, demand re-estimation, reordering, and price markdown procedures, in both traditional and Quick Response settings. While originally a retailer tool, as its features have expanded, use by the manufacturing segment has increased. An important feature is that the user specifies the level of the errors inherent in a retail buyer's plan vis-à-vis true demand from the consumer. More information on the tool and fundamental underpinnings can be found in Nuttle, King and Hunter (1991), Hunter, King, and Nuttle (1992), Hunter, King, and Nuttle (1996), and Lowson, King and Hunter (1999).

For this analysis the following measures are used to evaluate performance: for BC: Gross Margin, Gross Margin Return on Inventory (GMROI) which is the gross margin divided by the average inventory investment, and Service Level % (% of customers who find their first choice garment); and for VIM: Gross Margin and Percent Shipped On-Time. The goal for this study is to determine the wholesale cost at which VIM should offer the shorts to BC and also a replenishment strategy for BC along with the raw material stocking policy.

All strategies are simulated as make to order for the finished goods production process over a range of forecast volume error from –35% to 35% from the planned volume of 10,000 units. For each of the strategies there are several ways for VIM to operate. In particular, the number and timing of replenishment orders to BC, the amount of initial shipment to BC, and the stocking policy for raw material are important considerations. Naturally these factors differ depending upon the strategy in question. This section describes the different factors that were adjusted.

3.1 Replenishment to BC

One of the main goals in this analysis is to allow for replenishment with in-season reorders. The question remains as to how many reorders are needed and are feasible for the manufacturer. While there are many possibilities, for each strategy, we illustrate the value of one replenishment order as well as weekly replenishment. The timing of these orders is dependent upon the strategy's manufacturing lead time. Replenishment after week 12 of the selling season is believed to be unrealistic. Given this, Table 2 shows the possible weeks that VIM could take a

replenishment order from BC and be able to manufacture and ship it before week 12. In what follows, reorder week refers to the week that a replenishment order from BC is sent to VIM. The delivery week then depends upon the lead time of the particular scenario.

Table 2: Potential Weeks to Take Replenishment Order

YARN STOCK	GREIGE STOCK	DYED STOCK
1 - 4	1 - 7	1 - 9

3.2 Initial Offering

For the Quick Response simulation runs, the amount of initial inventory offering is variable. For the one reorder case, the amount of inventory sent to BC to start the season was set at the larger of 65% of the total seasonal plan (6500 units) and the 25% more than the expected demand until the delivery of the first in-season reorder. In order words, the initial inventory is at least 65% of the planned level of demand. For example, assume the first reorder delivery is scheduled to arrive at the end of week 8. Since the seasonality of retailer sales is flat, during period of time before the delivery 50% of the season's demand is expected to occur, i.e., 5000 units. Increasing this by 25% yields 6,250. Since this is less than 65%, the initial inventory is set to 6,500 units.

Figure 1 shows the level of initial inventory for each strategy for each possible reorder week for the one replenishment order case.

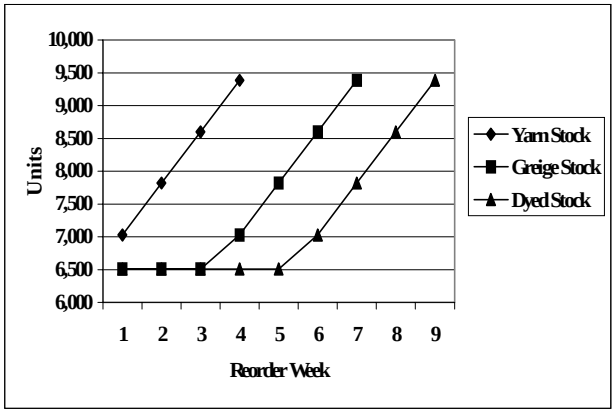

Figure 1: Initial Inventory for Different Reorder Weeks

For weekly replenishment, the initial inventory was set to 6,500 units.

3.3 Raw Material Stocking Policy

The amount of starting raw material inventory, the number of times the raw material should be replenished and the target inventory level are important to the ultimate success of the program. Since garments are made to order, the timing of replenishment orders from BC determine the possible times when raw material should be restocked.

In terms of BC's ability to fill its orders, the best option would be for VIM to carry enough raw material to meet virtually any level of garment production. This may make sense depending upon the form of the raw material. As mentioned earlier, the yarns required for this product are basically a commodity such that there is effectively always yarn available. Similarly although somewhat less so, the fabric is used in other products. However, once dyed, fabric is allocated to the program and excesses must be "eaten."

The cost of raw material depends upon its form: (1) Yarn Stock costs about $1.00 to produce, (2) Greige Stock costs about $1.60, and (3) Dyed Stock costs about $2.60 per inventory unit. (All costs have been scaled to $1.00 for yarn.)

In order to understand the important role of having the correct raw material on-hand, in the results that follow we consider the case of "perfect raw material supply" as well as not. The perfect supply case provides an upper bound on performance.

In the case of "imperfect supply," we consider the following questions: (1) how much raw material is necessary to achieve a more or less "perfect supply" and what are the cost consequences and (2) if the supply is not perfect, what is the corresponding decrease in performance?

For convenience, inventory is expressed in finished goods units, i.e., one unit of raw material (no matter the form) is enough to produce one finished good unit.

4 RESULTS AND ANALYSIS

The following subsections report the results of simulation of the various strategies for one and weekly BC replenishment. All values reported represent the average over the range of forecast volume error (±35%). The number of simulation replications for each forecast error level was set such that any apparent differences are statistically significant.

4.1 BC Performance

We first look at the value of replenishment to BC based upon PoS data. In the sections that follow we look at the impact of one and weekly reorders.

4.1.1 One Replenishment Order

As previously stated, the performance measures for BC include Gross Margin, GMROI, and Service Level %. Figures 2, 3, and 4, show the impact on these performance measures, respectively, for each strategy for each possible

week of reorder. In each case, the value corresponding to the Traditional case is also displayed for comparison.

Figure 2 shows a clear improvement in Gross Margin over the traditional case in all strategies tested. The best week to reorder depends upon the particular strategy, however, in general, this reorder should be made very early in the season. While more weeks of PoS data improve the quality of the reorder, it is clear that it is important to replenish BC's stock as quickly as possible to overcome in the initial assortment mix error. In the case of Dyed Stock, its relatively short lead time allows time to gather two weeks of PoS data before reordering.

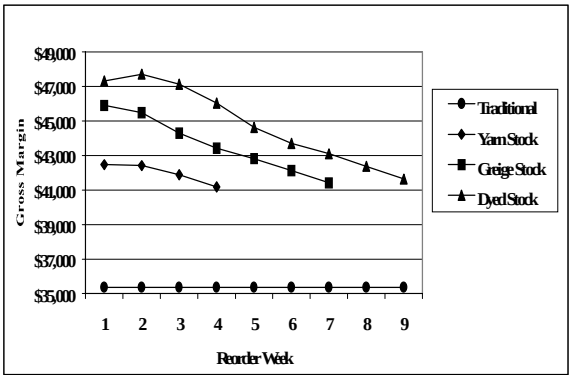

Figure 2: Impact of Reorder Week on Gross Margin

The "best of breed" for the Yarn Stock, Greige Stock and Dyed Stock cases represent about a 20%, 30%, and 35% improvement in Gross Margin over the Traditional (no replenishment case).

Figure 3 shows the impact of the reorder week on GMROI. GMROI advocates delaying the reorder a few weeks for Greige and Dyed Stock. Under all options, performance is far superior to Traditional. To understand this we need to look at the components of the GMROI calculation. Recall that GMROI is the Gross Margin divided by the average inventory investment. In general, more initial inventory leads to higher average inventory investment that, in turn, has the effect of reducing the GMROI. In contrast, delaying the receipt of replenishment leads to lower average inventory levels which, would tend to increase GMROI. Thus, it is not immediately clear whether carrying more initial inventory and delaying the reorder will have a positive or negative impact on GMROI. However, as shown in Figure 2, later reorders lead to lower Gross Margin. In the Yarn Stock case, the negative impact on GMROI due to the decrease in Gross Margin and increased initial inventory with later reorder weeks dominates. However, notice with Greige Stock and Dyed Stock, GMROI increases with week of reorder until weeks 3 and 5, respectively, thereafter there is a downward trend. A quick glance at Figure 1 shows that the initial inventory is 65% of plan up until these weeks, thereafter it increases. Thus, the lower inventory investment overcomes the general decrease in Gross Margin in the early weeks.

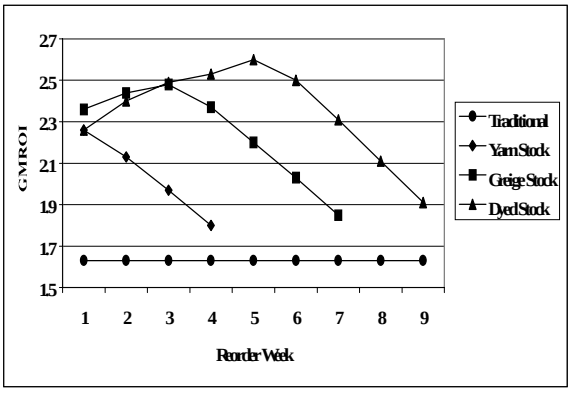

Figure 3: Impact of Reorder Week on GMROI

Service Level (Figure 4) follows the same basic trend as Gross Margin, i.e., reordering early leads to a service level in the 85-95% range which is significantly better than the roughly 73% for Traditional.

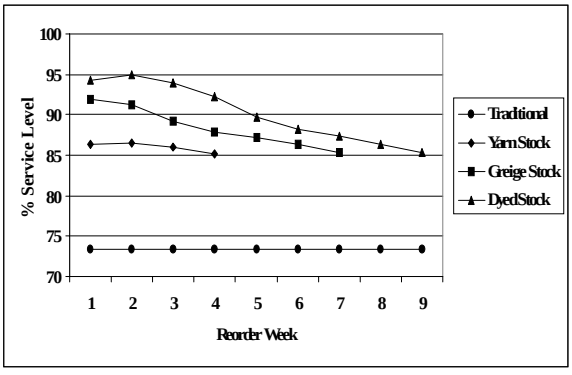

Figure 4: Impact of Reorder Week on % Service Level

4.1.2 Weekly Replenishment

In Figures 5, 6, and 7, the impact of allowing weekly replenishment is displayed for the performance measures. In each case, the value corresponding to the "best of breed" for the one reorder case as well as the Traditional case is also displayed for comparison. Figure 5 shows that weekly reorders yield higher Gross Margins, however the increase over one reorder is only 1%, 3%, and 4%, respectively for the Yarn Stock, Greige Stock and Dyed Stock options. Weekly reorders reduce inventory investment and can have a significant impact on GMROI. Figure 6 clearly shows this effect. Service level (Figure 7) shows the slightly better stocking position that leads to the improvement in Gross Margin shown in Figure 5.

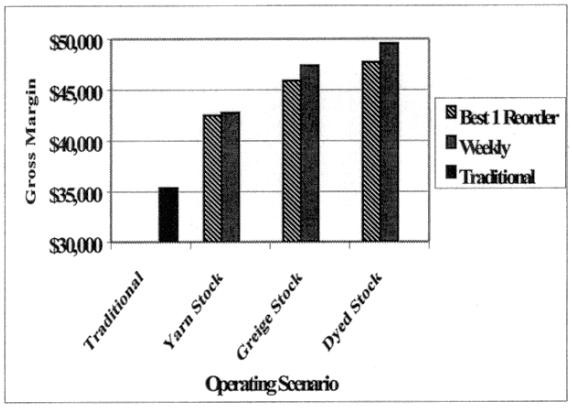

Figure 5: Comparison of Gross Margin for Weekly vs. One Reorder

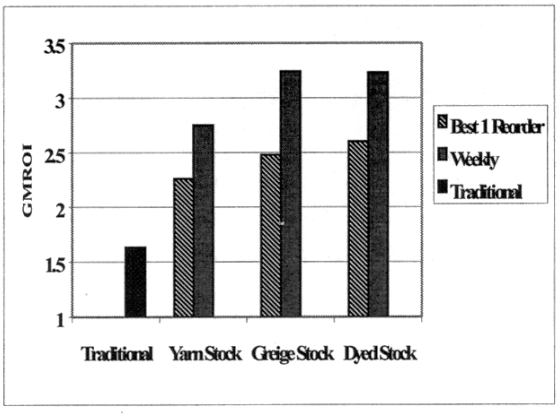

Figure 6: Comparison of GMROI for Weekly vs. One Reorder

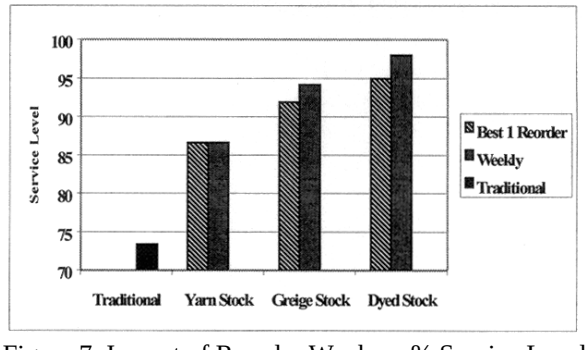

Figure 7: Impact of Reorder Week on % Service Level

4.2 VIM Performance

In order to analyze the potential for VIM we consider the raw material stocking policies discussed earlier. In particular, we first consider VIM's Gross Margin under the assumption that they are able to have a "perfect supply" of raw material and consider the cost of having it. In following sections we look at VIM's Gross Margin when they replenish the raw material. We also look at the different scenarios' effects on On-Time Shipment Percentage.

4.2.1 Gross Margin with Perfect Supply of Raw Material

Figure 8 shows the Gross Margin for VIM under the various options assuming a perfect supply of raw material, i.e., exactly the raw material that is necessary is produced, no more, no less. This is obviously an upper bound on performance for VIM. Notice that compared with Traditional, these values represent about a 10% increase in Gross Margin for VIM. Compared to BC's Gross Margin where Dyed Stock with weekly reorders is preferred, for VIM, Yarn Stock with a single reorder yields the best results. The reason is that, in general, the demand re-estimation algorithm tends to somewhat over-estimate demand early in the season, and moving from Yarn Stock towards Dyed Stock results in fewer goods being ordered by BC and, thus, lower margin for VIM.

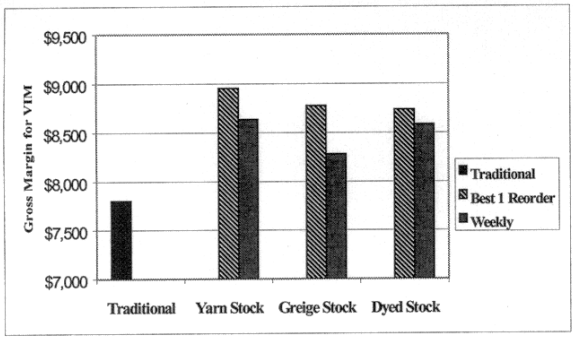

Figure 8: Gross Margin Potential for VIM

A natural question is "How much initial inventory is necessary to achieve a perfect supply?" We answer this in two parts. First, if the raw material inventory must be produced prior the season, how much is needed? Figures 9 and 10 answer this question for various scenarios.

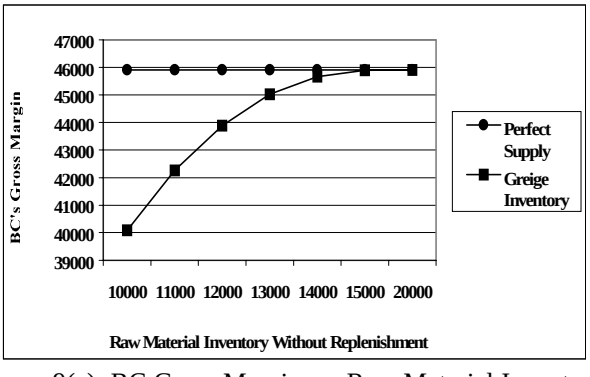

Figure 9(a): BC Gross Margin vs. Raw Material Inventory: Single Reorder from Greige Stock

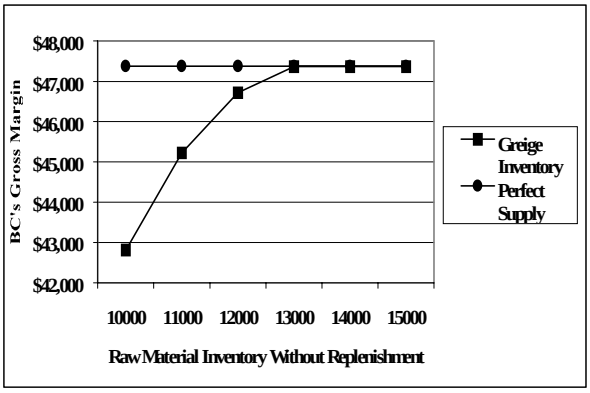

Figure 9(b): BC Gross Margin vs. Raw Material Inventory: Weekly Reorders from Greige Stock

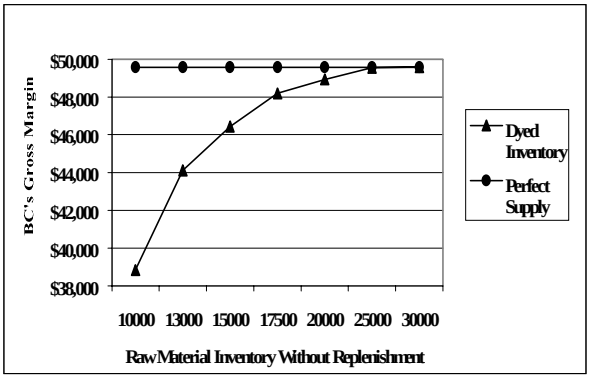

Figure 10(a): BC Gross Margin vs. Raw Material Inventory: Single Reorder from Dyed Stock

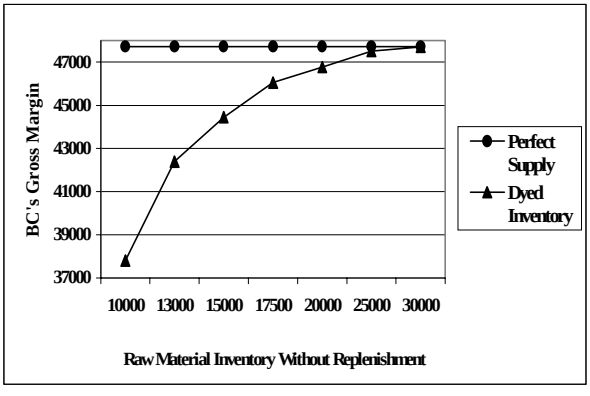

Figure 10(b): BC Gross Margin vs. Raw Material Inventory: Weekly Reorders from Dyed Stock

The Yarn Stock cases are not shown as they look just like the Greige Stock case. This is because Yarn Stock, like Greige Stock, can be differentiated into any SKU, thus the amount of inventory to achieve a "perfect supply" is the same. However, once dyed, the raw material can be easily used to produce SKUs in some other color. Therefore, more initial inventory is necessary to achieve a "perfect supply." For the Dyed Stock case with a single reorder occurring in week 2, VIM would need to carry approximately 25,000 units of dyed fabric or over twice as much in order to match BC's Gross Margin in the "perfect supply" case. This is necessary to cover the range of error but would make the whole program totally unprofitable. Even in the best case, VIM's profitability is only marginal.

4.2.2 Raw Material Replenishment

Another option is to start with some nominal level of initial inventory and then replenish it after PoS data has been observed. With a single reorder to BC, due to the lead times, this would require that the replenishment of garments to BC be delayed to allow time to produce more raw material and then convert it to garments. However, the advantage of this option is that the initial raw material need only be enough to cover the initial garment shipment to BC. Table 3 shows the Gross Margin for the three cases. The BC Gross Margin values attained are within 3% of those of the "perfect supply" cases.

With weekly BC reorders, the initial raw material inventory must cover the initial garment shipment to BC plus enough to cover the first few BC reorders that must be produced before there is time to replenish the raw material. In the Greige Stock case, the raw material lead time is 2 weeks, so first raw material reorder would not be available until week 4 of the selling season. For Dyed Stock this is week 6.

Table 3: Gross Margins with In-Season Raw Material Replenishment

Raw Material Reorder Week	BC Replenishment Week	BC Gross Margin	VIM Gross Margin
YARN STOCK			
2	2	$42,203	$7,903
3	3	$41,802	$8,174
4	4	$41,098	$8,479
GREIGE STOCK			
2	4	$42,536	$8,175
3	5	$40,842	$7,824
4	6	$38,855	$7,398
DYED STOCK			
2	6	$42,500	$6,381
3	7	$40,969	$5,827
4	8	$39,027	$5,148

Figures 11, 12 and 13 show the impact on BC's and VIM's Gross Margin for various levels of initial commitment of raw material for the Greige Stock , Dyed Stock cases and Yarn Stock cases, respectively. Notice that the ability to shape the raw material inventory based on PoS data allows both to achieve performance very close to that of "perfect supply." Greige Stock would be preferred by VIM while Dyed Stock would be preferred by BC.

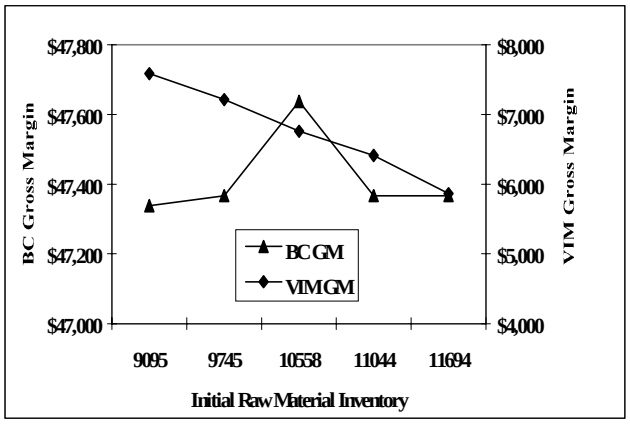

Figure 11: BC and VIM Gross Margin vs. Initial Raw Material Inventory: Weekly Reorders from Greige Stock

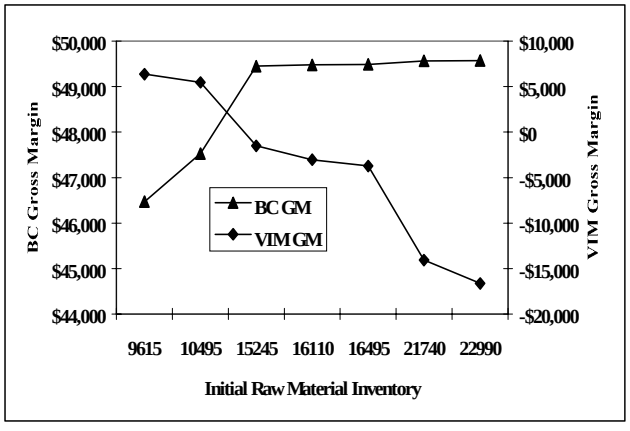

Figure 12: BC and VIM Gross Margin vs. Initial Raw Material Inventory: Weekly Reorders from Dyed Stock

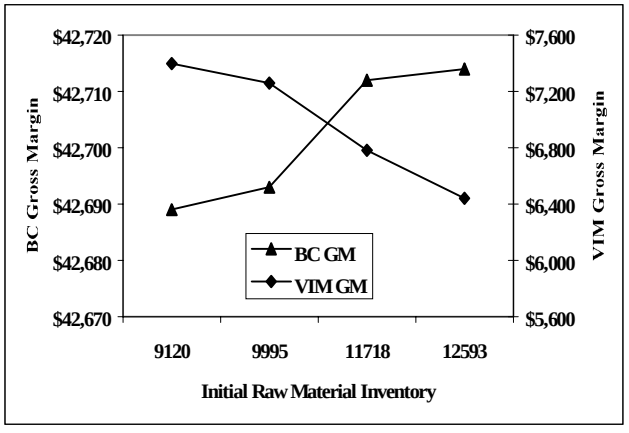

Figure 13: BC and VIM Gross Margin vs. Initial Raw Material Inventory: Weekly Reorders from Yarn Stock

4.2.3 On-Time Shipment Percentage

Another area of concern for VIM and BC is the ability of VIM to make its shipments in a timely manner. In the situations where there is no raw material replenishment, under the Yarn Stock case VIM ships 98.9% of its finished goods on time with an initial raw material level of 13,000 and increases to 99.9% with 15,000 units. Greige Stock fares similarly with an on-time percentage of 99.9% at 13,000 units. With 17,500 units of raw material, Dyed Stock results in an on-time shipment percentage of 97.3% and this increases to 99.8% at 25,000 units. Clearly, the inventory levels that result in the maximum Gross Margin for BC also result in extremely high on-time shipment for VIM.

We also looked at the on-time shipment percentages for situations in which raw material replenishment occurred. With just one replenishment, all situations had percentages well above 99%. Almost all weekly replenishment strategies returned on-time shipment percentages of greater than 99% as well.

4.3 Break Even Analysis

A natural question that follows then is: How much more per unit could BC afford to pay VIM and yet still attain a Gross Margin at the same level as that of Traditional? Figure 14 shows this in terms of the percentage increase over the base cost of $3.90. For example, for weekly reorders under the Greige Stock option, BC could pay VIM nearly 30% more per garment than under the Traditional case. All values reflect the use of BC's Gross Margin under perfect raw material supply and as such represent an upper bound.

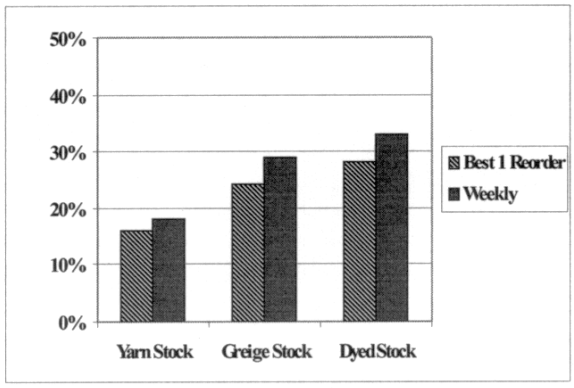

Figure 14: Breakeven Analysis

Table 4 shows breakeven values for different levels of raw material ordered in the cases where there is no raw material replenishment. Yarn, Greige, and Dyed stocks are all represented.

As shown in Table 4, BC could pay VIM up to 16.9% more per unit under Yarn Stock, up to 29% more per unit under Greige stock, and up to 33% more per unit under Dyed Stock. When comparing just a raw material

Table 4: Breakeven Percentage Increase in Wholesale Cost with No Raw Material Replenishment

YARN						
	10,000	**11,000**	**12,000**	**13,000**	**14,000**	**15,000**
Weekly	14.1	15.9	16.7	16.9	16.9	16.9
Best 1	5.1	9.2	12.5	14.1	15.4	15.9
GREIGE						
	10,000	**11,000**	**12,000**	**13,000**	**14,000**	**15,000**
Weekly	20	25.1	27.95	28.97	28.97	28.97
Best 1	12.6	17.2	20.5	22.6	23.6	24.1

DYED							
	10,000	**13,000**	**15,000**	**17,500**	**20,000**	**25,000**	**30,000**
Weekly	10.3	22.8	27.4	30.8	32.1	33.1	33.1
Best 1	7.2	18.2	22.6	25.4	26.7	28	28.2

inventory of 10,000 units, which is what is ordered under the Traditional case, BC can still pay VIM between 5% and 12.56% more with one finished goods reorder and between 10.26% and 20% more with weekly finished goods reorders while still achieving the same Gross Margin as it would in the Traditional case.

Finally, under replenishment of the raw material the breakeven points are only slightly less than those of shown in Figure 14.

5 SUMMARY

Determining one strategy to use over the others is not an easy decision. The results show that the use of shared PoS data can lead to both parties achieving Gross Margins near those of a "perfect supply" system. However, it is obvious that whatever strategy is chosen, the results are significantly greater than those of traditional supply.

At the time of writing, no decisions have yet been made as the negotiation process is only just beginning. Clearly there are tradeoffs in terms of risk. For BC, the shortest lead time with weekly reorders allow for the least risk from their vantage, however, this requires that VIM assume risk in potentially obsolete raw material. The tables are turned under the Yarn Stock option. Greige Stock may be a happy medium depending upon the overall level of uncertainty across products using this fabric.

Questions that still need to be addressed include the following.

- What are the logistics costs associated with in-season replenishment?
- VIM is also assuming risk in terms of the level of replenishment. It is possible that capacity booked for this program in order to eliminate scheduling backlog may go unused. Are there other products that can be brought in under such situations and what are the implications in terms of raw materials to support such a move?
- Are there advantages to elimination of BC's distribution center from the product flow and have VIM ship directly to BC's customers and what are the ramifications of such a policy?

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