TAILORED JUST-IN-TIME AND MRP SYSTEMS IN CARPET MANUFACTURING

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A great deal of attention has been focused in the literature on Just-in-Time (JIT) manufacturing since the last decade [1, 2, 3, 4, 8, 9, 10]. It is typical that JIT is applied and studied when the entire production process moves to JIT [6]. The purpose of this article is to show how, under certain circumstances, JIT can be applied to low-tech industries and can be used alongside a traditional MRP system. Of course, JIT in this form is a variation of the classical JIT manufacturing techniques [4, 6].

This article is a description of how a carpet manufacturer met standard orders within 24 hours by tailoring its JIT manufacturing techniques. In particular, the following managerial questions are addressed. How can a company compete on time with both customized and standard products? How can "mass customization" be achieved by managing standard products with JIT and customized products with MRP in one production facility?

PRODUCT, MANUFACTURING PROCESSES AND PROBLEMS

The firm under consideration for this new manufacturing process is a producer of high-end carpet tiles. Carpet tiles with a hard backing are installed much like traditional hard surface tiles. The company was the recent winner of the Malcolm Baldrige Outstanding Quality Award and is well known in the carpet industry for its capability to quickly respond to the market by developing new high-quality products. Along with quality, customer service is another selling point of the firm. Specifically, the firm was the first one to install "Quick Response," which guarantees shipment of products the following week. However, recent developments and competition in the carpet industry have led to some carpet manufacturers promising shipment of broadloom carpet in 24 hours. Note that while broadloom is not the same product as carpet tiles, its lower prices make it a competing product.

Two product lines are offered by this company. One line, representing approximately 65% of current total sales, is a series of standardized products called "standards," that sell through catalogs. The other line, representing approximately 35% of current total sales, provides customized products called "specials," in which new base colors and/or patterns are specified by customers and checked by the company's designers. While the fabrication of the products is identical for both product lines, the dyeing processes are different since special colors and/or designs are utilized for specials. Accordingly, a considerably higher markup is applied to specials due to the special attention given to these products and their customers during the whole production process.

The existing process encompasses two facilities located several miles apart. Materials are transferred between the two facilities several times a day. The company's marketing department receives incoming orders and establishes due dates (see Figure 1). The average (total) manufacturing lead time is one week, or five working days. A traditional MRP system is employed to determine due dates and reorder quantities for raw materials. Basic raw materials are the same, and dye shades are made by combining a small number of primary colors.

The production flow and process are illustrated in Figure 2. The specific process can be characterized as follows. First, dyes are prepared to color the yarn that will be used for the base of the carpet tile. The yarn is then dyed. The dyed yarn is then either tufted or bonded into a broadloom form of carpet. Ordinary carpet would then be backed with a flexible backing. However, carpet tiles are given a hard backing instead. After the broadloom form of the carpet has been backed, it is then cut into squares (18" x 18"). For the standards product line, customers can choose between plain base carpet and geometric or a commonly designed carpet pattern. Specials are often made of standard base colors with special logos or colors dyed on the carpet tile. Products are then ready to ship after the dying process is completed.

A big part of the process involves setups and changeovers between the two product lines. In the last stage of the production process (tile pattern), patterns are dyed in what is called a colorway. A colorway is a set of five different dyes. The dyeing machines can produce any pattern using the current five dyes that

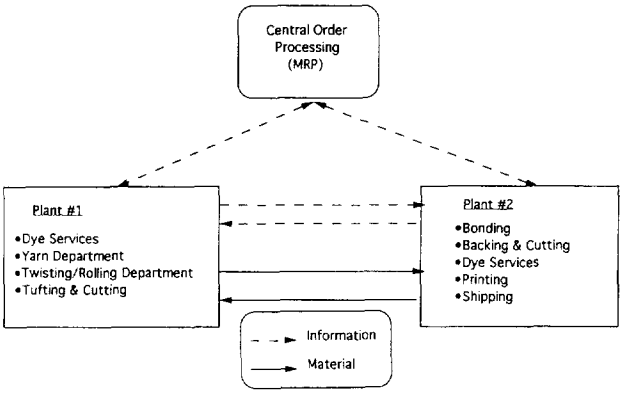

FIGURE 1: Business layout/information and material flow

are loaded on the machine. When products call for a different set of colors, a changeover must be made. The changeover takes approximately 45 minutes. When producing standards, production can start immediately after a changeover. When producing specials, a "strike" is required before production can begin after a changeover. A strike is a trial run of one yard of the product to test the shade of the dye and the detail of the pattern. A strike takes approximately 30 minutes. When the strike is off-shade, adjustments must be made on the machinery or the dye and then another strike must be run. When specials are run, it takes an average of 2.5 strikes before production can begin. Thus, an average changeover for specials takes two or more hours while an average changeover for standards takes only 45 minutes.

In the first process, yarn dyeing, a similar process occurs. The greige yarn is dyed a single color. In order to fulfill an order for a base, often two or three colors of yarn are combined in the twisting department. Thus, two or three vats must often be used in order to complete one order. Standards are again much easier to produce. The colors of standards are well established and do not require trial dyeing before the actual yarn dyeing can begin. Like in the tile pattern area, changeover for standards dyes are much quicker than specials. In both the yarn dyeing and pattern dyeing departments, standards dyes are also easier to make since the formulas have been well defined over a long period of time. The most frequently used standards dyes are made in large 500- and 1,000-gallon containers and are maintained at all times.

Efforts have been made to reduce both the lot sizes and lead times in the production process. Lot sizes have been reduced to the point where they currently equal the order size plus 5% for specials and 500 yards or more for standards. Manufacturing lead times are fairly consistent between production processes due to the company's low off-quality and smaller batch sizes resulting in less queueing time. It was also observed that work-in-process (WIP) spends the majority of its time in queue rather than actually in production.

JIT PHILOSOPHY APPLIED TO STANDARDIZED PRODUCTS

From the discussion in the previous sections, one can see that the line of standards seems to be an ideal candidate for consideration of JIT manufacturing. For

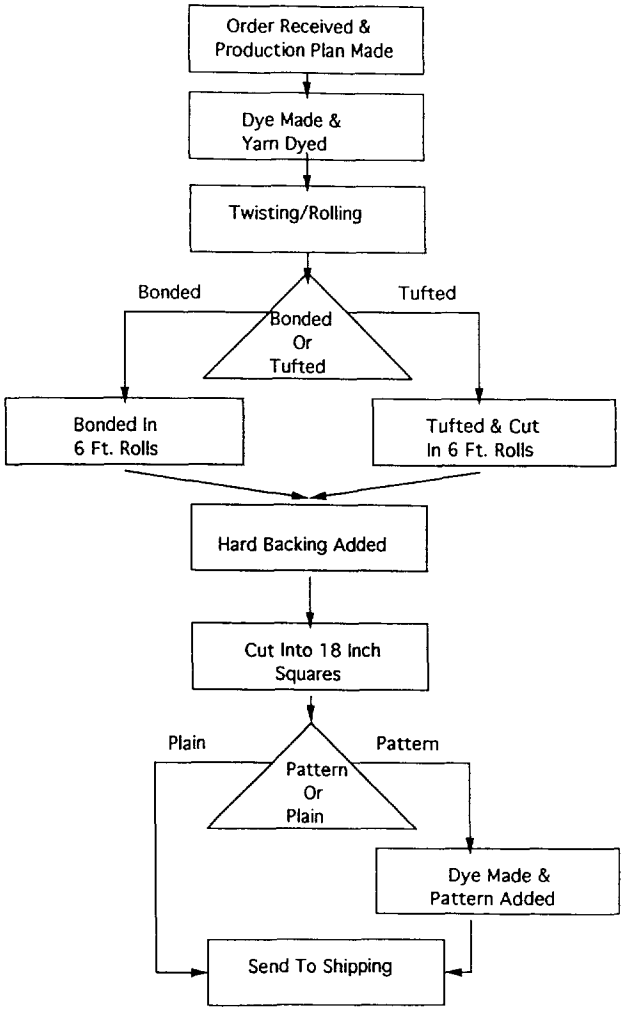

FIGURE 2: Current process flow

TABLE 1: Production Information for Standards Products

Department	*Number of Machines*	*Standards Production Rate*	*Standards Changeover Time*	*Machines Needed To Produce 250 Yd/Hr*
Yarn Dying	10 Vats	200 Yd/Hr	1 Hr	5 Vats
Yarn Rolling/Twisting	2 Rollers	400 Yd/Hr	.5 Hr	1 Roller
Tufting & Splicing	12 Tufting Machines	25 Yd/Hr	.5 Hr	6 Tufting
Bonding	8 Bonding Machines	40 Yd/Hr	.5 Hr	4 Bonding
Backing	1 Machine	530 Yd/Hr	0 Hr	Shared
Cutting	2 Cutters	450 Yd/Hr	.5 Hr	1 Cutter
Tile Pattern	2 Printers	250 Yd/Hr	1 Hr	1 Printer

the implementation of JIT to be successful, it is required that very few changes be made in the products themselves [3, 4, 6]. This implies that a firm must already have high-quality production processes, steady demand, quick changeovers, short lead times, and low variability in the production process. In this company, efforts over many years have led to high-quality processes with low variation. The standards product lines are already established and require few changeovers per day for production. The standards product lines have been produced for years, and operators are accustomed to producing them with quick changeovers. The standards product lines are also well established in the marketplace and demand for them has remained steady for quite some time. For every point that can be made in favor of producing standards by JIT techniques, a counterargument can be made concerning specials that would make it impossible to manufacture them using JIT. For this reason a process must be established that allows standards to be produced using JIT and allow specials to be produced the same way they are currently being produced.

The production of carpet tiles, like most other textile products, utilizes multiple, slow-paced, and low-capital equipment. From the yarn dyeing through the pattern printing, this is a valid statement. The only process that is completed on only one machine is the backing process. The backing process, however, can change carpet shade and change from tufted to bonded instantaneously. The use of multiple machinery in each department will make it possible to dedicate machinery to the production of standards or specials and thus produce standards using JIT procedures and specials using the traditional MRP system.

THE NEW PRODUCTION PROCESS

Under the new system, raw materials are ordered using the existing procedures that utilize a reorder point. Since the raw materials are the same for both standards and specials and are used in the same proportion, this works efficiently without increasing the number of stockouts. The new system requires additional planning personnel to handle the standards orders. JIT manufacturing simplifies the production planning process so only one additional planner is necessary. Reduced work loads for specials production planners free up their time to help plan for the production of standards. Very few changes are needed in the company's computerized production planning system since the JIT production process is self-regulating. The new planning personnel are responsible for ensuring that the daily, and often hourly, production plans are met in each department to ensure smooth-flowing production. This often requires working closely with those in charge of producing specials so that resources can be shared when needed. The lines between standards and specials should not be drawn stringently, but should be loose so that as demand for one type of product fluctuates, resources can be shared between the two production types.

The production of the standards products is done on machinery dedicated to them. One may recall that currently demand is split almost 65/35 between standards and specials. However, when looking at time to produce, standards require considerably less time. Thus, the split between standards and specials for machinery requirements is approximately 50/50 (see Table 1). The machinery that is dedicated to standards can be used for specials and vice versa when the current demand alters greatly from this 50/50 split. This flexibility is the key to the success of the newly established JIT production system. During some days, demand for standards is greater than what can be produced on the dedicated machinery. When this happens the other machinery, which has more flexibility in meeting its due dates, can be used for the production of standards. This should actually happen very rarely. Most often the opposite will occur, in that standards equipment will be used to help meet spe-

cials delivery due dates when the daily standards production has been met.

It should be pointed out that this new production system is not able to function as a typical JIT *pull* system. The reason for this is that the flexibility in the standards product line is established during its first and last processes. For this reason the system's individual departments cannot pull from each of their preceding processes like a typical JIT system. Instead, information needs to be shared between the first dyeing process and the last dyeing process/base order fulfillment. Working in this way, as an order begins in the last processes, work to replace the base inventory can begin in the first process. From the perspective of customer demand determining the work load, this can be viewed as JIT. Furthermore, the existing rule of 500-yard batches was changed for standards to match the size of customer orders exactly. Using these procedures requires WIP to be carried in substantial amounts to buffer the formation processes and the final dyeing and order fulfillment processes. When this new production system was first installed, we recommended that a one-day inventory be carried between the formation processes and the final fulfillment processes for each base product. As the production system began to become refined and any problems that occured were fixed, this quantity has been reduced greatly. After the new system had been fully implemented for a short time, we recommended that these levels be reduced to 12 hours' worth of WIP for common base patterns and fewer hours' worth of WIP for less popular base patterns. This represents a substantial reduction in total WIP from the previous production system which, at all times, had five full days of WIP on hand.

The installation of this JIT system was a gradual adjustment. Changes in the manufacturing process dictated the correct lot sizes and WIP inventory that should be carried. It was safe to discontinue WIP buffers between every process except the last pattern dyeing process. Lot sizes initially continued to be 500 yards or greater. However, these were quickly reduced or increased to exactly equal the periods' demand requirements for each base product. In the beginning, production periods were one day. That is, orders received today should be planned for tomorrow so that the first yarn dyeing process can set its day's production plan knowing what the final production process, tile pattern, is going to produce. As the new production process came on line, this one-period-per-day production was increased to two production periods a day. In this way, every 12 hours the first process, yarn dyeing, will know what the final process, tile pattern, is going to produce and can establish a 12-hour production plan. The remaining processes between yarn dying and tile pattern are captive to the production rates established by tile pattern. As a result, demand pulls inventory from base stock to tile pattern and sets the replenishment production in motion. The items will be replenished in 12 hours, just in time for demand to pull from them again.

RESULTS AND INSIGHTS

The obvious benefit to this new production system is the ability to gain market share by meeting orders for standards products in 24 hours. The current facilities have ample available space if capacity expansion becomes necessary in the long run. Since the majority of the textile machines being used are low-capital and easy-to-install items, capacity expansion is not a future concern. Even if there are no increases in market share, this new production system will allow the firm to maintain its current market share by meeting its competitor's new quick delivery programs in broadloom carpet. No other competitors producing carpet tiles are currently offering this type of quick response. One-time start-up costs were required for adjustments in the MRP system and the development of new system requirements; however, these were minimal. Savings that were realized in this new production process came from reductions in WIP inventory, based on a 12% annual holding cost. Calculations of these expenses and savings are summarized in Table 2.

While these annual savings are not very significant, cost savings are not the driving force behind the tailored application of JIT manufacturing techniques. This was and still is seen as a way to further meet customers' desires and thus improve the firm's overall profitability. Quick response as a key manufacturing strategy [5, 7] will continue to be emphasized in the carpet industry. The development of a production system of this type allows this firm to stay on the cutting edge of technology in the carpet market. Over time, additional savings can be real-

TABLE 2: Cost/Savings of New Production System

One-Time Start-Up Expense	
Adjustment to existing production planning system	$100,000
Annual Operating Expense/(Savings) Adjustments	
Planning personnel salary	$50,000
Reduction in standards WIP (reduction of 52,000 yards)	$124,800
Net Expense/(Savings)	$74,800

ized in this system as lead times, lot sizes, and WIP are further reduced.

One area in which this firm is currently focused is in-depth research into the production flow. The production rates of each department are currently balanced. However, the exact timing between departments, and total production time from dyeing to receiving the tile into WIP inventory, would need to be investigated. The total production time should be targeted somewhere between 8 and 12 hours.

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