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The Transfer of Japanese Manufacturing Management Approaches to U. S. Industry

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Just-in-time (JIT) provisioning of manufacturing inventories is a notable feature of Japanese manufacturing management. Kawasaki Motors, USA, has committed itself to JIT objectives, which result in moving toward lotless repetitive manufacturing, a streamlined mode of operation characterized by minimal inventories and "shop paper," plus flexible market response. Kawasaki USA has forged a hybrid process of effecting change, featuring Japanese JIT objectives but without Japanese-style consensus mechanisms for making decisions and effecting changes.

Japanese expertise in repetitive manufacturing management emerged as the marvel of the industrial world in the 1970s. Japanese companies generally have not been secretive about their special management skills and approaches, but Western industry has been slow to learn about and profit from Japanese successes, partly because of a prevailing premise that Japanese socioeconomic, geographic, and cultural factors rather than management approaches explain their successes.

Today, however, many manufacturers are studying and trying out Japanese approaches. Much of the activity has centered around *quality circles* (Nelson, 1980), a concept in which small groups of workers meet periodically to explore ways to improve quality and productivity. Only recently have Western manufacturers become aware of the Japanese kanban system and just-in-time (JIT) manufacturing control. In this paper, JIT, kanban, and quality circles are considered in the context of a particular type of production: *repetitive* manufacturing. As an illustration, the evolving repetitive manufacturing management system of a Japanese plant operating on U.S. shores—Kawasaki Motors—is considered.

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Repetitive Manufacturing and JIT Parts Delivery

Industrial processes all too often have been oversimplified with dichotomous terms such as job shop-flow shop or intermittent-continuous. High volume assembly of TVs, toys, pharmaceuticals, and canned goods sometimes is considered as continuous process production even though assembly runs are in lots and may be controlled by job orders or lot orders as in a job shop. The American Production and Inventory Control Society (APICS) (1981) is attempting to popularize terminology that will distinguish between the true process industries, whose products may be counted in fractional parts (gases, fluids, grains, flakes, pellets), and the industries that make discrete units in large amounts. The term being suggested for the latter is *repetitive* manufacturing.

In Western industrialized countries planning and control by lots is the dominant pattern in repetitive manufacturing. The Japanese have developed systems of repetitive manufacturing that attempt to do away with lots, that is, move toward lotless manufacturing. Lotless operations are the norm in the continuous process industries, and some repetitive manufacturers have been able to achieve lotless final assembly either by (a) dedicated assembly lines each making only a single model, as in automobile assembly, or (b) running mixed models down a single line, as is the practice in some tractor assembly plants. But in Western countries subassembly, fabrication, and purchasing in support of final assembly generally is lot-oriented. The Japanese have had some success in extending lotless repetitive processing to levels below final assembly, that is, multiechelon lotless manufacturing, and also in expanding the pursuit of lotless processing to firms making a wide variety of consumer and industrial products.

One Japanese technique for facilitating relatively lotless processing is the Toyota kanban system. Kanban was introduced at Toyota in 1972, and to date only a few other large Japanese original equipment manufacturing (OEM) companies have implemented kanban (APICS, 1981). The detailed workings of the kanban system are explained elsewhere (Sugimori, Kusunoki, Cho, & Uchikawa, 1977) and need not be dwelt on here. As interesting as kanban is, it is but one manifestation of a widespread Japanese manufacturing management approach characterized by simplicity and avoidance of waste. The approach bears close scrutiny for the purposes of this paper, which are to develop some preliminary judgments about the feasibility of transferring Japanese management expertise to U.S. industry.

The Japanese live on a small, crowded collection of islands where space costs are at a premium and natural resources are scarce. Waste, in the form of defective production or idle inventories taking up floor space, is a more obvious problem and serious concern in Japan than in countries blessed with natural abundance. It is not surprising that Japanese industry has developed hand-to-mouth manufacturing and inventory approaches with emphasis on high quality.

A term that has emerged to describe the Japanese hand-to-mouth philosophy is JIT. JIT is incorporated to a high degree in the kanban system. That is, the Toyota kanban system is geared to providing major assemblies just in time to go into final end products at the proper final assembly line work station; subassemblies just in time to go into major assemblies; parts just in time to go into subassemblies; and so on down to the level of the purchased part—and even beyond that into and throughout the manufacturing stages in suppliers' plants.

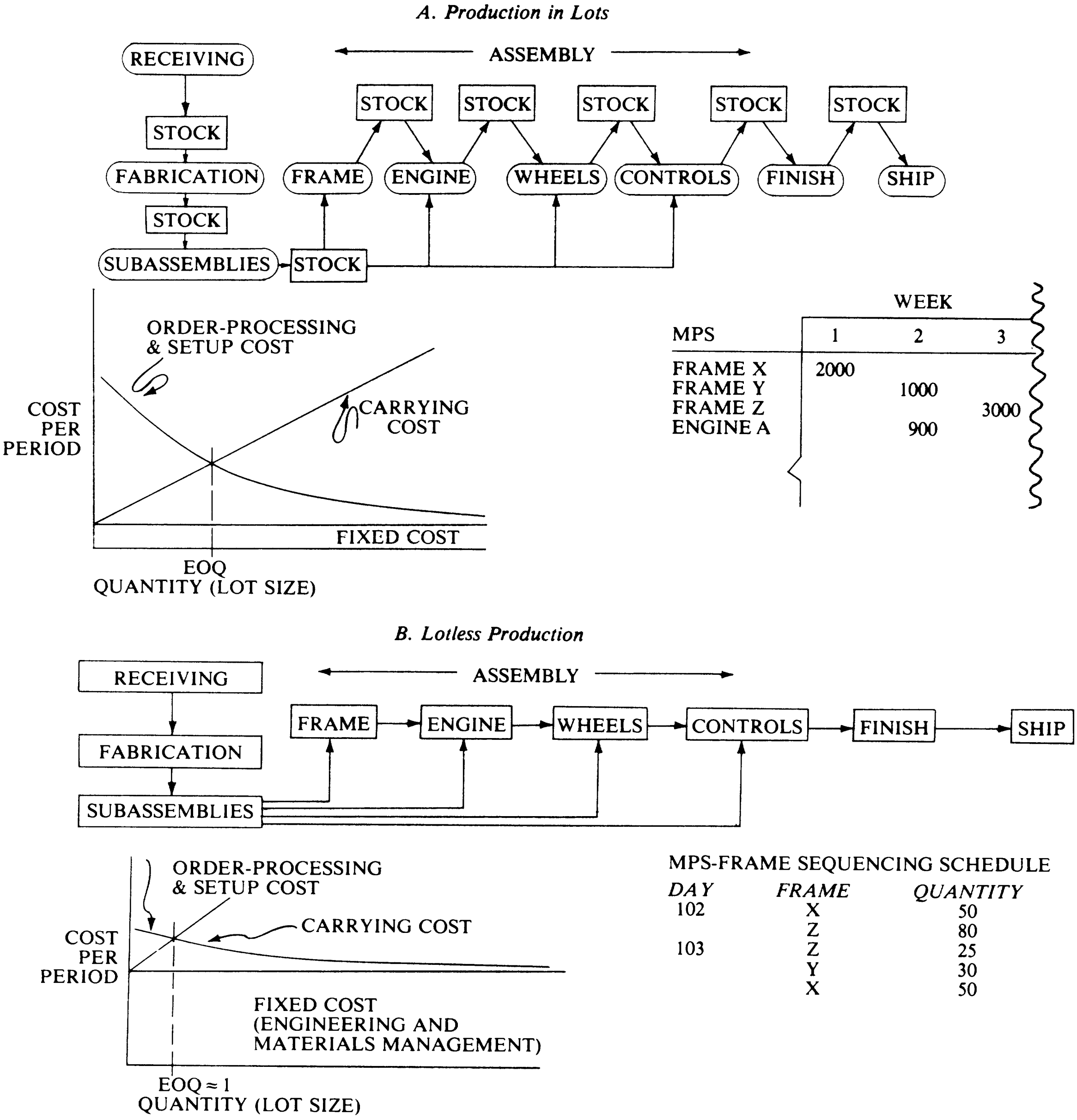
Material requirements planning (MRP), a U.S. innovation, has a similarity to kanban in that MRP also is bent on providing parts when they are needed to go into a parent item, up through all levels in the product structure. The difference is that Japanese JIT means, generally, the right day or even hour; MRP usually is content to provide parts in the right week. MRP can and sometimes does operate with daily or smaller time buckets, but there is an economic reason why most Western factories have weekly buckets: Labor costs of setup dictate that orders for the same part often be grouped into lots of a size sufficient to cover up to several weeks' parent-item requirements. With production quantities often providing weeks' worth, there is little value in regenerating planned orders more often than weekly.

The Japanese also must live with the economics of lot-sizing. But they have concentrated on altering one of the key inputs, labor cost per setup, in the basic economic order quantity equation. Reducing the setup cost and thereby adjusting economic lot sizes downward—ideally to equal one—is one of the keys that allows the Japanese factory to deliver parts just in time. When orders are small and frequent, simple noncomputer-based systems for order generation become practicable. The following example explains further the JIT approach of minimum lot sizes in contrast with the job-lot approach that has been perfected largely in the United States.

Lot-Size Economics

Figure 1 shows some of the major differences between the JIT and the job-lot approach to manufacturing. Motorcycle manufacturing is used as the example. Part A of Figure 1 shows the familiar job-lot way. Materials are bought, parts are fabricated, subassemblies are made, and assemblies are built in large enough lots that there generally are significant stocks of parts between each process stage. A schedule for this approach is shown at the right in Figure 1, Part A. The schedule, stated in weeks, shows intermittent runs of different models of the given part. In this case the part is a motorcycle frame, but it could just as well be a crank, bracket, seat, bolt, or any other material, part, assembly, or the whole motorcycle. A high carrying cost rate coupled with high cost per setup leads to an intermediate lot size—the EOQ—which is shown in the cost diagram in Part A.

Figure 1
Motorcycle Manufacturing With and Without Lots[a]



[a]Adapted from Schonberger, 1981.

MRP may be used advantageously in the job-lot approach of Part A. MRP plans the timing of the lot so that it is in time for the next demand. Because job-lots typically are several days' or weeks' worth, it is generally sufficient that MRP due dates/release dates be planned once a week. The many disruptions that conflict with the schedule during the week are handled by priority control (dispatching).

The JIT approach attempts to carry the MRP goal of correct order timing much farther; the ultimate or ideal would be piece for piece delivery of parts. The effect, shown in Figure 1, Part B, is virtual elimination of the large stocks of parts between process stages. The schedule becomes a daily or twice daily or hourly quantity.

The cost diagram in Part B represents the altered lot-size economics that make JIT possible. The carrying cost rate is unchanged, but setup cost is greatly reduced, as evidenced by the nearly flat, rather than steep, setup cost curve. Setup cost reductions are achieved by spending heavily on production engineering. (This exchanges one obvious cost for another, but in so doing there are considerable derivative benefits of inventory reductions and smoothed production, as is explained below.) That is, engineers design machines for quick and easy changeover of fixtures, dies, and other tooling. The fixed cost of engineering for quick setup is high, but the tradeoff is a low variable cost for labor to perform setups for changing part numbers. For parts that are bought rather than made, the same principle may apply, but the reduction is in purchase order-processing cost rather than setup cost. Order-processing cost cuts may be attained by better long term materials management—for example, better vendor selection, deliberate encouragement of local area vendors, better and longer term vendor contracts, and close vendor relations and contract monitorship.

Competitive Niche

A company that produces in large volume may, it seems, decide on either the job-lot approach or the repetitive approach. To some extent, the choice seems forced by the firm's competitive niche. That is, a company that manufactures telephones in many styles and colors may have great difficulty making JIT/repetitive production work, even if total sales volume is huge. Computer-based MRP, with a daily dispatch list feature, seems preferable for planning and controlling the great and ever-changing variety of possible telephone configurations demanded by customers who mainly want to be different. Another type of telephone manufacturing is the factory that makes a small variety of standard telephone sets in large volume—more of a "focused factory" (Skinner, 1974). This producer has fewer complications in need of sorting out by computer. Repetitive rather than job-lot production seems suitable.

These two examples represent extremes, and in the extreme case of differentiated versus standardized products the choice of job-lot or repetitive systems may be forced. But most manufacturers are more in the middle than at the extreme, and those firms with intermediate degrees of product differentiation may choose to put their emphasis on variety, or they may instead choose to emphasize lower costs and prices. It would appear that OEM companies in the United States tend toward the former—the variety strategy—and the Japanese OEM companies tend toward the low price and high quality strategy. But in overall head-to-head competition the Japanese have been having the edge, which leads one to wonder if U.S. emphasis has been misplaced. It is instructive to consider the case of one U.S. firm that recently reversed itself and chose a lotless/JIT rather than an MRP future for itself.

JIT at Kawasaki, USA

In early 1980 the Kawasaki motorcycle plant in Lincoln, Nebraska, was about to implement an MRP system. The plant management team were all North Americans with experience in job-lot oriented U.S. industry but were also knowledgeable about the Japanese JIT and kanban system in use at Kawasaki, Japan.

The kanban system for triggering parts movement and production appeared feasible, but, more importantly, the job-lot orientation inherent in MRP seemed inappropriate. If Kawasaki, Lincoln, was to be able to serve the North American market at a lower cost than could Kawasaki, Japan, it was essential that the Lincoln plant approach the level of productivity that has been attained, via JIT/ kanban, at the parent plant in Japan.

Lincoln plant management harbored the usual doubts about making JIT/kanban work in the U.S. culture in which labor and management often are viewed as adversaries. But in 1979 inventory problems became particularly acute. In particular, Kawasaki, Japan, as a key supplier of all motorcycle engines plus many other parts, was geared to ship parts to the United States in steady quantities (knocked down kits of 200 motorcycle equivalents), which matched poorly with Lincoln's more erratic large-lot-oriented production scheduling. (Included in materials from Japan were kits of steel tubing, which Kawasaki, Lincoln, fabricates into motorcycle frames in a manufacturing sequence of punch press, welding, and painting. Thus, the Lincoln plant has a several-level bill of materials with attendant potential for work-in-process inventory stockouts and excesses.) A Kawasaki, Japan, study group visited the Lincoln plant to try to help resolve the problems. One result was that the Lincoln management group became convinced that JIT, and perhaps kanban, should be pursued and that the MRP project should be abandoned.

Before the end of the year Kawasaki, Lincoln, had tried out a simple one-card kanban system for feeding certain parts to the production lines. Included were about 100 kinds of small "hardware"—bolts, washers, nuts, rubber grommets, and so on. After a period of marginal success with the kanban system, it became clear that the magic is not in the kanban card, but that a surer path to productivity improvement is to cultivate multiechelon JIT and small lot or lotless processing. The tinkering with manual order cards (kanban) on the shop floor continues. Meanwhile substantive gains have been achieved in moving toward JIT. A few examples may be noted.

Production/Capacity Planning

From the outset the Kawasaki, Lincoln, plant, now seven years old, has had the common Japanese production/capacity planning strategy: level load, *but without inventory buildup.* In some Japanese factories this strategy translates into a lifetime employment policy, which is feasible if the company is able to control its markets via high quality and productivity. Kawasaki, Lincoln's approach is an adaptation more consistent with the U.S. socioeconomic climate: a no-layoff policy.

In recent months a soft market combined with a high rate of productivity improvement has resulted in excess labor. The excess is greater than attrition can absorb. Consequently, production line workers have been available to build a storeroom, calk walls, rebuild a frame welding area for JIT parts flow, and attach a new JIT-oriented feeder line to one of the production lines. This is in keeping with the Japanese belief in an informed, involved, versatile workforce. Workers glimpse the big picture and are more able and inclined to offer worthwhile suggestions for productivity improvements (Ouchi, 1981. See, especially, Chapter 3.)

Organizing for Productivity Improvement

In Japanese industry manufacturing engineering is everyone's business. By one report (Hay, 1981) most Toyota foremen are or are studying to be industrial engineers, who lead their workers in the never-ending job of improving manufacturing methods. In Japan such methods analysis often is formalized via quality circles—Toyota calls its "small group improvement activities." (In repetitive manufacturing, quality improvements serve to reduce waste and rework and to smooth the output rate, thereby improving productivity. The distinction between quality and productivity blurs. Japanese quality circles thus are oriented toward both quality and productivity improvement, whereas a not uncommon view in the United States is that quality circles are concerned exclusively with quality matters.)

Kawasaki, Lincoln, has no quality circles or other formal study groups. But plant management has developed a notion that it believes may achieve the same results. The idea is to instill in everyone's mind a vision of what the plant is evolving toward, and to allow wide latitude for the workforce to pursue the vision in a variety of ways. The vision is stated thus: The whole plant is visualized as a series of stations on the assembly lines, whether physically located there or not.

The object is JIT production and parts delivery with no waste—the same as in Japan. The mechanism is individual American ingenuity. The Japanese way is to take a long time and seek consensus, which helps assure successful implementation. The U.S. way is to decide fast without real consensus or commitment and then run into an obstacle course in the implementation phase. The hybrid approach in the Lincoln plant perhaps avoids many of the implementation obstacles by inculcating (a) a vision of an ultimate plant design and (b) a JIT objective for plant operation.

Productivity Improvements

The plant configuration vision and the JIT objective are scarcely a year old, but there are notable successes. As has been mentioned, production line workers, rebuilt a frame-welding area. Motorcycle frame welding had been run as a job shop, with frames run in job lots through several welding stages, and inventory buildups at each stage. Now there are several frame welding lines, each dedicated to a particular model of motorcycle. For a given model, a number of welding booths are located close together in a line, and a special welding jig is in each booth. As a model of frame is run, the product is passed piece by piece from booth to booth, with no inventory buffers between. Thus, JIT parts movement has been achieved within frame welding. The next step, making frame welding "a station on the assembly line," may be achieved in the future through implementation of kanban to link frame welding to frame painting.

It also was mentioned earlier that production workers had attached a new feeder line to a main assembly line. The assembly line for the KLT three-wheel motorcycle previously had been supported by a separate subassembly area making differentials in job lots. The line foreman, apparently imbued with the JIT concept, had told industrial engineering that he thought differential assembly could be attached to the main assembly line. The foreman led the conversion project, and today a differential production line feeds directly into the KLT line, with a typical work-in-process (WIP) inventory of just two differentials.

Setup Time

The many delegations from other U.S. plants that have visited Kawasaki, Lincoln, are most likely to remember the punch presses that are equipped with carousel roller conveyors for die storage. The conveyors keep the dies at just the right height for quick and easy attachment to the fixture. It now takes about 10 minutes to set up for a new model of framing tube versus hours for the same setup a year ago. It now is economical to run tube fabrication operations in the same small lot sizes (200) as for parts kits received from Japan—as opposed to lot sizes in the thousands before the carousel die storage and transfer conveyors were developed.

JIT Purchasing

JIT purchasing is common in Japan, but perhaps the only well-established case of it in the United States is with TRI-CON, a Kawasaki motorcycle seat supplier. In 1977 Tokyo Seat Company established its TRI-CON subsidiary near the Kawasaki plant in Lincoln, Nebraska. TRI-CON's motivation was to become indispensable by locating close enough to be able to react quickly to any quality or delivery requirements that Kawasaki might have. The striking feature of the service provided by TRI-CON is its twice a day deliveries. More-than-daily delivery generally is unheard of in the United States in discrete manufacturing; once a month is more typical.

In 1981 the Kawasaki purchasing manager began training his buyers and other staff in JIT purchasing concepts. Several JIT-oriented purchase agreements are in various stages of development. The idea is to establish very high quality, responsive suppliers, in the Lincoln vicinity where possible, and enjoy the mutual advantages of long term JIT agreements: low inventories (which the supplier also may achieve via JIT agreements with its suppliers), avoidance of large lots of defectives (because there are no large lots), and stability of the supplier-buyer relationship.

Plant Configurations for JIT Operations

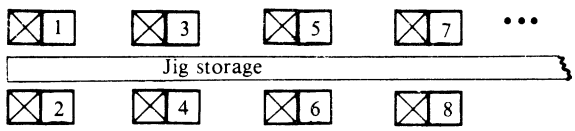
As some of the above examples indicate, Kawasaki, Lincoln's productivity improvements are gained by moving away from job-shop and toward multi-echelon lotless repetitive production. There are several possible plant configurations along the way, as Figure 2 illustrates using welding booths as the example. The first configuration, Part A, is that of a job shop. Each welding booth has access to welding jigs, which hold steel tubing in place for welding into frames. Job orders specify frame model, order quantity, and routing from booth to booth. Dispatch lists note which job order to run next at particular booths, and move tags assist in the transfer between booths.

Part B shows the extensive physical changeover to welding production lines, which is the present configuration in the Lincoln plant. Each line is dedicated to a particular model, which eliminates the changing of jigs in a given booth. This is a layout concept known as group technology (GT), which the British write about (Burbidge, 1975) and the Japanese extensively employ. Shop paper is reduced to a daily schedule by frame model. WIP buffer/queuing inventories drop to zero, and inventories of completed frames awaiting transfer to painting drop from, typically, many days' supply to a maximum of one or two days' worth.

Part C shows how Kawasaki, Lincoln, plans eventually to cut down the day's worth of finished frames by implementing kanban. Kanban is a pull system in which the downstream work center pulls, via a kanban card, more parts from upstream fabrication areas. Because kanban meshes fabrication

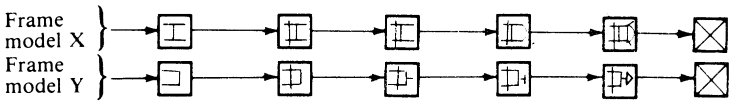
Figure 2
Plant Configurations[a]

A. Welding Booths; Job-Shop Configuration



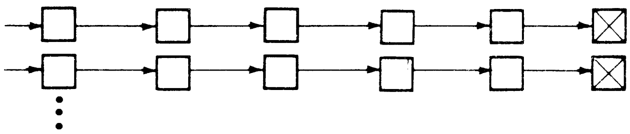
Notes:
1. Numbered boxes represent welding booths.
2. Jobs are routed between all pairs of booths.
3. Frames in various welded states, symbol ⊠: may be several days' supply at each booth.
4. Shop paper for every booth:
   - ° Job orders
   - ° Dispatch lists
   - ° Move tags

B. Dedicated Welding Lines



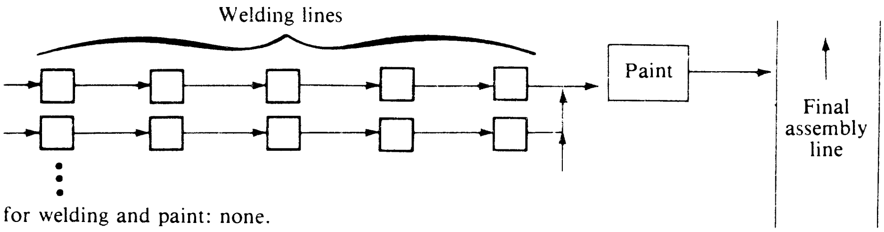
Notes:
1. Completed frames, symbol ⊠: one or two days' maxium supply for each line.
2. Shop paper for each line:
   - ° A daily schedule

C. Dedicated Welding Lines with Kanban Cards



Notes:
1. Completed frames, symbol ⊠: one or a few standard containers' full.
2. Shop paper for each line:
   - ° One kanban card for each empty container arriving from downstream work center (i.e., paint)

D. Dedicated Welding Lines Physically Connected to Paint and Final Assembly



Notes:
1. Shop paper for welding and paint: none.

[a]Adapted from Schonberger, Sutton, and Claunch, 1981.

output with assembly usage—always somewhat variable—the kanban system cuts buffer stocks. (When production is run to a schedule, as in MRP, it is a push system, i.e., the scheduled run is made and the finished parts are pushed downstream, whether downstream work centers need them or not.)

In Part D the last bit of buffer inventory and the last bit of shop paper are removed—by physically wedding the dedicated feeder line to main assembly. The Lincoln plant may never achieve this configuration for welding frames, which then go to painting before feeding to final assembly. But, as has been described, this configuration has been achieved for feeding differentials into the KLT assembly line.

Flexibility

The primary advantages of JIT and repetitive production are lower costs and prices with better quality. To some degree these benefits are gained at the expense of product line variety. A JIT/repetitive manufacturer is likely to offer fewer models and styles than an MRP company. Typically, for example, Japanese auto manufacturers have offered a narrower line of models than have U.S. counterparts. If a repetitive manufacturer is to offer a good deal of variety, that variety should be within fairly narrow limits, for example, a variety of chrome trim styles, all of which are similar enough to be formed from the same material on the same machine tool engineered for quick setup changeovers.

At the same time JIT leads to increased flexibility and market responsiveness. Because all parts manufacturing is geared to the final assembly rate, the total production lead time is very short, as compared with job-lot producers. JIT plants, including Kawasaki, Lincoln, make the most of their capacity for market responsiveness by generally resisting the temptation to make parts simply in order to keep an expensive machine busy. Instead, a sales-oriented master schedule dictates machine usage. When model changeover and machine-tool setup times have been drastically reduced, assembly lines and fabrication centers may be balanced to run mixed models. The daily model mix produced is closely matched to the daily marketing mix distributed and sold, so that finished goods inventories may be lean and still provide a high rate of service (few model stockouts) to final customers. Internally, information linkages (e.g., via kanban) serve to keep fabrication centers, and even suppliers, making the same model mix as is being run in final assembly, with appropriate offsets for leadtime—sometimes only a matter of hours (e.g., the four-hour response time for TRI-CON to deliver seats to the Kawasaki, Lincoln, plant).

MRP in its most advanced forms (i.e., MRP II) has the admirable capability of providing integrated planning of manufacturing and financial resources forward to distribution centers and backward to suppliers. Fully developed multiechelon JIT also integrates forward and backward but with only a fraction of the inventories, computer processing, and planning documentation. It is not easy, or cheap, to become a JIT/repetitive manufacturer, and plants whose mission is to provide product variety are limited in how far they can progress toward JIT/repetitive processing; MRP may be necessary. But, based on the still limited information on the Kawasaki, Lincoln, experience, the JIT approach is workable in the United States, and a certain amount of conversion to such a mode of operation may be necessary if U.S. industry is to compete with the Japanese.

Future Research

For many production/operation management (P/OM) practitioners in the United States, there is an element of déjà vu in learning about the Japanese JIT approach. A similar period of enlightenment was experienced in the 1970s in connection with MRP. Orlicky (1975) had concluded that order quantities, the focal point of inventory management for nearly half a century, were really unimportant as compared with order timing. Converts to MRP adopted this conclusion with close to religious fervor. It seemed unlikely that there would be a second period of enlightenment in the 1980s and that it would feature a return to the view that lot sizes may indeed be a key to successful production and inventory management. Yet that is part of the JIT message, and Japanese industrial success with small-lot and lotless JIT processing is convincing.

Such developments open up a host of research opportunities for the P/OM academician. For one thing, considerable thought and study are needed to sort out the proper areas of application for lot-oriented MRP versus relatively lotless JIT/kanban. The issue is complicated in that it relates to the central question of what a given manufacturing firm has been, is, and can be. At one extreme is a lot-oriented job shop geared for variety, which is the way that many manufacturers start out, and at the other extreme is a repetitive OEM firm geared for the mass markets, which many might aspire to become.

There also are important operational issues that beg attention. What is the best system design for a given plant and how may it be discovered and implemented? Yamaha in Japan has devised what seems to be an ingenious fusion of kanban and MRP, suitable for its situation as a repetitive manufacturer dependent on numerous job-lot-oriented fabrication shops. Kanban cards control parts feeding final assembly, and *synchro cards,* computer-produced by a highly advanced version of MRP, trigger orders from the job-lot oriented fabrication shops (APICS, 1981). The academic researcher, along with consultants and practitioners, surely have this sort of innovative design work to do in a variety of industries.

The fundamental truths seem to be not yet fully known, much less the details. Understanding Japanese JIT and examining attempts in the United States to borrow from the Japanese answer some questions but open up many new ones.

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