CHAPTER 13

Just-in-Time

This chapter addresses just-in-time (JIT) approaches for manufacturing planning and control. JIT is a key building block for modern approaches to manufacturing planning and control (MPC), and is both a philosophy and a set of techniques. Moreover, the techniques go beyond traditional manufacturing planning and control systems. JIT changes manufacturing practices, which in turn affect MPC execution. JIT greatly reduces the complexity of detailed material planning, the need for shop-floor tracking, work-in-process inventories, and the transactions associated with shop-floor and purchasing systems. These gains come at the cost of more tightly coordinated manufacturing processes—both inside a company and with supplier firms that produce under JIT. The chapter concentrates on the MPC aspects of JIT but necessarily touches on broader aspects as well. It is organized around the following seven topics:

- *JIT in manufacturing planning and control:* What are JIT's key features, and how do they impact MPC systems?
- *A JIT example:* How can the basic principles of JIT be illustrated in one simplified example?
- *JIT applications:* What are some concrete examples of JIT practice?
- *Nonrepetitive JIT:* How can JIT concepts be applied to the nonrepetitive manufacturing environment?
- *Joint-Firm JIT:* How is supplier-customer coordination supported with JIT?
- *JIT software:* What features of computer packages support JIT?
- *Managerial implications:* What changes are required to fully pursue the benefits of JIT?

JIT in Manufacturing Planning and Control

Figure 13.1 shows how just-in-time programs relate to our manufacturing planning and control framework. The shaded area indicates the portions of MPC systems that are most affected by implementation of JIT. The primary application area is in back-end execution. However, JIT extends beyond manufacturing planning and control. JIT programs raise

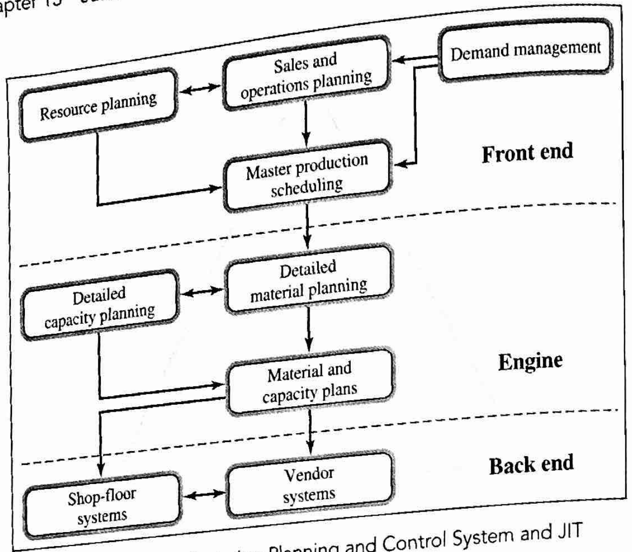


Figure 13.1 Manufacturing Planning and Control System and JIT

fundamental questions about manufacturing strategy and effectiveness. For this reason, we begin with a discussion of the major elements in a JIT program. Thereafter, we turn to the impact on the MPC system and the overhead cost savings from reduced MPC system transaction processing. The section closes by describing four fundamental JIT building blocks.

Major Elements of Just-in-Time

Many definitions have been put forward for just-in-time, and they have evolved over time. One popular definition of JIT is an approach to minimize waste in manufacturing. This focus is too broad: it helps to subdivide waste into time, energy, material, and errors. A useful common denominator running through this and other JIT definitions is a broad philosophy of pursuing zero inventories, zero transactions, and zero "disturbances" (*zero disturbances* means routine execution of schedules day in—day out).

The JIT literature is largely one of cases. The best-known JIT examples are from firms with high-volume repetitive manufacturing methods, such as the classic case of Toyota. The most important features of these applications have been the elimination of discrete manufacturing batches in favor of production rate goals, the reduction of work-in-process inventories, production schedules that level the capacity loads and keep them level, mixed

model master production schedules where all products are made more or less all the time, visual control systems where workers build the products and execute the schedule without paperwork or complex overhead support, and direct ties to vendors who deliver high-quality goods frequently. All of these have MPC implications.

Just-in-time objectives require physical system changes—and programs to make the changes. A prime example is setup time reduction and a drive toward constantly smaller lot sizes. This is necessary to make all of the products constantly. It's also consistent with reducing inventory levels. Setup times are typically reduced by applying common industrial engineering techniques to analyzing the setup process itself, often by workers themselves using a video camera. The results of setup time reduction have been impressive indeed. Changeovers of several hours have been reduced to less than 10 minutes. The goal now being achieved by many firms is expressed by Shigeo Shingo: SMED (single-minute exchange of dies, meaning all changeovers take place in less than 10 minutes).

Another physical program is improved quality through process improvements. Most JIT firms have programs of quality awareness and statistical process control. In a repetitive manufacturing system, any quality problem will result in a stoppage of the entire flow line, unless undesirable buffer inventories are held.

Quality improvement has taken many forms and is largely beyond our present scope. Two critical aspects for JIT are *TPM* and *poka-yoke*. TPM can stand for both total preventive maintenance and total productive maintenance. The goal is to apply the diligence of product quality improvement to equipment and process quality. Poka-yoke means foolproof operations. This is achieved by building operations in processes so that quality is evaluated as it's created. This also ensures low cost through finding defects at the time they're created. These quality programs have an impact on MPC system requirements and design.

Most JIT programs include continual improvement as a maxim for day-to-day operations. Every day, each worker should get better in some dimension, such as fewer defects, more output, or fewer stoppages. Continual improvement is achieved by making thousands of small improvements in methods and products in a never-ceasing quest for excellence. JIT best practice includes a strong degree of worker involvement and worker participation.

JIT firms often group their equipment for cellular manufacturing: a group of machines manufactures a particular set of parts. The equipment layout minimizes travel distances and inventories between machines. Cells are typically U-shaped to increase worker interactions and reduce material handling. Cross-trained workers can run several machines. Cellular manufacturing makes "capacity" more flexible, so surges or mix changes are more readily handled. An extension of the cellular concept is the plant within a plant, where a portion of a factory focuses solely on one group of products.

Figure 13.2 JIT Benefits

Manufacturing throughput time reductions
Materials moved shorter distances
Less material movements in/out of storage
Reduced transactions
Simplified MPC systems
Reduced changeover times
Greater responsiveness to market demands
Inventory reductions
Labor cost reductions
More satisfied/cohesive workers
Better team work
Space reductions
Quality cost reductions
Quality improvements

In summary, a JIT orientation includes several action programs:

1. Reduction of setup times and lot sizes
2. A "no defects" goal in manufacturing
3. A focus on continual improvement
4. Worker involvement
5. Cellular manufacturing

Figure 13.2 lists the typical benefits gained in a JIT program.

JIT's Impact on Manufacturing Planning and Control

JIT influences all three areas of our MPC framework (front end, engine, and back end). JIT's primary contribution is in the back end, providing greatly streamlined execution on the shop floor and in purchasing. JIT can eliminate standard shop-floor reporting systems, reduce costs of detailed shop scheduling, significantly reduce work in process and lead times, and support better vendor scheduling.

However, JIT is not without influence on the front end and engine. In the detailed MRP planning of the engine, JIT reduces the number of part numbers planned and the number of levels in the bill of materials. Many part numbers formerly planned by MRP analysts can now be treated as "phantoms" (i.e., as part numbers still in the bill of materials but not transacted into and out of inventories). This means that instead of MPC being based on detailed operation steps to make individual parts, the planning is at the level of assemblies, using cross-trained workers and cellular manufacturing to eliminate the detailed planning. The result is often an order of magnitude reduction in the complexity of detailed material planning, with a concomitant reduction in planning personnel. Moreover, with planning/execution at the assembly level instead of with detailed operations and parts, the overall flow time from parts to finished goods is significantly reduced.

In the front end, JIT also gives rise to important changes. JIT production plans and master production schedules require relatively level capacity loading for smooth shop operations. In many cases, this is a rate-based MPS—that is, producing so many units per hour or day. This drive toward more stable, level, daily-mix schedules dictates many of the required JIT activities, such as setup time reduction. To the extent that lead times are sufficiently reduced, many firms that had to provide inventories in anticipation of customer orders (made-to-stock firms) now find themselves more like make-to-order or assemble-to-order companies, better able to respond to customer orders. This, in turn, can affect demand management.

In JIT execution, orders move through the factory so quickly that it's not necessary to track their progress with a complex production activity control system. A similar argument holds for purchased items. If they're converted into finished goods within hours or days of receipt, it's unnecessary to put them into stockrooms, pick them, and go through all the details normally associated with receipts from vendors. Instead, the JIT firm can simply pay the vendor for the purchased components in whatever products are completed each time period; there will be so little work-in-process inventory that it's not worth either party keeping track of it.

The concept of updating component inventory balances when finished items are received into stock is called **backflushing.** Instead of detailed work-in-process accounting systems based on shop-order transactions, some JIT firms just reduce component part inventory balances by exploding the bills of material for whatever has been delivered into finished goods. However, backflushing implies a very high level of data integrity.

JIT execution is focused on simplicity. The intent is to design manufacturing cells, products, and systems so goods flow through routinely. With problems of quality and disturbances largely eliminated, routine execution becomes just that: routine. Simple systems can be employed by shop people without detailed records or the need for extensive overhead staff support.

The Hidden Factory

A manufacturing firm comprises two "factories." One makes products and the other (the hidden factory) processes transactions on papers and computer systems. Over time, the former factory has been decreasing in cost, relative to the latter. A major driver for these costs is transactions. **Logistical transactions** include ordering, execution, and confirmation of materials moving from one location to another. Included are the costs of personnel in receiving, shipping, expediting, data entry, data processing, accounting, and error follow-up. Under JIT, the goal is to eliminate the vast majority of this work and the associated costs. Work orders that accompany each batch of material as it moves through the factory are eliminated. If the flow can be simplified, increased in volume, quick, and guaranteed, there is no need for paperwork.

Balancing transactions are those needed to verify that an activity actually occurred. These checks are largely associated with the planning that generates logistical transactions. Included are production control, purchasing, master scheduling, forecasting, and customer order processing/maintenance. In most companies, balancing transaction costs are 10 to 20 percent of the total manufacturing overhead costs. JIT again offers a significant opportunity to sharply reduce these costs. MRP planning can be cut by perhaps 75 to 90 percent in complexity. Improvements generated by vendor scheduling can also be extended. Vendor firms no longer need to process *their* sets of transactions.

Quality transactions extend far beyond what one normally thinks of as quality control. Included are identification and communication of specifications, certification that other transactions have taken place, and recording of backup data. Many of the costs of quality identified by Juran and others are largely associated with transactions. JIT, with closer coupling of production and consumption, has faster quality monitoring and response capability.

Still another category is **change transactions.** Included are engineering changes and all those that update the MPC system database, such as routings, bills of materials, and specifications. Engineering change transactions are some of the most expensive in the company. A typical engineering change might require a meeting of people from production control, line management, design engineering, manufacturing engineering, and purchasing. The change has to be approved, scheduled, and monitored for execution.

One way that firms attack the hidden factory is by finding ways to significantly reduce the number of transactions. Stability is another attack, and again JIT is important since it is based on stabilized operations. Still another attack on hidden factory transaction costs is through automation of transactions (as with bar coding), eliminating redundancies in data entry, and better data entry methods. But stability and transaction elimination should be pursued before turning to automation of transactions. JIT is clearly a key.

JIT Building Blocks in MPC

As Figure 13.3 shows, JIT links four fundamental building blocks: product design, process design, human/organizational elements, and manufacturing planning and control. JIT provides the connecting link for these four areas.

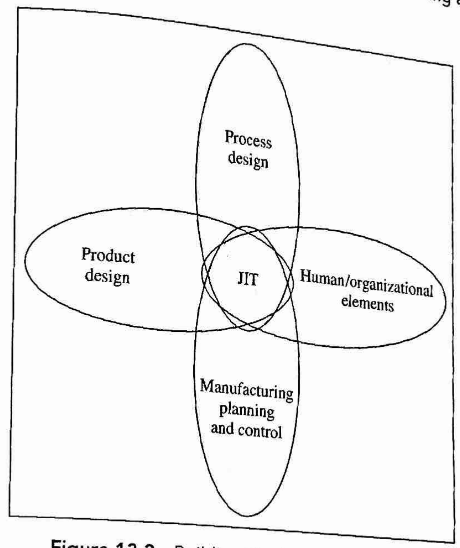


Figure 13.3 Building Blocks for Just-in-Time

Critical activities in product design include quality, designing for manufacture in cells, and reducing the number of levels in the bill of materials to as few as possible. Since each level in a bill of material represents a stock point, reducing the number can significantly reduce inventory requirements and speed processing.

Reducing the number of bill of material levels and process design are closely related. For fewer levels to be practical, the number of product conversion steps must be reduced through process design changes, often through cellular manufacturing. Equipment in cellular manufacturing is positioned (often in a U shape) to achieve rapid flow of production with minimal inventories. The object is to concentrate on material velocity. Jobs must flow through in short cycle times, so detailed tracking is unnecessary.

Bandwidth is an important notion in designing manufacturing processes. A wide bandwidth system has enough surge capacity to take on some variation in demand for the products as well as a fairly mixed set of products. The impact on MPC systems is the focus on inventory and throughput time reductions, where inventory is not built to level out capacity requirements. JIT systems are designed to be responsive to as large a set of demands as possible. Superior manufacturing processes support greater bandwidth. The objective is for MPC systems to schedule any product, right behind any other, with minimal disruption.

Human/organizational elements are another building block for JIT. One aspect of this is continual improvement, which implies cross training, process improvements, and whatever else is needed to enhance worker performance. The objective is continual learning and improvement. Human/organizational elements recognize that workers' range of capabilities and level of knowledge are often more important assets to the firm than equipment and facilities. Education is a continuing investment in the human asset base. As the asset base's capabilities grow, need for overhead support is reduced and overhead personnel can be redeployed to address other issues.

Linking human/organizational elements into the other activities has a significant effect on the operation of the production process and MPC system. Bandwidth and the avoidance of building inventories to utilize direct labor mean surge capacity must be available. Implementing surge capacity with direct labor personnel means these people will not be fully utilized in direct production activities. In fact, the **whole person** concept is based on the premise of hiring *people,* not just their muscles. As a consequence, direct workers take on many tasks not usually associated with "direct labor." This work can be done in nonpeak production times. This includes equipment maintenance, education, process improvement, data entry, and scheduling. From a JIT standpoint, the human/organizational elements building block puts a greater emphasis on scheduling by workers and less on scheduling by a centralized staff function. The entire process is fostered by the inherent JIT push toward simplification. With no defects, zero inventories, no disturbances, and fast throughput, detailed scheduling is easier; moreover, any problems tend to be local in nature and amenable to solution on a decentralized basis. The whole person concept implies a shift from indirect labor to direct, where jobs are more widely defined.

The final building block in Figure 13.3 is the manufacturing planning and control system and its link to JIT. Applying JIT requires most of the critical MPC functions described in this book. It will always be necessary to do master production scheduling, production planning, capacity planning, and material requirements planning. If the bill of materials is reduced to two or three levels, detailed material planning and associated transaction costs can be cut significantly. If detailed tracking is done by direct laborers under the whole person concept, additional savings can be achieved.

We see then that JIT has the potential for changing the character of manufacturing in a company, since it reduces MPC transactions. JIT can significantly reduce the size of the "hidden factory" that produces papers and computer transactions instead of products. Figure 13.4 provides a more detailed listing of JIT's building blocks and objectives. Many of these will be described in the next section, which presents a detailed JIT example.

A JIT Example

In this section we develop a detailed but simple example to show how MPC approaches based on MRP would be modified to implement JIT and describe the necessary building blocks (Figure 13.4) to achieve this. The product is a 1-liter saucepan produced in four models by the Muth Pots and Pans Company. (See Figure 13.5.) The product's brochure

Figure 13.4 JIT Objectives and Building Blocks

Ultimate objectives:

- Zero inventory
- Zero lead time
- Zero failures
- Flow process
- Flexible manufacture
- Eliminate waste

Building blocks:

- Product design:
  Few bill of materials levels
  Manufacturability in production cells
  Achievable quality
  Appropriate quality
  Standard parts
  Modular design
- Process design:
  Setup/lot size reduction
  Quality improvement
  Manufacturing cells
  Limited work in process
  Production bandwidth
  No stockrooms
  Service enhancements
- Human/organizational elements:
  Cross training/job rotation
  Flexible labor
  Continual improvement
  Whole person
  Limited direct/indirect distinction
  Cost accounting/performance measurement
  Information system changes
  Leadership/project management
- Manufacturing planning and control:
  Pull systems
  Rapid flow times
  Small container sizes
  Paperless systems
  Visual systems
  Level loading
  MRP interface
  Close purchasing/vendor relationships
  JIT software
  Reduced production reporting/inventory transaction processing
  Hidden factory cost reductions

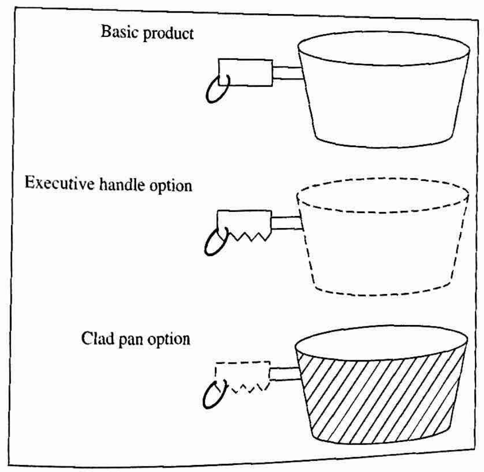


Figure 13.5 The 151 One-Liter Saucepan Line

sums up its importance: "If you ain't got a Muth, you ain't got a pot." We'll look at elements of a JIT program for the saucepan that range from leveling production to redesigning the product. Some of these elements have direct MPC relevance; others will affect MPC only indirectly.

Leveling the Production

We start the saucepan's JIT program by considering how to "level and stabilize" production. This means planning a level output of 1-liter saucepans with the full mix of models each day (or week or some other short interval). Full-mix production in a short interval provides less inventory buildup in each model. Moreover, the schedule can respond to actual customer order conditions more quickly. Level output implies "freezing" to stabilize production and related activities on the floor. Before seeing how this might be done, let's compare Muth's manufacturing situation with traditional MRP-based approaches.

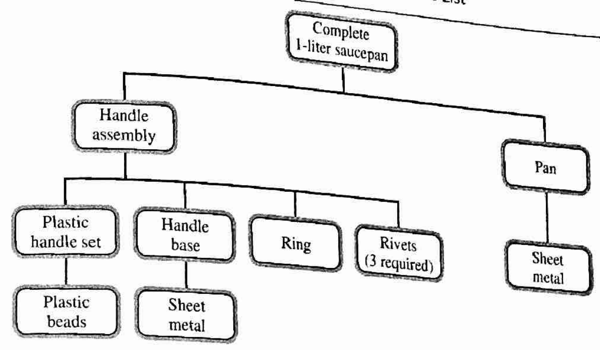
Currently, Muth uses production planning to set the overall production rate, necessarily building inventories in anticipation of the Christmas season demand peak. The annual forecast for each of the four models is given in Figure 13.6. A master production schedule, for each of the four models, is exploded to produce a material requirements planning record for each of the 14 component part numbers shown on the part listing in Figure 13.7. Safety stock is carried for all components, and production is in the lot sizes indicated in Figure 13.7. Figure 13.8 gives lead times and routing data; lead times are computed on the basis of two days per operation, rounded up to the next whole week using five-day weeks. A typical MRP record is shown as Figure 13.9.

To plan for level production, the first step is converting the forecasts to the daily requirements for each model. Using a 250-day year, this conversion is shown in Figure 13.10. Note the difference between the current lot sizes and the daily requirements. Daily production will put pressure on process design to reduce setup times. Two other possible

Figure 13.6 Annual Forecast Data

Completed Pan Model Number	Description of Model: Handle	Metal	Annual Forecast
151A	Basic	Sheet	200,000
151B	Basic	Clad	2,500
151C	Executive	Sheet	25,000
151D	Executive	Clad	100,000

Figure 13.7 Product Structure and Parts List



	Lot Size	Safety Stock	Finished Item Number: 151A	151B	151C	151D
Models (end items)						
Complete pan 151A	8,000	5,000	X			
Complete pan 151B	900	1,000		X		
Complete pan 151C	3,000	3,000			X	
Complete pan 151D	6,000	5,000				X
Component parts						
Regular pan 1936	14,000	10,000	X		X	
Clad pan 1937	8,000	6,000		X		X
Basic handle assembly 137	14,000	8,000	X	X		
Exec. handle assembly 138	8,000	5,000			X	X
Basic handle set 244	9,000	8,000	X	X		
Exec. handle set 245	9,000	8,000			X	X
Basic handle base 7731	14,000	8,000	X	X		
Exec. handle base 7735	12,000	5,000			X	X
Ring 353	24,000	15,000	X	X	X	X
Rivets 4164	100,000	50,000	X	X	X	X
Sheet metal 621	1 coil	1 coil	X		X	
Clad sheet 624	1 coil	1 coil		X		X
Handle sheet 685	1 coil	1 coil	X	X	X	X
Plastic beads 211	5 tons	1 ton	X	X	X	X

mixed-model master production schedules are shown in Figure 13.10, in addition to the one based on daily production batch sizes. The first shows quantities to be produced if hourly batches are to be made. The second shows an MPS with the minimum batch size of one for model 151B.

Figure 13.8 Routing and Lead Time Data

Department	Item	Routing	Lead Time
Final assembly	Complete pan	1. Spot weld	2 days
		2. Inspect	2 days
		3. Package	2 days
			Total = 6 days = 2 weeks
Punch press	Pan	1. Blank and form	2 days
		2. Roll lip	2 days
		3. Test for flat	2 days
		4. Straighten	2 days
		5. Inspect	2 days
			Total = 10 days = 2 weeks
Handle base	Handle base	1. Blank and form	2 days
		2. Inspect	2 days
			Total = 4 days = 1 week
Handle assembly	Handle assembly	1. Rivet	2 days
		2. Inspect	2 days
			Total = 4 days = 1 week
Injection molding	Plastic handle set	1. Mold	2 days
		2. Deburr	2 days
		3. Inspect	2 days
			Total = 6 days = 2 weeks
	Purchased Items		
Purchasing	Sheet metal		Purchased lead time one week for all items
	Clad sheet metal		
	Plastic beads		
	Ring		
	Rivets		

Figure 13.9 MRP Record for Basic Handle Assembly (Part 137)

		Week 1	2	3	4	5	6	7	8	9	10
Gross requirements			8		8	3	8		8		8
Scheduled receipts											
Projected available balance	10	10	16	16	8	19	11	11	17	17	9
Planned order releases		14			14			14			

Q = 14; LT = 1; SS = 8.
All quantities are in thousands.

Figure 13.10 Master Production Schedule Data*

	Model 151A	151B	151C	151D
Option configurations:				
Handle	Basic	Basic	Executive	Executive
Pan	Sheet	Clad	Sheet	Clad
Annual forecast (units)	200,000	2,500	25,000	100,000
Possible mixed model master production schedules:				
Daily batch MPS	800	10	100	400
Hourly batch MPS	100	1.25	12.5	50
Minimum batch MPS	80	1	10	40

Data are based on a 250-day year and an eight-hour work day.

Pull System Introduction

A "pull" system exists when a work center is authorized to produce only when it has been signaled that there's a need for more parts in a downstream (user) department. This implies no work center is allowed to produce parts just to keep workers or equipment busy. It also means no work center is allowed to "push" material to a downstream work center. All movements and production are authorized by a signal from a downstream work center when it has a need for component parts. Frequently, it's believed that the pull system creates the benefits in JIT. In fact, primary payoffs come from the discipline required to make the system work. Included are lot size reductions, limited work in process, fast throughput, and guaranteed quality.

Signals for communicating downstream work center demand vary widely. They include rolling a colored golf ball from a downstream work center to its supplying work center when the downstream center wants parts; yelling "Hey, we need some more"; sending an empty container back to be filled; and using cards (kanbans) to indicate more components are needed. A widely used technique is to paint a space on the floor that holds a specific number of parts. When the space is empty, the producing department is authorized to produce material to fill it. The consuming or using department takes material out of the space as it needs it; typically, this occurs only when the space authorizing that department's output is empty. For the Muth example, we'll use an empty container as the signal for more production; that is, whenever a using department empties a container, it sends the container back to the producing department. An empty container represents authorization to fill it up.

Given that Muth has committed to a level schedule where all models are made every day, the firm is almost ready to move into a pull mode of operation. Two additional issues need to be faced. First, there's the question of stability. For most pull systems, it's necessary to keep the schedule firm (frozen) for some reasonable time. This provides stability to the upstream work centers, as well as overall balance to the workflow. For Muth, assume the schedule is frozen for one month, with the daily batch quantities given in Figure 13.10 (1,310 pots per day).

The second issue is determining the container sizes to transport materials between work centers—a fairly complicated issue. It involves material handling considerations, container size commonality, congestion in the shop, proximity of work centers, and, of course, setup costs. For example, consider the container used between handle assembly and final assembly of the pots using the basic handle, part 137 (810 being used per day). The center is currently producing in lots of 14,000. We'll choose a container size that holds 100 pieces representing just under an eighth of a day's requirements. Note this choice puts a great deal of pressure on the handle assembly work center to reduce setup times.

Figure 13.11 shows the flow of work in Muth's new system for handle assembly to the final assembly line. Only two containers are used for part 137; while one is being used at the final assembly line, the other is being filled at handle assembly. This approach is very simple and is facilitated by the two departments being in close proximity. Figure 13.12 shows the factory layout. A worker from the final assembly line or a material handler can return empty containers. Any empty container is a signal to make a new batch of handles (i.e., fill it up). It's interesting to note the difference in average inventory that will be held in this system, compared with the former MRP methods and the lot size of 14,000. The system with a small container approaches "zero inventory," with an average inventory of about 100 units. Compare this to the inventories shown in the MRP record of Figure 13.9 (average projected available inventory balance = 13,400).

This pull system example has no buffer at either work center. It would be possible to add another container, which would allow greater flexibility in handle assembly, at the cost of extra inventory in the system. As it is, the final assembly area would use up a container in just under one hour. This means the system has to be responsive enough for the empty container to be returned to handle assembly and a batch made in this time frame. An extra container allows more time for responding to a make signal (an empty container) and also allows more flexibility in the supplying department. The extra inventory helps resolve problems—for example, when several production requests for different parts (containers) arrive at the same time.

Product Design

To illustrate the implications for product design, consider the basic and executive handles for Muth's 1-liter saucepan shown in Figure 13.5. There are two differences between the

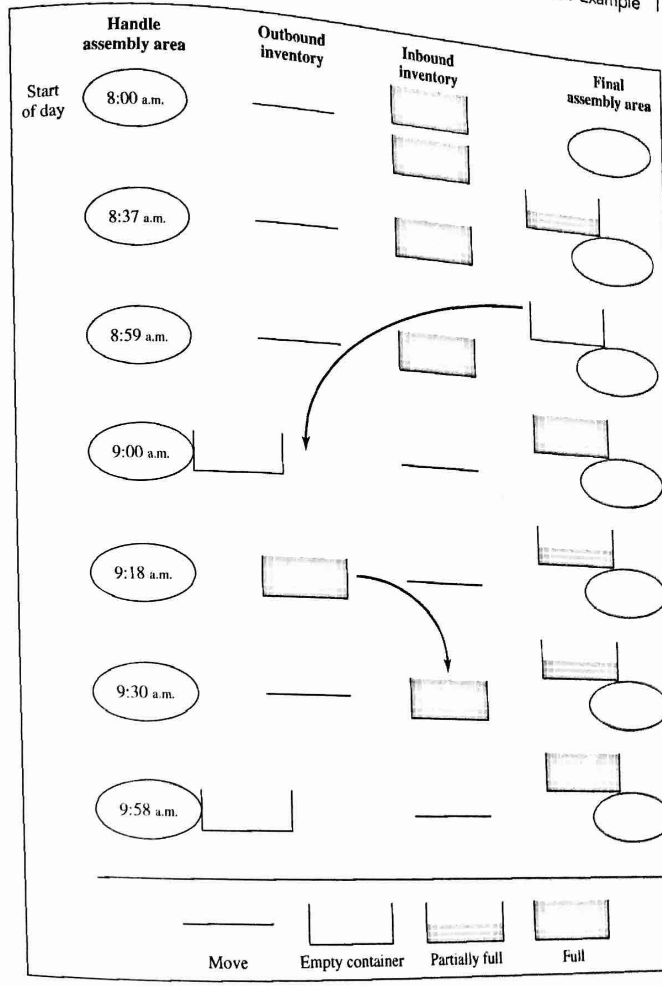


Figure 13.11 Pull System for Muth Pots and Pans

handles: the grips and the ring placement. With some redesign of the plastic parts on the executive handle, the handle base becomes a common part and the ring placement is common between the two handle models; the methods for handle assembly could also be standardized. The only difference would be the choice of plastic handle parts. Such a redesigned handle base is shown in Figure 13.13.

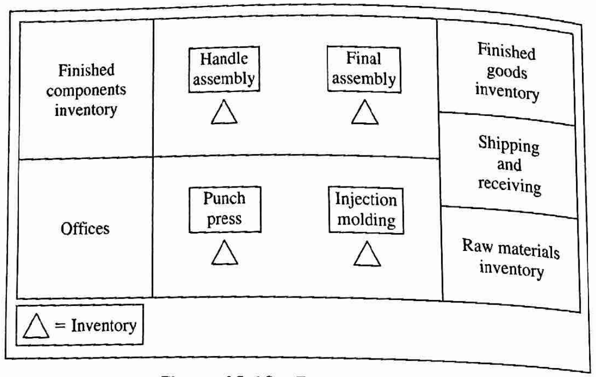


Figure 13.12 Factory Layout

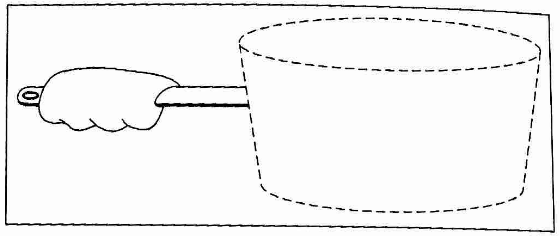


Figure 13.13 Redesigned Handle Base

In addition to the improvements this design change makes in handle subassembly, there are potential impacts in other areas as well. For example, handle bases would have one combined lot of production instead of two, with attendant reductions in inventory. It might now be possible to run the handle base area on a pull system as well, with containers passing between the handle base area and the handle subassembly area. Another advantage is a simplification in the bill of materials, a reduction in the number of parts that must be planned and controlled with MRP, and a concomitant reduction in the number of transactions that have to be processed.

Process Design

The product redesign, in turn, opens opportunities for process improvement. For example, it may now be possible to use the same equipment to attach both kinds of plastic handles to the handle base. Perhaps a cell can be formed, where handle bases are made and assembled

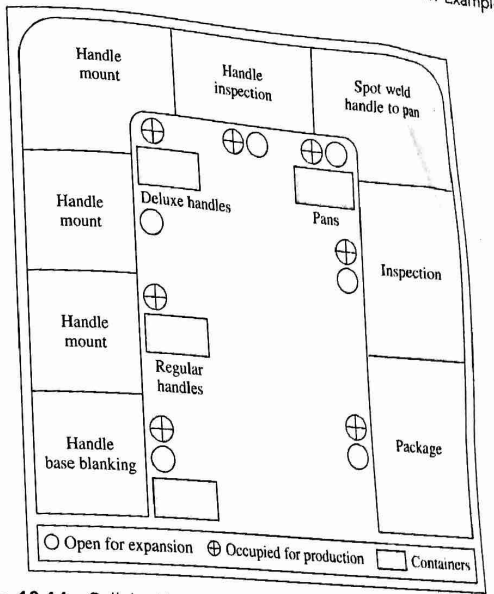


Figure 13.14 Cellular Manufacturing of Handle Assembly and Final Assembly

as a unit. Figure 13.14 shows one way this might be accomplished, including an integration of the handle assembly cell and the final assembly line in a U-shaped layout. Note in this example that no significant inventories are anywhere on the line, and both handle base material and plastic handle parts are replenished with a pull system based on containers.

Figure 13.14 also illustrates the bandwidth concept. Several open stations along the line would permit adding personnel if volume were increased. Moreover, perhaps Muth would like to establish different production rates for certain times. For example, perhaps this pan might be manufactured in higher volumes near the Christmas season. What's needed is the capacity at the cell to move from one level of output to another. This added capacity probably means the dedicated equipment will not be highly utilized.

The cell is designed to permit variations in staffing to better respond to actual customer demands. If an unexpected surge in demand for executive handle pots comes through, the cellular approach will allow Muth to make the necessary changes faster—and to live with this kind of problem with smaller finished goods inventories. Over time, perhaps this cell can be further expanded in terms of bandwidth and flexibility to produce handles for other Muth products.

The value of quality improvement can be seen in Figure 13.14. The inspection station takes up valuable space that could be used for production. It adds cost to the product. If bad products are being culled by inspection, buffer stocks will be required to keep the final assembly line going. All of this is waste to be eliminated.

Bill of Materials Implications

The product redesign results in a streamlined bill of materials. The number of options from the customer's point of view has been maintained, but the number of parts required has gone down (e.g., components have been reduced from 14 to 10). With the cellular layout shown in Figure 13.14, the handle base and handle assembly no longer exist as inventoriable items. They are "phantoms" that won't require direct planning and control with MRP. The product structure given as Figure 13.7 now will look like Figure 13.15.

Several observations can be made about Figure 13.15. One is that handle assemblies have ceased to exist as part of the product structure. If we wanted to maintain the handle assembly for engineering and other reasons, it could be treated as a phantom. Figure 13.16 shows what the MRP record would look like in this case. In Figure 13.16, there's some existing inventory to use up; phantom treatment allows this to occur, and will always use this inventory before making more.

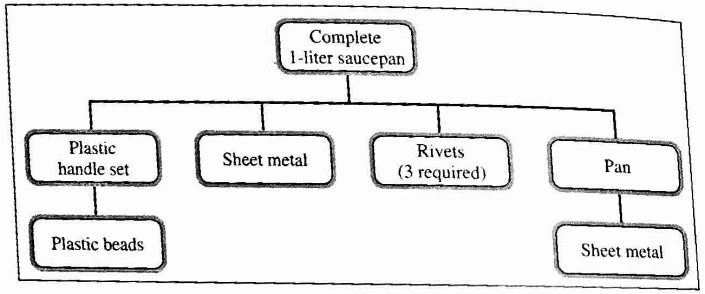


Figure 13.15 Simplified Product Structure

Figure 13.16 MRP Record for Phantom (Part 137)

		Week 1	2	3	4	5	6	7	8	9	10
Gross requirements		4,050	4,050	4,050	4,050	4,050	4,050	4,050	4,050	4,050	4,050
Scheduled receipts											
Projected available balance	15,000	10,950	6,900	2,850							
Planned order releases					1,200	4,050	4,050	4,050	4,050	4,050	4,050

Q = lot for lot; LT = 0; SS = 0.

Another observation is that pans *do* remain as inventoriable items. Elimination of these two part numbers and their associated inventories may well be the next goal for product and process redesign. Still another is to understand the magnitude of the reduction in transactions represented by the JIT approach illustrated in Figure 13.14. All MRP planning for the eliminated part numbers (or phantom treatment) is now gone. This affects MRP planning as well as stockrooms—and all other indirect labor associated with MRP control.

Finally, we need to consider the effect on lead times, the resultant ability to better respond to market conditions, the reductions in work-in-process inventories, and the greater velocity with which material moves through the factory. If the combined lead times are computed for the product structure in Figure 13.7 and lead time data in Figure 13.8, five weeks are required for the flow of raw materials into pots. The JIT approach cuts that to just over two weeks, which could be reduced even further.

JIT Applications

Toyota is the classic JIT company in that it has gone further than any other discrete manufacturing firm in terms of truly making the production process into a continuous flow. Much of the basic terminology and philosophy of JIT have their origins at Toyota. A key issue in JIT at Toyota is understanding that automobile manufacturing is done in very large factories that are much more complex than our simplified example. Parts will flow from one work center to many others with intermediate storage, and flows into work centers will also come from many work centers with intermediate storage. The JIT systems at Toyota have to reflect this complexity. Before delving into the complexity, however, it's useful to first see how a **single-card kanban system** functions in a manufacturing environment with many work centers and intermediate storage.

Single-Card Kanban

Figure 13.17 depicts a factory with three work centers (A, B, and C) producing component parts, three work centers (X, Y, and Z) making assemblies, and an intermediate storage area for component parts. A single component (part 101) is fabricated in work center C and used by work centers Y and Z. To illustrate how the system works, suppose work center Z wishes to assemble a product requiring component 101. A box of part 101 would be moved from the storage area to work center Z. As the box was removed from storage, the accompanying kanban card would be removed from the box; shortly thereafter, the card would be placed in the card rack at work center C. The cards in the rack at any work center represents the authorized production for that work center.

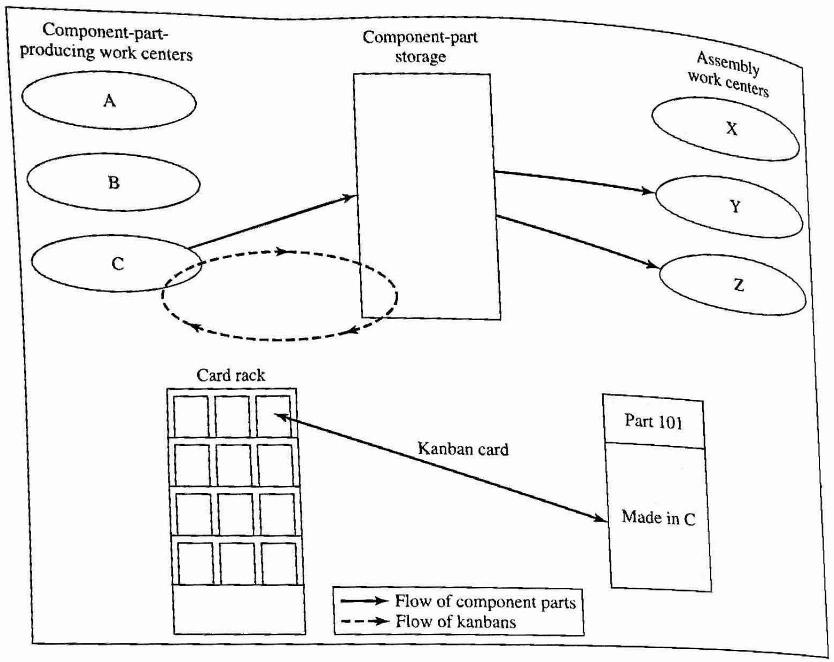
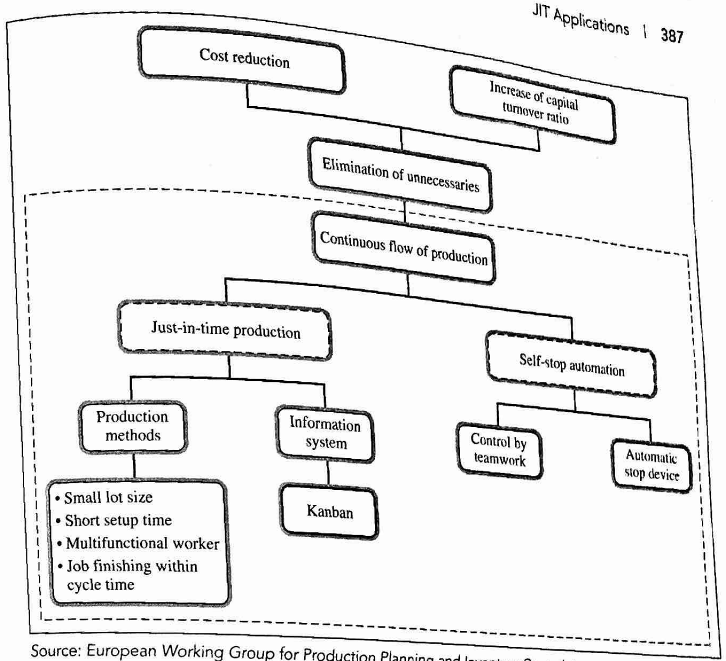


Figure 13.17 Single Kanban System

The greater the number of kanban cards in the system, the larger the inventory, but also the greater the autonomy that can be attained between the component-producing work centers and the assembly work centers. Some priority system can be implemented in the component work centers, such as working on a first-come/first-served basis or imposing some time requirements (such as all cards delivered in the morning will be returned with filled containers in the afternoon of the same day and all afternoon cards will be delivered the next morning).

Toyota

The production system at Toyota is in many ways the most advanced JIT system in the world. The revolutionary techniques developed by Toyota have now been adopted by all the major automobile companies in the world. Toyota still turns its inventories faster than most companies in the industry while also being very competitive in price, quality, and delivery performance.



Source: European Working Group for Production Planning and Inventory Control, Lausanne, Switzerland.

Figure 13.18 Toyota's Production System

Figure 13.18 shows the Toyota production system and where JIT fits within the overall approach. To some extent, the role given to JIT in Figure 13.18 may appear less encompassing than one might expect. For example, the "elimination of unnecessaries" is seen as fundamental. All of the objectives and building blocks for JIT listed in Figure 13.4 are in basic agreement with those in Figure 13.18. The box for production methods is basically the same as process design in Figure 13.3. Included under this heading is the multifunctional worker, which matches with several aspects of the human/organizational element building block. Also included is "job finishing within cycle time"; this is consistent with the dominance of material flow velocity and the subservient role of direct labor utilization.

Toyota's Kanban System

The Toyota view of just-in-time production shown in Figure 13.18 includes "Information system" with "Kanban" below it. The information system encompasses the MPC activities necessary to support JIT execution. Kanban is the Toyota technique for controlling material flows. The situation at Toyota is much more complex than that illustrated in the single-card kanban example. Toyota has intermediate storage after production of components and additional intermediate storage in front of assembly work centers. This means the work flows from a producing work center into an inventory, then to another inventory, and then to the next work center. For this reason, Toyota uses a two-card kanban system, but the principles are the same as for the single kanban card system. The chain of dual kanban cards can extend all the way back to the suppliers. Several of Toyota's suppliers receive their authorizations to produce via electronic kanban cards.

Figure 13.19 gives the formula used to calculate the number of kanban cards needed. In this formula, there's a factor for including safety stock, which Toyota says should be less than 10 percent. Using the formula, no safety stock, and a container size of 1, we can see the philosophy of the system. If a work center required eight units per day (one per hour) and it took one hour to make one unit, only one set of two kanban cards would be theoretically necessary; that is, just as a unit was finished, it would be needed at the subsequent operation.

The container sizes are kept small and standard. Toyota feels that no container should have more than 10 percent of a day's requirements. Since everything revolves around these containers and the flow of cards, a great deal of discipline is necessary. The following rules keep the system operating:

- ▲ Each container of parts must have a kanban card.
- ▲ The parts are always pulled. The using department must come to the providing department and not vice versa.
- ▲ No parts may be obtained without a conveyance kanban card.
- ▲ All containers contain their standard quantities and only the standard container for the part can be used.
- ▲ No extra production is permitted. Production can only be started on receipt of a production kanban card.

Figure 13.19 Calculating the Number of Kanbans

$$Y = \frac{DL(1 + \alpha)}{a} \tag{13.1}$$

where:

Y = number of kanban card sets
D = demand per unit of time
L = lead time
a = container capacity
α = policy variable (safety stock)

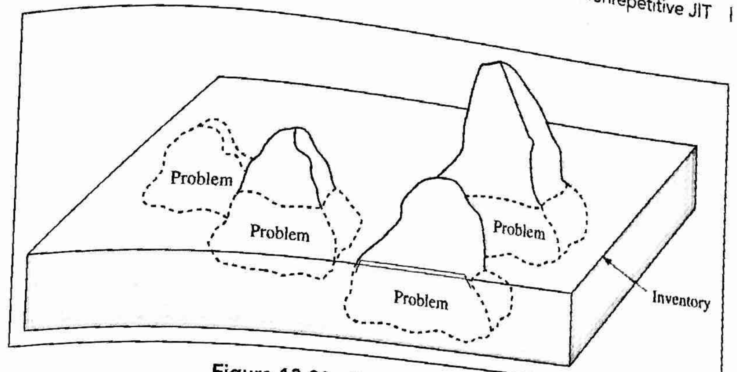


Figure 13.20 Toyota's View of Inventory

These rules keep the shop floor under control. The execution effort is directed toward flawlessly following these rules. Execution is also directed toward continual improvement. In kanban terms, this means reducing the number of kanban cards and, thereby, reducing the level of work-in-process inventory. Reducing the number of cards is consistent with an overall view of inventory as undesirable. It's said at Toyota that inventory is like water that covers up problems that are like rocks. Figure 13.20 depicts this viewpoint. If the inventory is systematically reduced, problems are exposed—and attention can be directed to their solution. Problems obscured by inventory still remain.

Nonrepetitive JIT

Many JIT principles for high-volume repetitive manufacturing apply in low-volume production environments as well. However, most low-volume manufacturers have balked at two basic problems: (1) the requirement of setting up high-volume flow lines dedicated to a few products and (2) level loading. However, merging of the two camps is taking place: even for the high-volume repetitive manufacturer, it's increasingly important to respond to customer pressures for greater flexibility in volume, product mix, and other service features. The lower-volume job shop manufacturers are in turn learning to adapt JIT concepts to their environments.

A Service-Enhanced View of Manufacturing

An examination of service operations provides insights into producing products faster with greater variety. Rapid response is critical, the number of possible product/service combinations continues to grow, end-item forecasting is more difficult, and large buffer inventories are unacceptable.

All of this argues for a JIT mode of manufacture—one whose objective is to be able to accept any customer order and turn it out right behind any other, with flexibility to handle surges in volume or mix changes, all done on a routine basis. The traditional JIT view of level capacity must be adapted in nonrepetitive situations. Responsiveness to fickle demand requires a large bandwidth in terms of surge capacity. No one wants the fire department to be operated at high capacity utilization; immediate response is essential. Surge capacity must be in place in both equipment and labor. A different view of asset management and labor utilization is required. Fixed assets (both capital and people) will be less intensively utilized to increase material velocity and overall system responsiveness.

Flexible Systems

Leading-edge firms are coming to understand requirements for volume and product flexibility. Some have had experience in repetitive manufacturing applications of JIT and are now moving into nonrepetitive applications. An example is a telecommunications equipment manufacturer, which began JIT in its high-volume telephone handset operations. The firm had a limited number of high-selling models; in two years its inventory turns were tripled, work in process was reduced by 75 percent, failure rates in manufacturing were cut in half, and setup times fell 50 percent. Thereafter, the firm turned to its low-volume telecom systems plant, where more than 150 basic circuit boards were manufactured, and every end item was somewhat of a custom order. The company learned it needed to go back to the basics of JIT—product engineering, process engineering, and the whole person concept—to successfully implement JIT for its nonrepetitive products.

The firm developed cellular designs, began cellular manufacturing with great flexibility, and cross trained people with an emphasis on being able to handle volume surges in the telecom systems plant. MRP was still used for overall planning, but far fewer transactions were processed by the hidden factory of indirect labor. In the first six months, first pass yields improved 27 percent, work in process fell 31 percent, and manufacturing cells under JIT hit 100 percent of schedule. The people then helped out other parts of the company that were behind schedule!

Simplified Systems and Routine Execution

A major issue in any JIT firm, repetitive or nonrepetitive, is flow times. Work must flow through the factory so quickly that detailed tracking is not required. A related idea is

responsiveness. In several JIT systems for nonrepetitive environments, the firm installed what might be called a **weekly wash.** In its simplest form, weekly wash means week 1's sales orders become week 2's production schedule.

The weekly wash approach to JIT for nonrepetitive manufacturing shifts the emphasis from scheduling material to scheduling time blocks. The focus is on what's scheduled in the next time frame, rather than on when we'll make product X. This focus is driven by the actual requirements, rather than a forecast of needs. It's as though we were scheduling a set of trains or buses. We don't hold the train until it's full, and we can always cram a few more people into a car, within reason. By scheduling trains on a relatively frequent basis, attempting to keep capacity as flexible as possible, and assigning "passengers" only to a time frame, responsiveness to actual demand can be increased, and detailed scheduling can be made more simple.

Joint-Firm JIT

JIT has been applied and misapplied by companies with their suppliers. Some firms simply ask the suppliers to buffer poor schedules. On the other hand, when done well, a joint JIT approach can lead to greater bottom-line results for both firms and increased competitiveness in the marketplace. It is critical to understand the need for joint efforts in JIT. For example, we are told by several automotive component suppliers that they are able to provide lower prices to Toyota than other firms, because Toyota is easy to do business with—the company makes a schedule and sticks to it. Others change their requirements often, with serious cost implications.

The Basics

The first prerequisite to joint-firm JIT is a scheduling system producing requirements that are reasonably certain. Without predictability, JIT for vendors is a case of the customers exporting the problems. Although this may work in the short run, in the long run it can't. We've seen a factory where JIT benefits were extolled, only to find a new paving project—for vendors' trucks. Inventory had moved from the warehouse to trailer trucks! Similar war stories abound about warehousing firms in Detroit that are needed to buffer suppliers as auto companies implement JIT.

Joint-firm JIT needs, to whatever extent possible, a stable schedule. This is consistent with level schedules for the repetitive manufacturer. To the extent that a firm makes the same products in the same quantities every day—without defects and without missing the schedule—a supplier firm's schedule is extremely simple. For the nonrepetitive manufacturer, the issue isn't leveling as much as it is avoiding surprises. The level schedule may be violated in nonrepetitive environments, but there is a greater need for coordinated information flows and, perhaps, larger buffer inventories. However, there's a major difference between a *stable* (albeit nonlevel) schedule and one that's simply uncertain. The only cure for the latter case is buffer inventories.

Certainty is a relative commodity. A vendor might be able to live fairly well with a schedule that's unpredictable on a daily basis but very predictable on a weekly basis. A weekly MRP-based total, with some kind of daily call-off of exact quantities, could be reasonably effective. In fact, some firms have developed "electronic kanbans" for this purpose. The notion of weekly wash could also be used; that is, an inventory equal to some maximum expected weekly usage could be maintained and replenished on a weekly basis. For high-value products, it might be worth it to go to some kind of twice-weekly wash, or to obtain better advance information from the customer via an e-based system.

Other "basics" for joint-firm JIT include all the objectives and building blocks discussed earlier in the chapter. A JIT basic uniquely associated with suppliers relates to pruning their number. Many companies have reduced their vendor base by as much as 90 percent to work on a truly cooperative basis with the remaining vendors. Hidden factory issues have to be considered in vendor relations as well. Some people feel the secret in joint-firm JIT is to connect MRP systems in the firms. This isn't a good idea. The focus must be on coordinated execution. A better approach might be to use blanket orders (or *no* orders), MRP for weekly quantities, agreed-upon safety stocks, or amounts by which the sum of daily quantities can exceed weekly totals, and e-based systems to determine the next day in-shipment. All this could be done without intervention of indirect labor personnel.

A telecom equipment manufacturer has such a system: Each day at about 4 p.m., an e-mail is sent to a vendor specifying how many of a particular expensive item to deliver the day after tomorrow. The units delivered never enter a stockroom or inventory record. They're delivered directly to the line without inspection and assembled that day. The vendor is paid on the basis of item deliveries into finished goods inventory. Stability is handled by providing the vendor weekly MRP projections, using time fences that define stability. Daily fluctuations reflect actual market conditions.

Tightly Coupled JIT Supply

Major suppliers to automobile manufacturers utilize JIT extensively. As an example, consider a seat supplier and an automobile manufacturer. In such a case, the two firms need to develop a form of synchronous manufacturing, operating almost as a single unit. The execution is driven by JIT. JIT execution between these two firms means that the automobile manufacturer will pass the exact build sequence (models, colors of seats, etc.) to the seat supplier, perhaps something like 30 hours in advance. The supplier needs to *build* the seats and deliver them in this time frame. Seats are not built to inventory at the supplier, and no seats are inventoried at the auto manufacturer. The seats are delivered directly to the assembly line, to match the sequence, so the assembly team simply takes the next seat, and installs it in the next car.

This synchronization allows for almost no transactions between the firms, with the supplier paid by backflushing completion of cars off the line. Inventory costs are avoided, as well as damage from multiple handling with minimal use of protective packaging. But achieving the synchronization on a continuous basis requires *flawless execution* in both firms. The auto manufacturing company cannot change the schedule or take a car off of the line for repairs, since this would change the seat installation sequence. The supplier must make each seat perfectly, since there is no stock of seats to replace one that is imperfect. The bottom line here is that this form of joint-firm JIT is highly productive. But it is rigidly connected and requires joint excellence in execution. It works well—for certain kinds of products.

Less Tightly Coupled JIT Supply

In the majority of cases, two firms will not couple their manufacturing activities as closely as those of a seat supplier to its automotive customer. The supplier will have multiple customers, only some of which will be supplied by JIT. Similarly, the customer has multiple suppliers, and not all of these will be expected to deliver directly to the line. An alternative solution is for the customer to pick up goods from vendors on some prearranged schedule. This is increasingly done for several reasons. The most obvious is the savings in transportation costs over having each vendor deliver independently. In some cases JIT has been called "just-in-traffic." A second reason relates to stability and predictability. If the customer picks up materials, some uncertainty inherent in vendor deliveries can be eliminated. Finally, pickup offers more chances to directly attack hidden factory costs. The customer can, for example, provide containers that hold the desired amounts and that will flow as kanbans through the plant. Savings in packaging materials as well as costs of unpacking are helpful to both parties. Items can also be placed on special racks inside the truck to minimize damage. Defective items can be returned easily for replacement without the usual costly return-to-vendor procedures and paperwork. Other paperwork can similarly be simplified when third parties aren't involved and when the loop is closed between problem and action in a short time frame.

JIT Coordination through Hubs

A relatively new innovation that has JIT characteristics is the supply of materials through hubs. A hub is most easily seen as an inventory, placed close to the customer, and filled by the suppliers. The costs of carrying the inventories is born by the suppliers, and they are paid for their goods either as they leave the hub or as they are backflushed into finished goods at the customer. This form of supply is called **vendor-managed inventory (VMI)**.

VMI is well liked by customers, since it moves inventory carrying costs off their books and onto those of the suppliers. But the "no free lunch" principle applies: If the customer only exports its problems, and does not aid in the solution, the prices will have to be adjusted to make this work. Moreover, the firm with the lowest cost of capital in the chain is ideally suited to absorb inventory-carrying costs.

There is, however, a major potential saving in this relationship. When it is done well, the supplier should eliminate its own finished goods inventory, while the customer in turn also eliminates any inventories of these materials. All inventories are in the hub and are visible to both customer and supplier. The customer needs to take the responsibility for providing highly accurate information on its expected removals from inventory (i.e., its build schedules). This is typically provided via an e-based system. The supplier thus has *knowledge* of exact customer usage: no forecasts (guesses), and no surprise orders. The supplier also has the option of working in what we call the **uphill skier** mode, where it is the supplier's responsibility to supply, but in whatever ways it wishes (just as the uphill skier has the responsibility for not colliding with the downhill skier). Having a few customers who can be supplied with the uphill skier concept allows the supplier to use its capacities and logistics more effectively. For example, if a supplier knows the customer will take 55 units out of inventory 11 days from today, this provides a window for manufacturing and delivery, which is much less constraining than classic JIT coordination.

Lessons

The primary lesson to be learned in joint-firm JIT is to not shift the execution problems from the customer back to its suppliers: joint-firm JIT means *joint.* Many firms have made this mistake, demanding that their suppliers support them in closely coordinated execution—while the suppliers see the customer as "waking up in a new world every morning." Typically, when the consequences become known, the emphasis necessarily shifts to joint problem identification and solution, a focus on joint (chain) measures, the need for stabilized schedules, a true partnership, and help from the customers for the suppliers to implement JIT with *their* suppliers. The results for a manufacturer of office equipment were impressive: overcoming a 40 percent cost disadvantage, reducing its vendor base from 5,000 to 300, and winning several important awards for manufacturing excellence.

JIT Software

The MPC systems required to execute JIT are relatively straightforward. Most ERP systems include software that supports JIT execution. Figure 13.21 shows how this software typically functions.

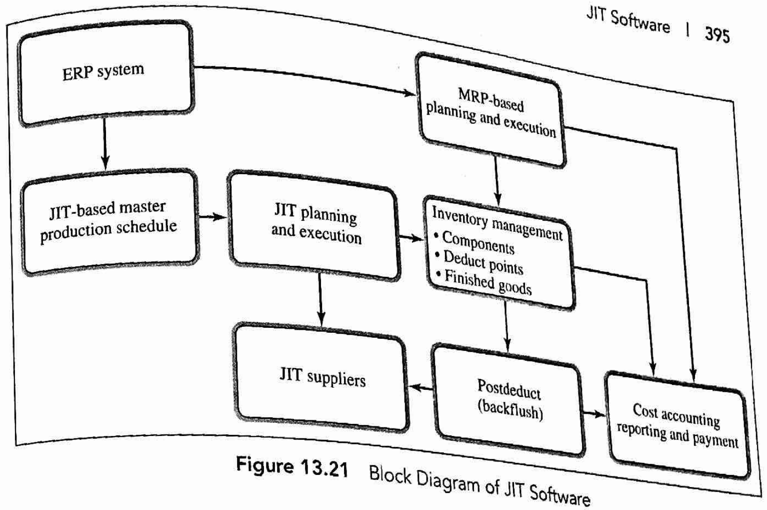


Figure 13.21 Block Diagram of JIT Software

The MRP-JIT Separation

Figure 13.21 depicts the way JIT typically functions as a part of the overall MPC system. An ERP system, such as SAP, provides the overall platform and integration with other company systems. Figure 13.21 shows a split into those items that are to be planned/controlled with JIT and those that will utilize classic MRP-based systems. For the JIT products, it is necessary to first establish a master production schedule, which typically is rate based. This MPS is then passed to a JIT planning and execution subsystem that utilizes simplified bills of materials (phantoms) and cellular manufacturing. The detailed planning is also passed to JIT suppliers, typically with an e-based system providing the exact build sequence.

JIT Planning and Execution

JIT planning and execution is driven by a daily build schedule, supported by the JIT dictates of flawless execution, zero failures, no buffer inventories, cellular manufacturing, pull systems, cross-trained personnel, etc. JIT planning and execution also utilizes an inventory management subsystem for any components that are planned with MRP-based systems. This subsystem also keeps track of finished goods, any hub inventories, and **deduct points.** A deduct point is a stage in the manufacturing process where the inventories for certain parts are backflushed. That is, in some JIT systems, the backflushing is not held off until the goods are finally passed into finished goods inventory. The accounting is done in stages. This is most usually seen in early stages of JIT, when the flow times are longer and the yields less certain. The use of deduct points also helps in migrating from MRP-based planning to JIT-based planning/execution. In fact, a typical improvement is to decide when a deduct point can be eliminated, since a deduct step requires production reporting to indicate that product completion has reached this stage. Figure 13.21 also depicts an accounting/reporting subsystem to collect performance data and support supplier payments.

Managerial Implications

The vision of JIT presented here is much broader than manufacturing planning and control. JIT is best seen as an integrated approach to achieving continued manufacturing excellence. A holistic view of JIT encompasses a set of programs, as well as a process where human resources are continually redeployed in better ways to serve company objectives in the marketplace. In the balance of this chapter, we feel compelled to speculate a bit on what this implies for manufacturing planning and control and related areas.

Information System Implications

Because JIT requires changes in the ways manufacturing is managed and executed, changes are required in the computer-based systems to support JIT manufacturing. The changes run counter to some classic IT systems in manufacturing. JIT calls for continuous improvement, reducing transactions, and eliminating the hidden factory. This implies an ongoing migration of MPC systems to support reengineered manufacturing processes. To the extent that JIT is for nonrepetitive manufacturing, personal computers are often used on the shop floor to support detailed scheduling. For joint-firm JIT planning and execution, the increasing use of e-based systems is taking place. In practice, there tends to be an evolution from simple buying and routine transaction processing to more coordinated work, including new product developments and other less structured activities. Many firms now are implementing extranets to support these objectives, where individual company pairings work on achieving increasingly unique benefits.

Manufacturing Planning and Control

JIT has profound implications for all detailed MPC activities. JIT (including its extensions into less tightly linked supply chains) offers the potential for eliminating or sharply reducing inventories, incoming quality control, receiving, kitting, paper processing

associated with deliveries and shipments, detailed scheduling done by central staff, and all the detailed tracking associated with classic production activity control systems. It is important to understand these benefits as the MPC system is enhanced to embody JIT thinking. Many of them are well hidden.

It is never easy to change IT systems. Organizations have grown around them, cost accounting and other areas seem to require data generated by these systems, and many jobs are involved. However, the potential is real, and leading-edge companies are increasing their competitiveness through JIT and related concepts.

Scorekeeping

A firm adopting JIT in its fullest context will need to think carefully about reward systems and managerial scorekeeping. Traditional measurement systems focus attention on producing the products, using cost accounting systems that have changed little since the Industrial Revolution. These systems are from an era when direct labor was the major cost source. Now, in many companies, material costs dominate, with direct labor cost (using traditional definitions) continually decreasing in relative importance. Far too many manufacturing firms are hobbled by antiquated measures such as tons or other overall productivity measures. For example, a large ice cream manufacturer evaluates its factories on "liter-tons" produced. A 1-liter brick of ice cream has less gross margin than a particular ice cream bar—but 1-liter bricks are always put in inventory at year-end to make the numbers look good.

JIT thinking focuses on material velocity, which is consistent with inventory reduction and lead-time compression. Under JIT, we must be wary of how "costs" are measured and the resultant implications for decision making. The values of bandwidth, flexibility, responsiveness, and worker skill enhancement need to be recognized. None of these is incorporated in traditional accounting systems. The entire approach to capacity utilization needs to be rethought in JIT. Utilization of capital assets may not be as important as responsiveness and material velocity. Being able to take any customer order, even when vastly different from forecast, and doing so with short lead times with minimal use of "shock troops" is the goal. Improved responsiveness to marketplace needs will separate successful firms from the also-rans.

What all of this means for cost accounting is that many traditional views will need to be scrapped. For example, some companies have given up the cost category of direct labor. The distinction between direct and indirect isn't useful, and basing product costs on multiples of direct labor cost leads to more erroneous implications than some other scheme. The whole person concept leads to the conclusion that the labor pool is an asset to be enhanced. It also dictates using direct labor for activities not normally associated with direct labor. Trying to apportion labor into various categories is constraining. A final scorekeeping issue is the top-management challenge to create the organizational climate where the JIT/supply chain management journey can best take place. We see this journey as the best means for survival in the years ahead. Leadership will be required to guide manufacturing firms through the necessary changes.

Pros and Cons

There are situations where JIT will work well and ones where it won't. Many authorities believe JIT to be what every Japanese company strives for. In fact, many Japanese firms with complex product structures are now actively working to implement MRP-based systems. However, JIT's realm seems to be expanding. At one time JIT was thought to apply only to repetitive manufacturing with simple product structures and level schedules. Increasingly, companies are applying JIT concepts to nonrepetitive schedules; product complexity is being partially overcome with decentralized computing on the shop floor; make-to-order schedules are being adapted to JIT; and JIT is being applied to interfirm contexts.

Some companies ask if they need to install MRP before adopting JIT, since JIT implementation often means they must dismantle parts of the MRP-based system. Although it's conceptually possible to implement JIT without first implementing MRP, for firms that can benefit significantly from MRP, it's usually not done. Unless we can find some other way to develop the discipline of MRP, JIT operations are at great risk. In the discipline's absence, when JIT takes away the buffers, there will usually be costly disruptions of the manufacturing process, poor customer service, and panic responses to the symptoms rather than to the underlying problems.

Concluding Principles

This chapter is devoted to providing an understanding of JIT and how it fits into MPC systems. Our view of JIT encompasses more than MPC-related activities, but there's a significant overlap between JIT and our approach to MPC systems. In summarizing this chapter, we emphasize the following principles:

- Stabilizing and in some cases leveling the production schedules are prerequisites to effective JIT systems.
- Achieving very short lead times supports better customer service and responsiveness.
- Reducing hidden factory costs can be at least as important as reducing costs more usually attributed to factory operations.
- Implementing the whole person concept reduces distinctions between white- and blue-collar workers and taps all persons' skills for improving performance.

- Cost accounting and performance measurements need to reflect the shift in emphasis away from direct labor as the primary source of value added.
- To achieve JIT's benefits in nonrepetitive applications, some basic features of repetitive-based JIT must be modified.
- JIT is not incompatible with MRP-based systems. Firms can evolve toward JIT from MRP-based systems, adopting JIT as much or as little as they want, with an incremental approach.

APICS/CPIM Certification Questions

1. Just-in-time (JIT) systems replace discrete manufacturing batches with
   a. Work-in-process
   b. Kanbans
   c. Production rate goals
   d. Cellular manufacturing
2. In a just-in-time (JIT) system, the goal is to reduce which of the following factors?
   I. Setup times
   II. Defects
   III. Forecast errors
   a. I only
   b. II only
   c. I and II
   d. I and III
3. TPM is an acronym for which of the following?
   I. Total preventive maintenance
   II. Total planned maintenance
   III. Total productive maintenance
   a. I only
   b. I and II only
   c. I and III only
   d. I, II, and III
4. The concept of *poka-yoke* refers to
   I. Making operations foolproof
   II. Designing processes to evaluate quality as production occurs
   III. Pull systems
   a. I only
   b. I and II only
   c. I and III only
   d. I, II, and III