NC STATE UNIVERSITY

JTATM

JOURNAL OF TEXTILE AND APPAREL, TECHNOLOGY AND MANAGEMENT

Volume 2, Issue 3, Summer 2002

MANAGING ERRATIC DEMAND: THE MULTI-CHANNEL MANUFACTURING APPROACH

Dennis J. Kulonda

University of Central Florida
Dept Of Industrial Engineering And Management Systems

ABSTRACT

Contemporary cellular approaches to the development of manufacturing architectures based upon lean manufacturing concepts are often hindered or prevented by the lack of a smooth regular demand for products. This is frequently the case in apparel manufacturing where demand is erratic because of the high variety of end items and the fickleness of fashion markets.

Multi-Channel Manufacturing (MCM) is an approach to cell development, which examines first the market channel requirements and configures cells based upon common customer service requirements. This paper describes the MCM approach and presents an application study in the apparel industry. Working through the case example, the paper describes the application of three MCM principles in seven specific application steps. The resulting revised system provides better customer service and reduced inventories albeit at some potential sacrifice in direct labor efficiency. Like other cellular designs, refinement of the system is a continual process. The paper illustrates trade-off's and extensions of the system to improve efficiency and performance. It has immediate applicability to apparel manufacturing.

KEY WORDS: Multi-Channel Manufacturing, JIT, Lean manufacturing, Quick Response, Erratic Demand

MANAGING ERRATIC DEMAND: THE MULTI-CHANNEL MANUFACTURING APPROACH

The purpose of this paper is to describe an approach to achieving a high performance manufacturing system in a difficult operating environment. Despite many constructive ideals in just-in-time (Ohno,1988), lean manufacturing (Womack and Jones, 1996) and world class manufacturing (Schonberger,1986), implementation on the factory floor remains fraught with pitfalls. In particular, erratic demand, defined as demand that exhibits no discernable pattern and high day-to-day variability, is not well handled by these techniques. Other barriers not easily resolved by continuous improvement programs include: high variety of outputs, processes which are inherently batch by nature, limitations on setup flexibility, and expensive capital equipment. Recognition of these difficulties caused Zipkin(1991) to coin the phrases "romantic JIT" and "pragmatic JIT" to differentiate the gap between ideals and reality. Multi-Channel Manufacturing is an approach to closing this gap through a structured approach to the re-engineering of manufacturing systems, particularly those encumbered by erratic customer demand.

Closing the Gap with Multi-Channel Manufacturing

Womack and Jones (1996,pp. 15-28) list five elements of Lean Manufacturing: identification of a value stream, elimination of waste, creation of a flow process through value-adding steps, use of pull systems and pursuit of perfection. These are conceptually the same tenets espoused in JIT by Ohno(1988) and in World Class Manufacturing by Schonberger(1986). Therefore, this paper groups the three as synonyms under the lean manufacturing (LM) umbrella. All LM solutions requires level selling in order to create level scheduling and a smooth flow (Womack and Jones (1996, p.81). Pursuit of perfection requires reduction of uncertainty through improved quality, less downtime and faster error resolution. When erratic demand cannot be assumed away or changed, LM solutions are a poor fit with the reality of the situation. Suri (1999, p330) illustrates the impracticality of pull systems in such an environment.

MRP systems are likewise a poor fit for producers facing erratic demand. It is amazing that MRP systems continue to be applied in situations where fast response is coupled with a high variety of outputs. Kulonda (2001) shows that these circumstances are not well-matched with the capabilities of MRP. One reason is that frequent changes to the master schedule amplify oscillations and cause untenable swings on the factory floor. Additionally, the forecasting models embedded within MRP systems to process independent demand typically require too much aggregation across SKUs to be useful.

Quick Response (Suri,1998) methods are philosophically aligned but offer little concrete guidance on mechanisms to cope with erratic demand and high variety of output. They primarily focus on deferment of final form until demand materializes. Quick Response clearly specifies the goal of first meeting customer quantity requirements but then focuses on cellular arrangements to assist in lead time reduction in order to complete the final product to order.

As introduced in this paper, Multi-Channel manufacturing (MCM) is a composite approach that is not intended to replace any of the above but rather to extend their capability by separating issues and employing best of breed strategies to develop a sound manufacturing system. This paper first describes the principles underlying MCM and then provides a realistic scenario with a variety of the manufacturing complications that affect implementation of manufacturing solutions. Finally, a case example is provided to illustrate how Multi-Channel Manufacturing has been applied to resolve the issues that arise from the manufacturing circumstances in the scenario.

Principles of Multi-Channel Manufacturing

Following are the principles which underlie Multi-Channel Manufacturing.

Divide to conquer. Uniformity often sounds desirable, yet it seldom results in systems which fit all the needs in an organization. Many factories have grown around a specific product/process culture based on internal considerations. Their products are sold to a wide variety of customers with different needs. A bearing manufacturer may produce bearings for automobiles, farm implements, machinery, and aerospace. Each customer has different needs that may not be well-served by a uniform system, for example, one based upon a common ERP system. Instead, MCM proposes a division into sub-factories, each focused upon the needs of a single market channel to circumvent the "one size fits all" syndrome.

Focus on customer response time first and then upon waste elimination. Systems which face erratic demand often end up relying on high levels of finished inventories to meet customer requirements. Substituting capacity for inventory lowers utilization of capacity
but may be the only way to reduce inventory while improving customer service.

System decisions must be based upon rational tradeoffs rather than steadfast adherence to a single dimension of performance. The distinction between romantic JIT and pragmatic JIT articulates this concept. Many of the obstacles to the accomplishment of ideal systems result from the economic realities imposed by past decisions. Pursuit of uncertainty resolution, stable flow, elimination of waste, customer satisfaction, inventory reduction, etc., remain objectives for continual improvement. Such instantaneous transformations of existing systems with attendant capital equipment and infrastructural investments is available only in ideal worlds.

Application steps

MCM is a composite approach which applies a sequence of steps beginning with meeting end customer requirements and then progressing backward to the point of beginning supply. Major steps in the process are:

1. Separate confounded demand streams by creating product families t match manufacturing capability to customer requirements by market channel.

2. Replace inventories with multiple focused sub-factories with responsive make-to-order systems tailored to its particular channel.

3. Use cellular design in each sub-factory to reduce work in process and cycle times as appropriate to manufacturing circumstances.

4. Use controlled release and a constant WIP to maintain short throughput times in any coupled non-cellular operations.

5. Use deferment strategies to replace finished goods inventories with intermediate inventories.

6. Eliminate wasted resources by developing flexibility to respond to remaining demand variation.

7. Work backward to replace any intermediate inventories with quick response systems to replenish them in small lots or eliminate them if consistent with customer

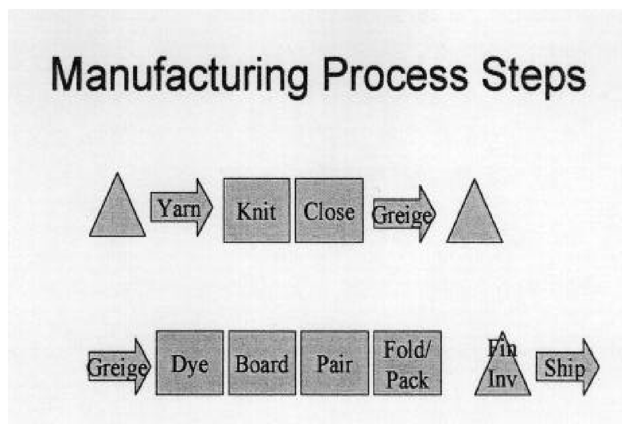

Figure 1 Functional Process Flow

An Application Scenario

Applying these steps and principles to the design (or re-design) of a specific manufacturing system requires an identification of priorities and tradeoffs among conflicting objectives. To illustrate the implementation issues, consider the realities encountered in a hosiery mill. The basic process flow for a mill is shown in Figure 1 and current practice to operate the mill is described below.

As diagrammed in Figure 1, yarn is knit into tubes on relatively expensive automatic knitting machines that are operated 24 hours per day, seven days per week. One operator tends many machines. Typical industry practice is to provide machine knitting capacity at the minimal amount necessary to produce annual requirements at a uniform annual rate. After knitting, the closing operation is a labor- intensive process that operates at a much faster rate than an individual knitting machine. Batches of knit goods are queued ahead of closing and closed tubes (greige goods) are inventoried and withdrawn as needed for dyeing to meet upstream demands.

Dyeing is performed in vats and is inherently a batch process. To compound difficulties, dye formulas often need adjustments to achieve exact color matching and vat production sequences must proceed from lighter shades to darker ones. The next operation, boarding is a heat setting process using large ovens with a continuous belt moving metal hosiery forms, called boards, through the oven for a specified drying time duration. One item, necessarily in a batch, is boarded using each of several belts. Because of the heat generated, boarding is isolated in one part of the mill. Inspection and matching in pairs follows boarding with the resulting output identified as being in the "longfold" state. Longfold items are subsequently final folded and packaged to a variety of specifications.

This manufacturing system currently operates by attempting to forecast product sales and building speculative inventories in batches to meet customer needs for ship-from-stock items. These include many kinds of final items: work socks, athletic socks, fashion items, ski socks, baseball socks. Demands for such items are both erratic and seasonal. Some custom items are made to order upon receipt of a customer order. Starting with less than 100 different yarns, finished items are made in several hundred different styles with as many as 20 colors per style and as many as ten different packaging variations. This creates more than 30,000 final SKUs, with a wide range of demand for each. Figure 2 shows an example of the variation in quantity ordered per day on the line coded as *actual* in the graph. The line coded *forecast* is explained later.

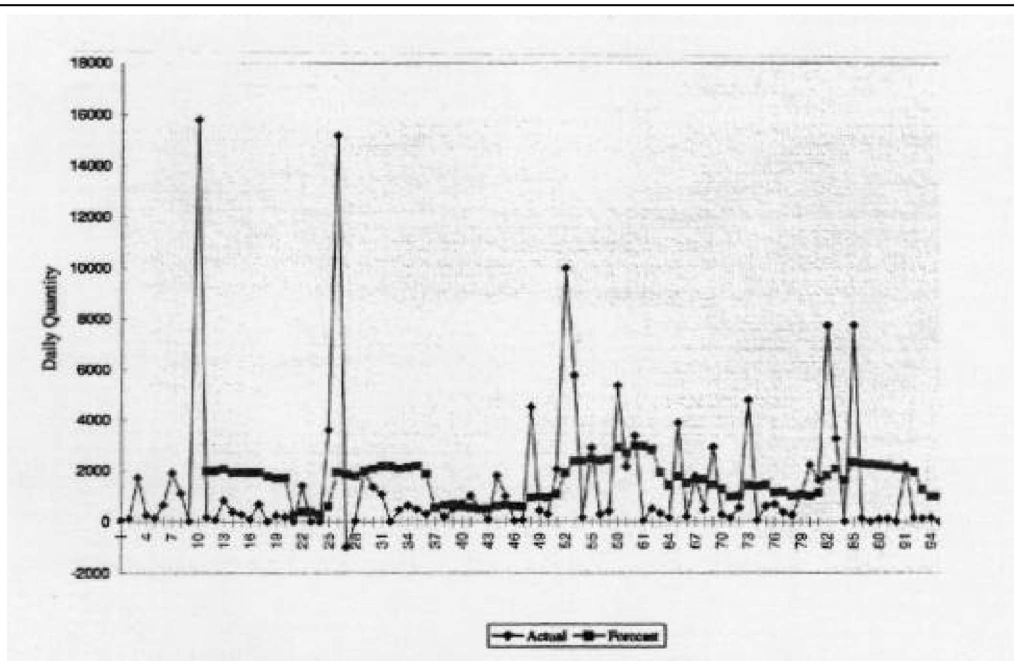

Figure 2 Example Daily Demand

Finally, the company in the scenario intends to implement an MRP II software package to integrate forecasting, inventory management, master scheduling, and materials planning with their financial systems in order to improve company performance. The next section of the paper describes how MCM concepts are applied in a series of steps to rationalize and streamline the manufacturing system

Applying MCM steps to the application scenario

The application scenario described above is drawn from an actual case that presents a range of implementation difficulties including erratic demand. This section demonstrates the application of MCM Principles to the resolution of those difficulties in developing a new system design. Since the time of this case it has become apparent that MCM principles are applicable to a wider range of situations that must serve erratic demands. This section will illustrate the MCM steps utilized to develop a new manufacturing system for this application scenario. Extension and generalization of these steps to other systems is explained later in the paper.

STEP 1 Create product families by market channel

The product array can be resolved as follows:

Table I Product Families

Family Category	Response Time	Channel	Production Strategy
Catalog Items	3 days	Company Brand	Flexpath
Standard Item Tailored packaging	11 days	Large Retail Chains	Fastpath
Private Product and Private Package	4 weeks	Contract Manufacturer	Fastpath

As shown above, each product family has different channels, each with a required response time. Each channel is mapped to a specific production strategy applying MCM principles. The two strategies here called Flexpath and Fastpath have different properties as explained below.

STEP 2 Create a focused sub-factory for each channel

Flexpath is a short cycle package-to-order arrangement, which fills catalog item orders in the required three days. The revised process steps are shown in Figure 3.

Physically the addition of the Flexpath channel requires a detour, as paired goods are ready for final folding and packing. Instead, these goods are left in the longfold state and stored in pick racks for final packing and shipping when an appropriate customer order requires them. From a timing perspective, customer orders received on day one can be pulled from inventory on the evening shift and staged for final pack and fold during the next day. Thus when small orders are received, they are merely packed to order rather than withdrawn from finished stock. This eliminates the need for prepackaged goods in each variety of packing style while providing next day service, a cut above the three-day target. In fact the longfold inventory would logically be stored in the distribution center. Space for several fold/pack workcells would be required but easily accommodated as

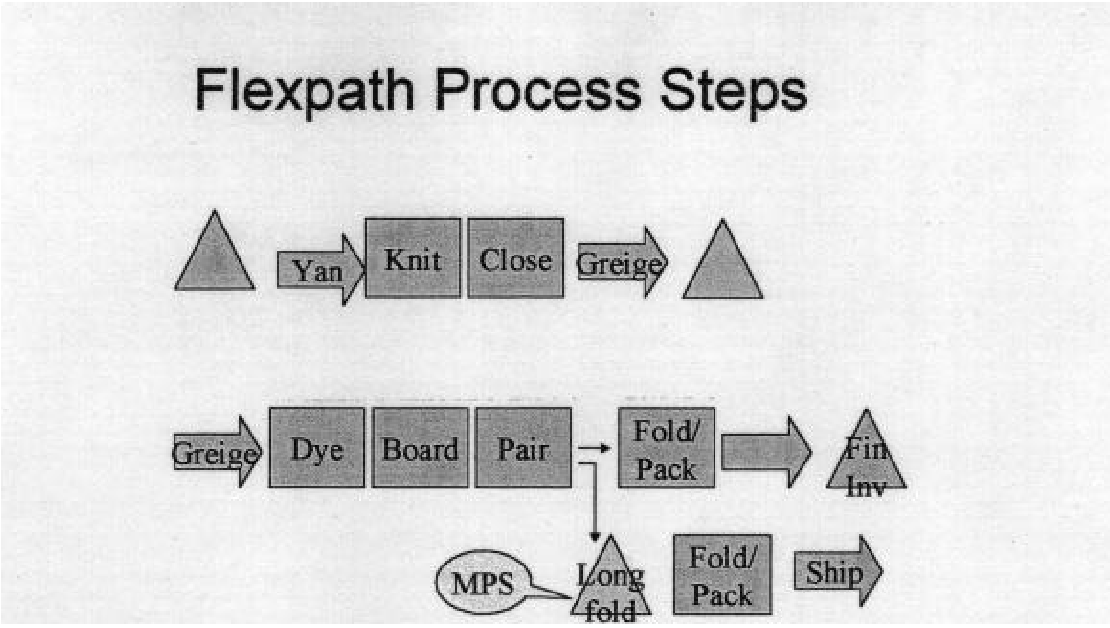

Figure 3 Process Revision for Flexpath

finished goods storage space declines as existing finished goods are gradually used but not replenished.

Note that the information system will require a longfold item master (and item number) in order to generate the required pull tickets upon order receipt. Additionally, master production scheduling (MPS) for longfold replenishment would have to occur at the longfold level. This would generate available-to-promise information at the longfold level rather than the end item level. This causes no particular difficulty so long as the packaging components are inexpensive and easily kept in abundant supply so that a multi-item available to promise statistic is not required.

Fastpath

The Fastpath process is designed to attain rapid finishing of higher volume items directly from greige goods inventory. Coupled with controlled release of finishing orders, the system can be designed to perform well within the 11 day target for large retailers, thereby eliminating the need to stock finished items to support their requirements. A schematic of the modifications to the process is shown in Figure 4 below.

STEP 3 Use cellular design to reduce in-process inventory and cycle times.

The Fastpath channel is constructed by creating and connecting workcells in boarding, pairing, folding and packing so that no inventory is accumulated between these processes. Dyeing, essentially a batch operation sensitive to environmental conditions as well as color sequencing requirements, is essentially decoupled from the cells.

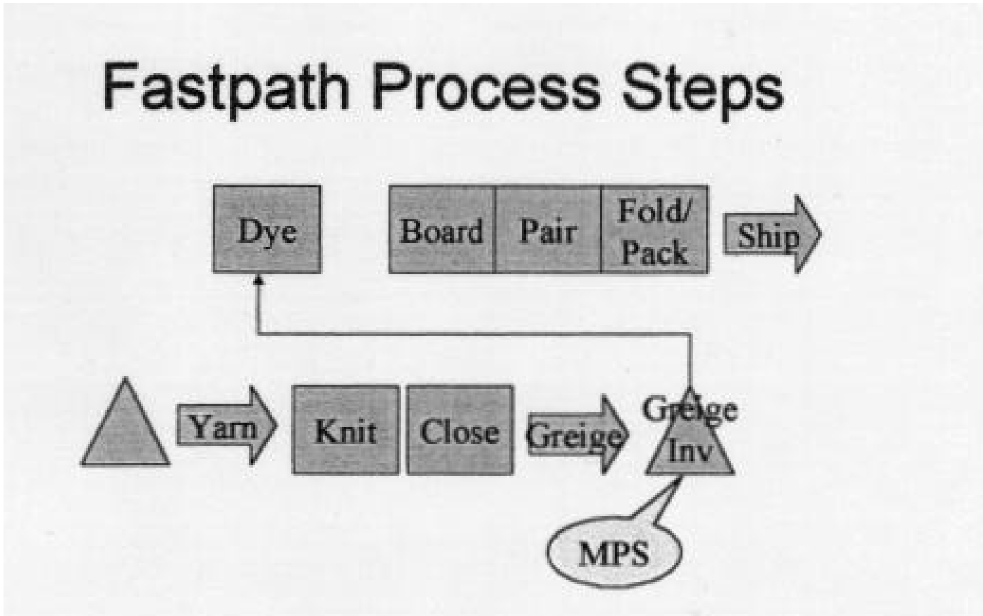

Figure 4 Process Revision for Fastpath Items

STEP 4 Use controlled release and a constant WIP to maintain short throughput times in any coupled non-cellular operations.

The impact of this decoupling can be mitigated by allowing a one-day float between dyeing and the newly created cells. The time allowed for dyeing could be as short as two days but longer allowances permit greater staging flexibility and hence dye cost economy. Initially a float of 4 days is a reasonable starting point. Dyeing is the bottleneck process since the cells require simple equipment and can be manned to the level necessary to finish dyehouse output on short notice. Allowing 2 days to complete finishing and movement to the shipping/distribution center implies a total process time of 7days well within the 11-day target.

As in the Flexpath design, these arrangements have important implications for the MRP II system. For example, customer orders for Fastpath items must be filled at the greige goods level and order promising is based upon greige availability. This is reasonable in that independent demand now exists at the greige goods level; however the system must have a way to generate shipping paperwork based upon an end item number as used by the customer in ordering. The net result is that some kind of order explosion is required at order entry to release both the shop order to produce the end item and the shipping paperwork. Further for Fastpath items, longfold levels will need to be identified as pseudo items to avoid shop orders and material issues from inventory to move items from pairing to packing within the integrated cell. If channel switching is used then a single longfold item is sometimes a stockable item and sometimes a phantom. Again typical software packages will not readily accommodate this nuance.

STEP 5 Use deferment strategies to replace finished goods inventories with intermediate inventories.

When both Flexpath (first) and Fastpath (second) are implemented, the multi-channel arrangement follows the schematic shown in Figure 5 below. As shown in this diagram:

- There is no finished goods inventory.
- All manufacturing follows one of the two paths.
- Longfold inventory for the Flexpath is replenished via Fastpath.
- Replenishment orders compete with customer orders for capacity in the Fastpath channel.
- Master scheduling for Fastpath orders is performed at the greige goods level.

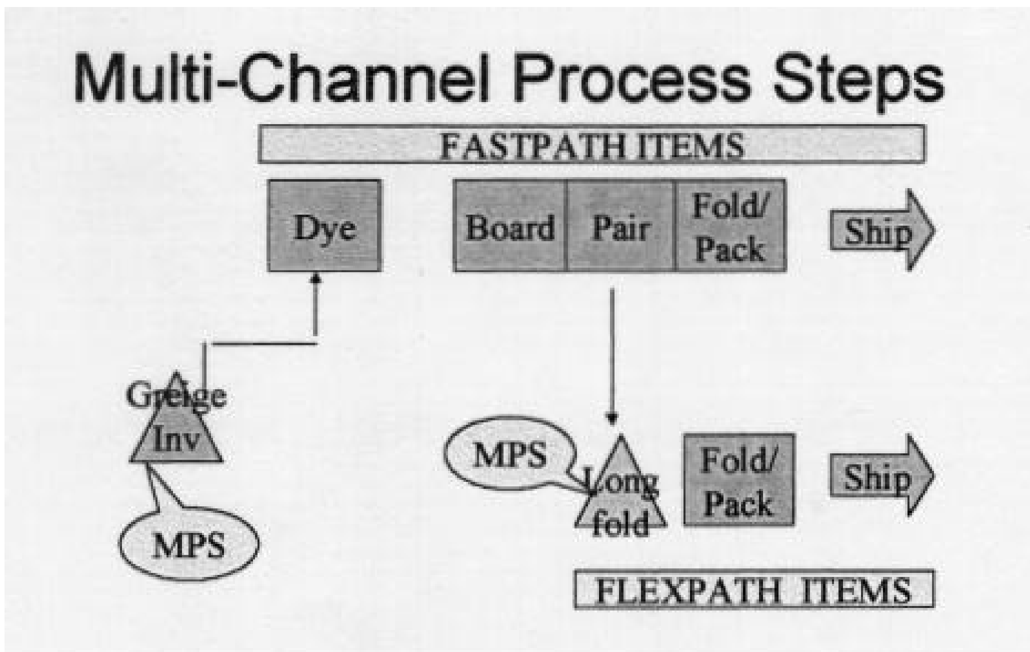

Figure 5 Multi-Channel Structure from greige forward

STEP 6 Eliminate wasted resources by developing flexibility to respond to remaining demand variation.

Manning each channel requires determination of a manning level which is capable of meeting customer satisfaction targets without incurring excessive costs of idle manpower in spite of the variation of demand on the system. A starting point to determine this amount is to smooth the demand by calculating a moving average with a periodicity equal to the desired response time. For example Figure 2 above is the demand pattern faced by the Fastpath channel. Here the demand spikes represent large custom orders that were accumulated over a number of days and subsequently shipped in a single day. The "forecast" line represents an 11-day moving average commensurate with the 11-day response time for the Fastpath channel. Again this is an initial point for establishing Fastpath capacity at for illustrative purposes of 3400 units/day. A similar analysis of demand facing the Flexpath subsystem, smoothed over 3 days suggests a starting capacity of 800 units per day in the Flexpath channel

Because the most desirable level of capacity depends upon the customer service levels (as measured by % order fulfillment within channel target time) it is necessary to assess tradeoffs between idle capacity and customer satisfaction. Figure 7 illustrates the issue using aggregate demand for the entire facility as measured in units per day during various time periods.

Here the ordinate represents daily units for each month. This would correspond to the expected seasonal shifts in the moving average of daily demand.

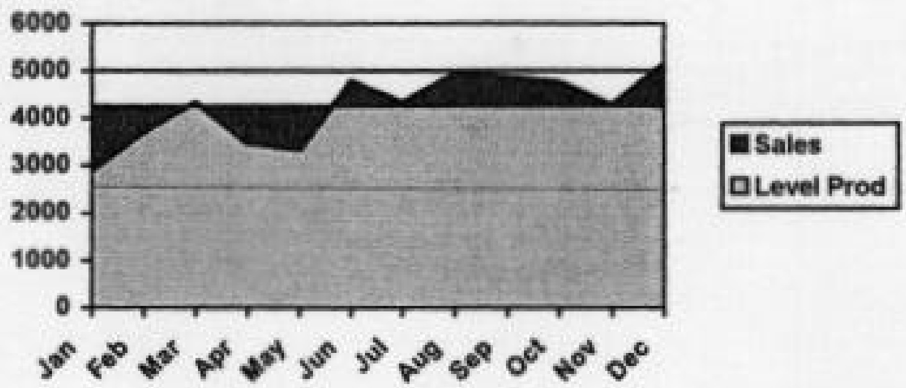

Figure 7 Aggregate Daily Sales rate by Month

As can be seen above manning to a level of 5000 units per day would provide capacity throughout the year thus eliminating any need for creation of seasonal inventories. Cost of idle capacity (unutilized manpower in this case) would be represented by the cost associated with the difference between the sales volume and the capacity level. On the other hand, a capacity level of 4200 units per day would require the creation of seasonal inventory in January through May to meet peak seasonal needs in the latter part of the year. Assuming the future needs can be accurately forecast (by item) there would be no excess capacity costs throughout the year.

Between 4200 and 5000 units per day, it is possible to find compromise daily rates where surges are accommodated by flexing shift length and workweek length upward. In this example, suppose that such a compromise is found at 4500 units per day. Then the economic trade between seasonal inventory and excess capacity costs is as shown in Table II below. The data are representative only.

Table II Example Trade off Analysis (000's omitted)

Production Plan	Annual labor and premium cost	Annual Inventory Investment
Level at average daily demand (for example 4200 units/day)	$1603	697 + Safety Stock
Manned for practical peak (for example 4500 units/day)	$1793	Safety Stock only
Difference	+$l90	-$697

In this example, the excess labor costs of $190,000 are offset by a reduction of $697,000 in inventory. This is economically justified if the inventory carrying cost exceeds 27.25% per year. This of course assumes that items to be built ahead can be forecast perfectly. Further, there are ways to mitigate the excess labor costs.

Allocating the 4500 units per day between Flexpath (800) and Fastpath (3700) initiates the process. Following a scheduling process which releases work on a daily basis to the bottleneck process (dyeing) in Fastpath maintains the 11 day cycle time with relative ease. An extensive discussion of the scheduling system is not appropriate here; however, it centers around creation of a daily dye schedule based upon incoming orders and anticipated longfold replenishment through the Fastpath channel. From there balanced flow with accumulation limits (dye- 2 days, rinse —0 days, board/pair/fold — 1 day, ship — 1 day) allows 7 days for backlogs ahead of dyeing. It employs the constraints theory logic of scheduling only the bottleneck and cross training downstream personnel to perform subsequent operations as needed to complete dyed orders.

STEP 7 Work backward to replace any intermediate inventories with quick response systems to replenish them in small lots or eliminate them if consistent with customer service requirements.

The logic of the design thus far raises the question of whether greige inventory might be eliminated by starting the Fastpath process directly from knitting. While this is conceptually possible, it depends upon resolving three issues:

- The ability to knit goods to order in an eleven-day time frame.
- Provision of spare knitting capacity is very expensive.
- Knitting production is currently leveled to provide greige stocks to meet seasonal requirements.

The MCM process is temporarily halted here as the company must accomplish the changes needed to substitute greige inventory and capacity for finished inventories. The next phase, substituting knitting capacity for greige inventory would follow the same steps as those outlined above; hence, the need to pause does not mitigate the descriptive value of the case.

CONCLUSIONS

The case scenario demonstrates the application of the seven MCM steps to an actual problem in order to apply the three MCM principles to create a high performance system in an environment with a variety of practical difficulties. Erratic demand is mitigated by dividing the system into multiple focused factories (here, only two are needed one, Flexpath, focused on responsiveness at the expense of inventory creation at the longfold state; the other, Fastpath, focused on efficiency within allowable time constraints). Flow discontinuities caused by batch operations like tub dyeing which require sequenced setups through the color range are accommodated by a controlled release scheduling system with daily schedules for the process steps included in finishing products to order. High capital costs of knitting machines are minimized by producing greige goods at a level annual rate and placing them in inventory based upon an aggregate forecast of greige items.

The system as designed is not yet ideal but does provide visibility of potential tradeoffs. Since the number of greige SKU's is two orders of magnitude smaller than finished SKU's, demand for greige items provides a much more reliable basis for planning. Ultimately, the greige inventories can be reduced by shortening response time for greige replenishment. This would involve closer matching of closing and knitting operations to reduce in-process levels. The trade-off between dyehouse economy and response time for finishing final products to order can be explored in further depth. Opportunities for continued improvement through acquisition of smaller dye tubs can be explored. Trade-offs between additional knitting capacity and reduced greige inventory can be studied. Even further, the possibility of elimination of greige goods inventory for the Fastpath channel might be considered as cycle times are further reduced.

By forging a composite system using the MCM approach, significant progress can be made. Overcoming barriers of this magnitude requires evolution not revolution. This is especially critical when the capital to implement the new system is available only from inventories that must be liquidated as apart of the evolutionary process. This case demonstrates the power of the composite approach toward achieving that end.

LESSONS LEARNED AND SUGGESTIONS FOR FURTHER RESEARCH

The case illustrates how the combination of concepts in the MCM umbrella is applied to achieve realistic gains. None of them alone provides a solution. Channel identification paves the way for JIT solutions and provides a means to control variability to the point that quick response systems are viable. Theory of Constraints logic provides the scheduling system needed to maintain system response times.

In practice, MCM implementation is complex. Channels must be identified and their order patterns studied. Cells must be designed within the channels. Ways to reduce and manage demand variability are needed to enable development of quick response systems. Trade-off analyses must be made in evolution. Obstacles must be identified and overcome. Management must be convinced to invest in surplus capacity and endure some labor inefficiency to eliminate inventories. Lean manufacturing concepts must be applied to find reasonable ways to balance flow between cells and among channels. Software systems may need to change to accommodate real time allocation of orders to supply channels. This combination of change is a great deal for an organization to absorb. Yet it can make the difference between survival and failure in today's volatile markets. Above all it requires a mindset shift away from traditional emphases on achieving high resource utilization and manufacturing efficiency to achievement of on-time delivery in a lean environment. Most of all it requires the confidence to believe that variable delivery requirements can be met without the security of a large finished inventory.

The synthesis of proven manufacturing concepts to attain solutions in particular environments is still in its infancy. This point of view follows the systems perspective promulgated by Hopp and Spearman (1996,p618). MCM is one example of the next level of detail in making the translation from concept to implemented change. Other recent work (Lewis, 2000) examines different lean manufacturing trajectories for various manufacturing contexts. Further research on other effective combinations in various environments may have useful implications. Within these synthesized environments lie many opportunities for improving the effectiveness of the system as a whole. For example, this paper clearly indicates the need for data structures in product and process nomenclature that will accommodate real time order allocation to channels. Reengineering of Channel Reordering Processes (Clark and Hammond, l999) to manage customer inventories represents a logical extension. Integration with retail stocks as described by Hunter, King and Nuttle (1992) and King and Hunter (1996) would provide increased demand visibility. Development of rules-based decision models for channel switching would be an excellent refinement inside the model. Simulation-based comparisons as applied to a similar problem in quick response (Hunter, King and Nuttle 1996) are a fruitful way to approach this trade-off analysis. This is obviously a fertile area for further work. Moreover, it would meet current management needs in the apparel industry.

References

Clark, T.H. and Hammond, J.H.," Reengineering Channel Reordering Processes to Improve Total Supply-Chain Performance", Production and Operations Management, Volume 6,Number 3, 248-265

Fisher and Raman (1996), "Reducing the Cost of Demand Uncertainty Through Accurate response to Early Sales," Operations Research,4,44 87-99

Fisher M.,Hammond J., Obermeyer W., and Raman A., (1999) "Configuring a Supply chain to Reduce the Cost of Demand Uncertainty" Production and Operations Management, Volume 6,Number 3,211-225

Hopp W.J. and Spearman,M.L., Factory Physics, McGraw-Hill

Hunter, N.A., King, R.E., and Nuttle, H.L.W., "Evaluation of Traditional and Quick -response Retailing Procedures by Using a Stochastic Simulation Model" Journal of the Textiles Institute,87 Part 2, No 1, 1996

Hunter, N.A., R.E. King and H.L.W. Nuttle, "An Apparel Supply System for QR Retailing," Journal of the Textiles Institute, 83(3), pp. 462-471, 1992.

King, R.E. and N.A. Hunter, "Demand Re-Estimation and Inventory Replenishment of Basic Apparel in a Specialty Retail Chain," Journal of the Textiles Institute, 87(1), pp. 31-41, 1996.

Kulonda, "MRP in the Third World", Journal of Production and Inventory Management, Quarter III, 2000

Nuttle, H.L.W, R.E. King and N.A. Hunter, "A Stochastic Model of the Apparel Retailing Process for Seasonal Apparel," Journal of the Textiles Institute, 82(2), pp. 247-259, 1991.

Lewis, M.A. (2000), "Lean Production and sustainable competitive advantage", International Journal of Operations and Production Management, Volume 20, Number 8, 959-978

Ohno T.(1988),The Toyota Production System: Beyond Large-Scale Production, Productivity Press

Schonberger R.(1986), World Class Manufacturing, The Free Press, 1986

Suri,R (1998) Quick Response Manufacturing, Productivity Press

Suri,R (1999) "Beyond JIT and the Lean Manufacturing Paradigm: Implementing Quick Response Manufacturing" IIE Solutions Conference Proceedings, Phoenix, AZ pp327-333

Womack, J.P and Jones, D.T.(1996), Lean Thinking, Simon and Schuster

Zipkin, P.H., (1991) "Does Manufacturing Need a JIT Revolution?", Harvard Business Review, January-February 1991, 40-50

AUTHOR'S INFORMATION:

Dennis J Kulonda
University Of Central Florida
Dept Of Industrial Engineering And Management Systems
P0 Box 162450
Orlando, Fl 32816-2450

(407)823-5568
dkulonda@mail.ucf.edu