INTEGRATING MRP II WITH JIT

J. Nicholas Edwards – Coopers & Lybrand (Thames Valley Region Fellow)

I. Introduction

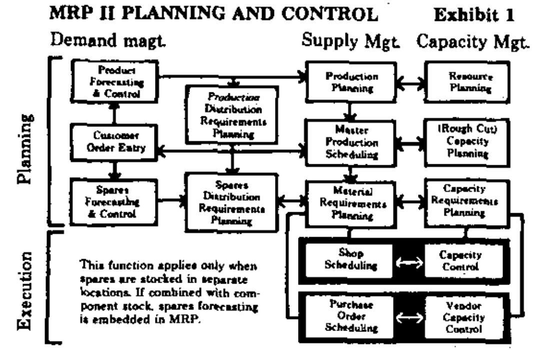
Over the last 35 years, US industry has been developing methodology in three independent areas of manufacturing: Manufacturing Engineering (CAD, CAM, etc.), Quality Assurance, and Production and Inventory Control (Manufacturing Resource Planning or MRP II).

Starting later and building on many US ideas, Japan, using a more integrated approach, has been developing a methodology encompassing all of these areas into a manufacturing strategy named Just-In-Time or JIT. Although JIT is not an inventory control technique, its dramatic effect in reducing manufacturing lead times and inventory caught the attention of many innovative minds in the Production and Inventory Control arena. Unfortunately, the planning and scheduling techniques of MRP II, specifically the Material Requirements Planning Module (MRP), appeared to its advocates to be in competition with the scheduling concepts of JIT. The "MRPers," especially the technicians and promoters of MRP, felt threatened by the "JITers." The "MRPers" failed to grasp the fact that JIT represents a manufacturing philosophy within which techniques such as MRP can be applicable.

Rethinking the way we manufacture is key to understanding JIT. This includes process simplification, elimination of waste, and synchronization through uniform plant load. MRP II, on the other hand, emphasizes organization, discipline and control; something that should occur before, during and after we simplify the process. If we are directed to the control aspects of MRP II alone, we could, to quote Ed Parrish, formerly of Black & Decker, a long-time Class A MRP II installation, "become trapped by the MRP mentality" where storeroom control *and lot sizing is often emphasized over process management.* MRP II advocates support the elements of JIT that stressed minimizing setups, quality defects, lead time and inventory reductions. They also support the value of flexible manufacturing cells, improved supplier performance, and level loading. The conflict between "MRPers" and the "JITers" appears to centre around process flow and scheduling due to reduced lead times. These lead times, dramatically reduced because of manufacturing with lot sizes approaching one, mean that we can start producing products as needed and can schedule it by 'Kanbans" or "Pulls" received from the next higher operation. Again it bears repeating that *the key to understanding JIT is that it begins by rethinking the way we manufacture.*

In order to better understand how MRP II interfaces with JIT, we will first begin with a review of the basic functions of MRP II and then a review of how JIT came into being.

MRP II PLANNING AND CONTROL **Exhibit 1**



MRP II Functions

From our perspective, we feel MRP II functions can best be shown as a matrix (Exhibit 1). We first divide the matrix horizontally into planning and execution activities and we further divide these functions vertically into demand, supply and capacity elements. The planning elements of MRP II are all vital to the success of any manufacturing strategy. In fact, US efforts, starting in the late 1950's to provide computer-based information support, have highly developed sophisticated functions such as:

Order Entry
Forecasting
Production Planning
Distribution Planning
Capacity Planning
Master Scheduling

We have witnessed the evolution from pioneering efforts in the early 1960's of Material Requirements Planning where many companies on their own were attempting to find a better way to plan parts as the Order Point system or the Project Control methods just were not sufficient for the management of inventory. With the mushrooming computer capabilities, many companies such as Black & Decker, JI Case, General Railway Signal, Jones & Lamson, Twin Disk, and others independently installed material planning systems to plan material at all levels of a product by using bills of material to create requirements in an "explosion" process, At each level, requirements were netted against inventory, both on-hand and on-order, to plan new supply orders (manufactured or purchased). This was fundamentally an order launching process. In time, this was refined to include "pegging" to give visibility to the source of the requirements. This allowed for better priority planning capabilities so that shops would work on the most important jobs first.

The next advance of MRP included the incorporation of the Master Production Scheduling (MPS) function to drive MRP. The MPS process was to plan end items or key option level components, first for availability and then for load impact. This resulted in MRP systems that were expanded to include capacity or resource planning and shop floor management systems. As part of this enhanced process, MRP was renamed MRP II (Manufacturing Resource Planning). MRP II was intended as a means of developing total control for manufacturing from initial planning to the latest priority in Shop Floor Control.

MRP II systems of the 1980's have now been refined to support many characteristics. These include multi-plant environments, single- and multilevel pegging, "as-plannned" and "as-built" configuration control, product control on a project-by-project basis, and repetitive manufacturing control where material is controlled by schedules instead of job lots. However, the original thrust of MRP has continued to remain the planning of material by part for how much and when needed.

JIT Background

JIT was largely developed by Toyota over a fifteen-year period starting in the early 1960's with significant gains having been made by the mid-1970's. At that time, Toyota was not a participant in MRP development.

JIT, as Toyota developed its methodology, virtually bypassed MRP because they worked toward a philosophy of extending the assembly line back through all the feeder operations (including the supplier network). Their goal was to put raw material in at one end, one piece at a time, and produce a car at the other end, one car at a time, with no interruption of the flow along the way. Their approach was to integrate and, thus simplify manufacturing. In a broader sense, the emphasis of many years of effort was to eliminate all forms of waste that would not add value to the product. Dr. Cho, of Toyota, sums it very well. Waste is "... *anything other than the minimum amount of equipment,* materials, parts and workers (working time) which are *absolutely essential* to production . . ." As part of this program to eliminate waste, quality improvement and programs to reduce defects were instituted to ensure that parts were made right the first time. This is one of the essential points to get away from "Just-In-Case" inventory to a "Just-In-Time" philosophy. Inventory itself was considered a waste of money and space, since effort had to be expended first to store the material, then to retrieve it, an even greater waste was considered to be a computer system that tells an operator which material, when, and how much is needed. Finally, reactivity to real demand necessitated an aggressive attack on set up times so that the lot size corresponded to usable demand.

In Toyata's drive to reduce waste, other aspects came along such as the need to schedule final assembly lines to avoid surging of components. This meant that instead of making trucks at the beginning of the month and sedans at the end, there was a mixed model assembly of both vehicles every day so that the manufacturer of truck axles would be continuously busy as opposed to either working feverishly at the beginning of the month and being without work at the end of the month or building inventory.

As part of the simplification process, they developed Kanban, a scheduling concept that works on the principle that each feeding operation replaces what is consumed by *the next succeeding operation — no more, no less.* MRP need not be eliminated by this approach — it performs a capacity and commodity planning function but is no longer required for individual part number planning or priority scheduling. It may be an over-simplification, but MRP deals with planning; JIT deals with operations and execution. The portion of Exhibit 1 showing the execution phase is drastically simplified and quite different under JIT. For a company evolving to JIT, the key connecting link can be Material Requirements Planning and scheduling; that is until JIT is sufficiently advanced to allow the "pull" *system concept with its negative feedback principles* to take over the detail scheduling.

This direction of process simplification at Toyota is in contrast to the MRP II approach where the emphasis was to pre define the manufacturing process and then attempt to manage the process with a computer system. This MRP task is accomplished by first quantifying base data such as bills of material, on-hand and on-order balances, and then using a series of logic rules (explosions, planned orders, etc.) to present information to manage the process to closer tolerances. Said another way, JIT is a dynamic process of *improvement while* MRP II *is a static* re-affirmation of accepted ways of doing things.

II. The Integration of MRP II into JIT

With the dramatic reductions in lead times and lot sizes that a Just-In-Time environment creates, the operation of MRP should be significantly altered as a planning tool. In practice, an eventual goal would be to have the combined manufacturing lead times shorter than the customer delivery lead times. For example, Toyota pours its engine block just 36 hours before it goes out the door in a car! Surprisingly, this is not nearly so dramatic as it appears. Henry Ford, in his 1925 booklet on "The Ford Motor Company", discussed how the River Rouge plant was designed to process iron ore and deliver cars in 33 hours. (Unfortunately, Henry Ford and the Ford process were extremely inflexible and almost caused the demise of the company.) Therefore, the first schedule of 10 days at Toyota exceeds its internal combined manufacturing lead time by many days.

With short manufacturing lead times, it becomes *practical to manufacture* to real demand. This expands to improved "forecasting" with suppliers, for their loads will be more accurate as the total internal manufacturing lead times are in hours and days, as opposed to weeks. In order to better understand the impact of JIT on MRP we propose that it be viewed from three different but overlapped perspectives:

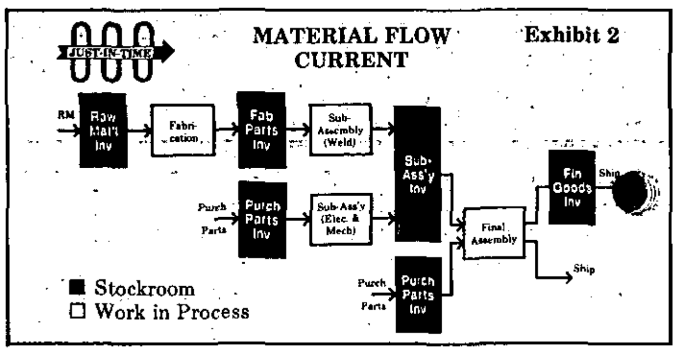
JIT/MRP Perspectives

1. Material Flow and Tracking
2. "Front End" Planning and Control
3. Material Planning and Control

The material flow and tracking deals with the relayout of the factory to reduce the footage travelled and the impact on inventory transaction processing. The "Front End" Planning and Control portion includes the Production Planning, Master Production Scheduling, Customer Order Entry and Final Assembly (or product) Scheduling. The Material Planning and Control area deals with the features needed in MRP to plan JIT controlled parts as well as MRP and Min-Max controlled parts.

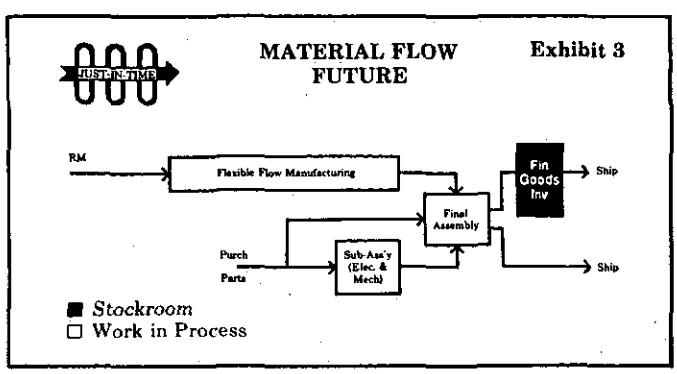
III. Material Flow and Tracking

One of the fundamentals of JIT production is the concept that the flow of material through the shop is always moving and the amount at any point in time is so small that elaborate tracking systems are both impractical and unnecessary. The reason is that with operations linked *closely together in space and timing, the product is visible* and factory control is simplified. Unfortunately, JIT is not implemented all at once. Thus, our first step is to highlight the migration of the material flow process.



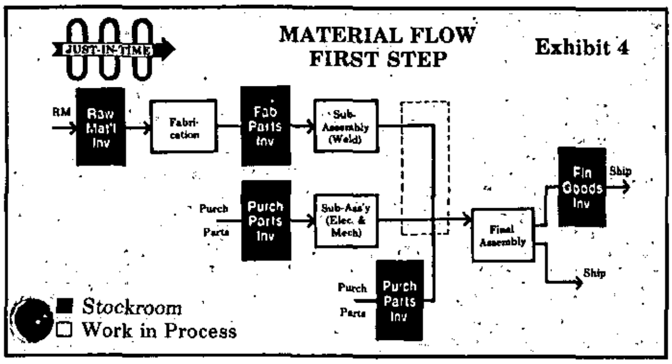
Material Flow

In order to gain an overview of the manufacturing process, the first step is to develop a picture that shows the current manufacturing flow through existing stockrooms and manufacturing areas. The following exhibit is an example of a typical batch flow (Exhibit 2).



The next step is then to develop a conceptual design of how material eventually would flow, integrating both fabrication and subassembly operations into final assembly. The material flow may look like Exhibit 3.

Once the conceptual design or goal has been established, we need to recognize that a JIT implementation is migratory. Therefore, interim flows that reflect temporary stockrooms should be identified. Exhibit 4 indicates the first major milestone in a typical JIT implementation sequence, i.e., the linking of subassembly manufacture directly to assembly, thus eliminating the subassembly storeroom.



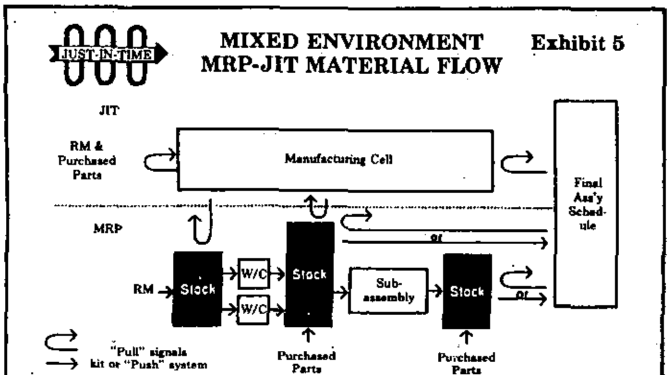
MRP not only must be able to adapt to these process improvements, it must be able to intelligently track material to these modified material flows until the goal is realized.

Material Tracking

Theoretically, material tracking in a JIT environment is not needed as the "pull" card or container is the only authorization for material to be moved. However, in order to migrate to this environment, a plan must be developed to change from a job lot environment to a rate or flow environment.

In MRP-scheduled environment, material tracking includes the timing of when a job is opened and material is allocated, how and when material is issued, when material is "transformed" to a higher level, and finally, when a job or a schedule is closed out. This is called a "push" environment where detail schedules and pick lists "push" material to the floor. The system must also recognize whether the particular process is in a "job" shop environment or a "rate" shop environment as different MRP "netting" logic may be used.

As the manufacturing process migrates into Just-In-Time where operations are synchronized, a shift to a "pull" environment occurs where the "using" operation gets or "pulls" material from a feeding operation, thus authorizing the feeding operation to make more material. This simpler "pull" environment does not require schedules, priority lists or pick lists, as the authority to make material is generated from the "consumer" of that material with its "pull" card!



A pictorial example of how this mixed "push" and "pull" environment follows as Exhibit 5.

Therefore, before we achieve a pure JIT environment, we most likely will operate a combined MRP JIT environment, where there may be at least three methods of tracking material:

Manufacturing Environment	WIP Tracking Method
Job Shop MRP	Job Orders
Repetitive MRP	1. Job Orders (as Lots) 2. Schedules (as gateways) 3. Floor-on-Hand (schedules are not netted)
JIT	Floor-on-Hand "Four-Wall" Inventory

The traditional job order approach (using requirements for shortages) is well understood. The repetitive manufacturing approach may use either Job Orders or Schedules to track material on the floor where schedules are effectively job orders for a defined period of time, e.g., a week. Unfortunately in some repetitive environments, job orders are still used to batch material, which is contradictory to the flow concept. Either way, netting is done against the job orders or schedules. As part of the material tracking approach, the process of transacting individual material issues to a job may be replaced by "backflushing" Work-In-Process (WIP) to reduce transaction volumes. Backflushing is the process where component material is "consumed" or "issued" upon completion (or occasionally start) of a job. A second, more preferable, repetitive tracking of WIP is to use floor-on-hand balances along with backflushing as completed material passes a "gateway" count point. These floor-on-hand balances represent the *quantity of a component on the floor regardless of whether* this component is now part of a subassembly. This means that job orders and/or schedules are *not* recognized in the netting process, only the floor-on-hand balances of components and assemblies.

In a JIT environment, material is "pulled" and the role *of material tracking is theoretically not necessary.* However material tracking is a valuable "audit assist" in highlighting potential imbalances and bill of material problems. In either case, the amount of transactions are significantly reduced.

Finally, the Shop Floor Control function in a JIT environment is not needed to track material since visibility of material is the key to JIT, making shop move *transactions and paperwork unnecessary. The issue of* labor data collection for cost data is a related issue and usually assumes a similarity to process costing.

Material Delivery

The key difference between MRP and JIT is in the delivery of material to the next higher operation. In an MRP (push) mode, pick or kit lists are the usual method of getting and delivering material to the floor. Quite often this material is "pushed" to a staging area whether or not material is required since the schedule instructs that the items be picked. This push is also used by many companies to assure adequate stock on hand, which adds no value.

In a Kanban environment, material is not "delivered". In actuality the using operation goes and gets (pulls) material from the supplying cell. This "pull" then becomes the authorization for the supplying cell to make a predefined quantity of the same item just pulled. It should be noted that in a job shop environment where the same item is rarely repeated the pull signal becomes the authorization to commence manufacture of the next predetermined block of work (usually 2-4 standard hours worth).

IV. "Front End" Planning and Control

Effective "front end" planning is key to the success of either an MRP II or JIT operating environment. In order to get an overall perspective on the planning process, it is first necessary to discuss what is necessary for pure JIT Planning and Control and then progress to a mixed environment where both MRP II and JIT are involved.

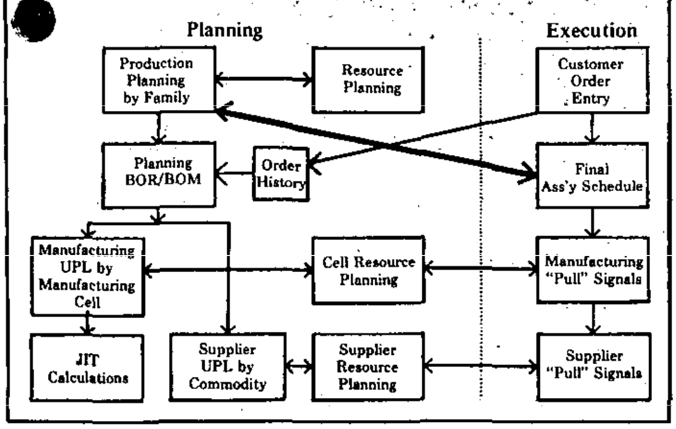
Using the MRP II Planning and Control Chart (Exhibit 1) as a reference, the Demand Management functions are primarily for distribution activities if needed The Supply and Capacity Management functions are more significantly altered. Specifically, the Production Planning function may be the only capacity or resource planning function in a JIT environment, especially if planning is by major families. When the entire materials continuum is synchronized to a final assembly scheduling function, customer orders (or finished goods stock replenishment orders for seasonality management) become the only people-managed schedule for the factory.

JIT Planning and Control

Both MRP II and JIT have the same starting point in the manufacturing planning process: a Production Plan by family. In an MRP II environment, the production planning process balances the market forecast along with the customer order backlog and/or the finished goods inventory to achieve a Production Plan. In a JIT environment, the production planning process is altered to balance the production plan to the market forecast by managing the manufacturing capacity through variable cell manning. By tracking the variability of customer ordered options in an order history assumulator, the JIT production planning process can be enhanced to include an option planning capability.

The Production Plan becomes the input to both the detail JIT planning functions as well as the limits for Final Assembly Scheduling (FAS) as shown in Exhibit 6.

JIT PLANNING AND CONTROL — Exhibit 6



The purpose of the Production Plan is to develop the Uniform Plant Load or "drum beat" by focused factory using a combined Bill of Resource and Bill of Material (BOR/BOM). The "drum beat" calculations are nothing more than determining the frequency in time that the product comes off a given line. This is expressed as "cycle time" in the automotive industry. "Cycle time" in the electronics industry often means lead time, ergo, the use of the "drum beat" phrase to avoid confusion. The "drum beat" (demand cycle time) along with the demand rate and lead time becomes the basis for the required JIT calculations such as standard cost revisions, cell manning and supplier demand rates or capacity required.

The Final Assembly Schedule (FAS) portion in JIT effectively replaces the Master Production Scheduling process in MRP II. The role of the Master Production Schedule in MRP II serves two functions, first to check for availability of product, and second, to check for load. In the JIT environment, the final assembly schedule is primarily to check for load by ensuring customer orders or finished goods stock replenishment orders meet but not exceed the Production Plan from the "planning" perspective as well as to sequence the final assembly schedule. The "availability" issue which balances supply schedules and on-hand balances against demands is secondary, for the JIT goal is to manufacture all products to the customer order as needed. The emphasis then is on planning and execution as opposed to demand and supply, since we plan product in families for capacity purposes and execute with end product numbers. This effectively eliminates the need to develop "planned" supply orders as in MRP II environments.

Also, if purchase lead times are short enough, then the supplier can deliver his material to "pull" signals without the use of "planned" purchase order.

In a pure JIT environment we only need a production plan at the family level (Level-1, if we call the end product Level-0) and final assembly schedule of customer orders (Level-0).

In summary, the JIT planning approach reduces to the following:

"Front End" Planning & Control
JIT Environment

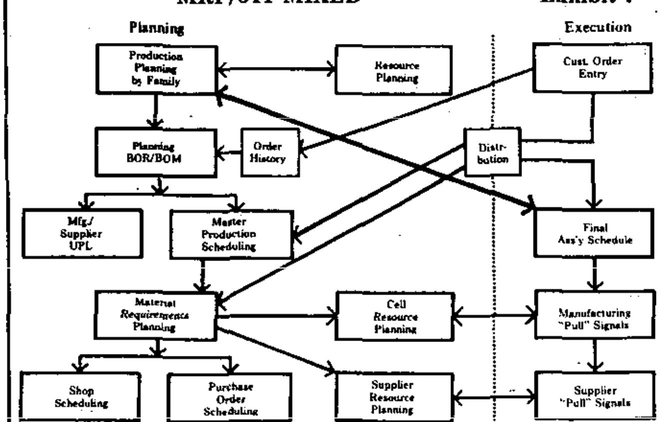
Manufacturing Approach	Planning Approach
Focused Factory	Production Plan-Level-1 (Family Level) Final Assembly Schedule End Products-Level-0 No Master Schedule

MRP II-JIT Interface

A dual environment occurs when manufacturing processes are partially managed by MRP II and partially converted to JIT. First it is important to recognize that material flow will be mixed. Some portions of the operations will be on a "push" environment while others will be on a pull environment. Exhibit 5 previously discussed in material tracking is an example of how this might operate.

With this mixed environment, an MRP II planning mode must be integrated with the JIT planning mode. Exhibit 7

MRP/JIT MIXED — Exhibit 7



highlights the merging of the key elements of MRP II Planning and Control with JIT Planning and Control. The key point is that the customer order must now be checked against a "distributor" function where a file look-up determines whether a part is JIT controlled or MRP II controlled.

For MRP II parts a second breakdown then determines which are Master Schedule controlled and which are MRP controlled. Because all JIT parts are effectively an extension of the assembly line, JIT parts are phantoms for planning purposes. Independent demand parts, such as spares, can end up as either MRP II parts or be controlled as JIT parts, if set up in their own focused lines.

In a mixed MRP II JIT environment, many different front end planning and control approaches may be utilized. The following summarizes some of these additional alternatives.

Front End Planning and Control

Manufacturing Approach	**Planning Approach**
Focused Final Assembly Lines	Production Plan-Level-1 (Family Level) Final Assembly Schedule. End Products-Level 0 No Master Schedule
Option Oriented Assembly Lines	Production Plan-Level-1 (Family Level) Master Schedule Level-1 (Major Subassemblies) Final Assembly-Level-0 (End Product) **OR** Production Plan-Level-1 Family Master Schedule-Level-0 ("Typical" End Products using *percentage bills of* material) Final Assembly Schedule -Level-0

As manufacturing migration occurs, usually through the Family Master Schedule approach, the method of planning and scheduling becomes simpler. The net result is that significant overhead savings can be achieved in the JIT Production Planning-Final Assembly Scheduling environment, since fewer parts planners are required.

V. Material Planning and Control

The third major area affecting MRP II in a JIT environment is in material planning. In a pure sense, material planning in JIT is done from the pull signals, as actual lead times are reduced. The only planning needed is for resources and commodity availability. In an MRP environment material planning is done with planned orders so that dependent demand on components can be developed through the explosion process. The ciritical issue becomes the process of moving from planned orders to pull signals while still satisfying the existing materials systems function.

MRP Migration to JIT

For the MRP migration toward JIT, a means must be developed that eliminates the need for planned orders. The first step is to enhance the MRP system to recognize schedules instead of using job orders. When a schedule approach is used, the MRP planning process nets against floor-on-hand balances at specific gateways. When an item "crosses" a gateway as a "completion," it adds to the on-hand quantity at the higher level and reduces the on-hand quantity of the lower level component. This allows for planning without using planned orders yet still retains the MRP planning environment with a net requirements explosion.

Next, the material planning portion of MRP II needs to be altered to highlight capacity or resource issues for JIT-controlled parts. The reason is that intermediate levels are not stocked and material planning under JIT is done at execution time with pull signals. Since Capacity Requirements Planning (CRP) is not required for JIT, the other need for planned orders is eliminated.

The MRP system in a JIT environment can be used to plan for cell manning, pull card volumes and cost standard recalculations. This requires a gross explosion capability not only by part number but also by supplier commodity group or manufacturing cell. For those parts not managed by JIT, this gross explosion can be used as a side benefit for estimating usages on Min-Max (reorder point) parts to compare with historical usage.

As discussed previously, material planning by part number through the use of planned orders does not occur in JIT. The order release function of MRP II is eliminated *as an execution function, for in a JIT environment,* work is both authorized and prioritized by the use of the "pull" system. In those situations where the manufacture of a product is not repetitive, then the "pull" signal is an authorization *when* to manufacture product and the gross explosion of the final assembly schedule determines *what* is to be manufactured or delivered by a supplier in sequence to the final assembly schedule.

For many MRP II purchasing systems, the planned purchase orders and released open orders are tracked on an order-by-order basis. Cooperative or JIT purchasing has the need to plan on a commodity basis for capacity and rate purposes only. The execution again will be handled by the pull system. Additionally, JIT purchasing systems must have the capability of planning commodity demand for capacity purposes. Exhibit 8 summarizes this MRP to JIT material planning migration.

MATERIAL PLANNING & CONTROL **Exhibit 8**

Migration Steps

Job Orders → Schedules/Rate

Rough Cut Capacity and Capacity Requirements Planning → Resource Calculations From Gross Explosions

Planned Order By Part Number → JIT Calculations by Commodity Group

Order Release → Pull Signals

Many MRP practitioners thought that a JIT environment could be closely approximated in MRP by planning with small lot quantities. The MRP environment in fact becomes complicated. Specifically, if material is to flow in daily or hourly quantities, the normal MRP approach would attempt to plan in daily or hourly discrete quantities. This may be impractical due to the long computer run times and mounds of exception signals or reports. Therefore, a longer planning interval of a week is usually used. That creates the need to develop a subsidiary daily scheduling system under MRP for the daily or hourly quantities. This becomes difficult to maintain.

When an MRP system plans for up to a weekly schedule the corresponding requirements may be a week's worth of material. However, material must be fed to the line in a daily or more frequent basis. To overcome this, pegged dependent requirement records would need to recognize both a "release interval" for delivery in addition to the normal "required" and "issued" quantities that already exist in a "push" approach. In this small lot MRP approach, it is necessary on the released parent assembly schedule, to show the expected daily rate along with the lot size or schedule quantity planned for longer running times – over one day. Experience has been that this complicated approach is unnecessary. Why not convert to a "pull" approach when ready?

VI. Other Issues

During the transition to JIT, other factors which affect manufacturing operations need to be addressed. These include engineering change control, cost accounting and performance measures.

Engineering Change Control

When a high degree of Engineering Change Notice (ECN) exists, there is less material in the pipeline in a JIT environment. When an ECN occurs, the only way to revise the manufacture of a product is to change the sequence of the pull system. The most practical way to assist in this process is to have multi-level pegging capability in MRP for the different configurations. This will allow the generation of revised pull cards. When the multi-level pegging capability is not available, then the process must be accompanied manually during the change-over either on an emergency basis or at the time of reproduction planning.

Cost Accounting-Standard Costs

The standard cost systems that currently exist may have to be modified to have a minimum of two standard costs with a method to approximate monthly actual costs in a process cost approach.

These costs are:

Standard Cost (F):	Beginning-of-Year for Inventory Valuation purposes throughout the year.
Standard Cost (V):	Most current (by month) based on latest process routing and production plan
Actual Costs Based On:	Material consumed Direct labor (may be part of variable overhead) Variable overhead based on criteria other than direct labor, e.g., cost drivers Fixed overhead

In a JIT environment there is no job costing, only a period costing of material and all variable costs of labor and overhead divided by the pieces produced to yield a cost per piece. The remaining fixed costs would most likely be charged based upon an expected monthly volume. Therefore, the "actual standard" calculated at the beginning of the month would be determined from the standard material cost plus all variable costs of direct labor and overhead. Variable costs would include material handling, inspection, maintenance and most any other labor related activity. Even depreciation, which should convert from a period approach to a depreciation per piece produced can be variable. The intent would be to have rent and other related items as the only fixed costs. This would be prorated based on expected volume.

The BOR/BOM can be expanded to include these factors. The Production Plan and Resource requirements are already part of the system. Thus, all the necessary data required to develop variable standard costs are resident in the modified MRP II database.

Performance Measures

Under a Just-In-Time philosophy, many of the existing MRP II measures become superfluous or inappropriate. The following are seven non-financial measures recommended:

1. **Schedule Attainment**
   This is a measure of how many units were produced as a percentage of the plan. There is no change here to existing MRP II measures.
2. **Schedule Linearity**
   Linearity to a schedule measures how well we perform to each day's schedule completion on an absolute basis. This applies to model mix not just the total schedule. For example, a schedule of 100 units per day could yeild the following results:

Day	Schedule	Actual	Absolute Variance
1	100	80	20
2	100	90	10
3	100	130*	30
	300	300	60
Daily average	100	100	20

$$\text{Linearity} = \frac{100 - 20}{100} = 80\%$$

*In a JIT environment, the 130 could not be produced unless the feeder operations were on a push environment and an extra 30 parts were in the pipeline.

Even though the actual production met the schedule, the linearity was only 80% as there was an average of a *20% swing each day.*

3. **Productivity at a Plant Level**
   Productivity at a plant level should be measured by the value earned as the product leaves the factory net of returns compared to the cost incurred.
   $$\text{Productivity} = \frac{\text{Value Earned}}{\text{Cost Incurred}}$$
   This is expressed as a percentage and includes costs of material, labor, and overhead. Coincidentally, this measure can serve as the basis of a gain-sharing program that would eliminate an existing piecework system.
4. **Productivity at a Focused Factory or Cell Level**
   Productivity at the cell level should be mesured by the earned hours of direct and indirect hours credited for scheduled completions compared to total hours expended.
   $$\text{Productivity} = \frac{\text{Earned Hours}}{\text{Total Hours}}$$
5. **Target Inventory and Investment Turn Rate**
   Calculate a target inventory based on lead times, lot sizing, safety stocks and transit times. These should be initially calculated by part number then summarized by ABC class, commodity group, and inventory category. Possible inventory categories could include:
   Finished Goods Stores
   Assembly WIP
   Purchased Parts/Fabricated Parts Stores
   Fabrication WIP
   Raw Material Stores
   Finally, these targets should be summarized for the

entire operation. By comparing these to the actual inventories by the same groupings, targets of opportunity can then be highlighted. The target and actual inventories can then be converted to an inventory turn rate which serves as a management tool for prioritizing these continuous improvement efforts.

6. **Lead Time Reduction**
   The improvement in supply lead times should be highlighted. These can be shown by reductions in:
   Part Number Lead Times and Combined Lead Times for:
   - Manufacturing
   - Purchasing
   - "From Stock" Components
7. **Quality Measures**
   The effectiveness of the quality programs should highlight all costs of quality including office losses as a percent of cost sales. This breakdown should include:
   - Internal Failure Costs
   - External Failure Costs
   - Appraisal Costs
   - Preventing Costs

   These measurements have the most significant impact as they are available to everyone to highlight the impact of employee involvement. The concept of MRP being used as a productivity tracking tool has been long espoused. The MRP data base is an appropriate repository for these "productivity" measures. Some examples are:
   - Lead time reduction from the item master file
   - Linearity from schedule completions and backflushes for components
   - Quality input from gateway tracking
   - Earned versus planned hours productivity control from a Standard Routing data base
   - Target inventory and investment turns from the Inventory or Part Master data base

   Trending of any of the above data could be obtained from a monthly history of data maintained in each file.

VII. Summary

MRP and JIT are synergistic. If a company does not currently operate with MRP then it may be advisable to start with JIT since the MRP system required to support the effort would be considerably simpler than those currently available. If, on the other hand, there is an existing MRP system then the user should be aware of the modifications required to compliment, not impede JIT implementation.

A number of principles that should guide the MRP/JIT effort follow:

- MRP is the planning tool; JIT is the execution function.
- Significant changes must be made to existing MRP systems.
- MRP must migrate with JIT implementation.
- Computer systems should enhance; not deter, lead-time, space, and headcount reductions.
- Systems improvements in and of themselves do not improve productivity; it is process simplification that makes for significant improvement.

It is the merging of MRP into JIT philosophies that will result in significant gains in customer service, as well as the reduction of both inventories and operating costs.

References

Master Scheduling: Its New Importance in the Management of Materials. *R. Evedell, Modern Materials Handling, Oct. 1972.*

Master Production Scheduling in a Repetitive Manufacturing Environment: A Case Study. *J. N. Edwards, APICS Conf. Proceedings, Oct. 1982*

The Production Plan: The Top Management Interface *R. Evedell, APICS Conf. Proceedings, Oct. 1982*

Integrating JIT with MRP *J. N. Edwards and J. W. Anderson, APICS Conf. Proceedings, Oct. 1983*

Integrating JIT with MRP: An Update *J. N. Edwards and J. W. Anderson, APICS Conf. Proceedings, Oct. 1984*

Master Scheduling for a Just-In-Time Environment *J. N. Edwards, APICS conf. Proceedings, Oct. 1985*

About the Author

J. Nicholas Edwards is a Director in the National Manufacturing Consulting practice. He specializes in manufacturing consulting with primary emphasis on Just-In-Time, Flexible Flow, and manufacturing control systems. Prior to joining Coopers & Lybrand, he was Vice President of Rath & Strong Production and Inventory Control organization.

He was one of the originators of the PIOS manufacturing control system now offered by McCormack & Dodge and adapted by Cullinet.

He has been a regular lecturer at the American Management Association and American Production and Inventory Control Society. He is a Certified Management Consultant of the Institute of Management Consultants, and a founding member of the Association for Manufacturing Excellence, a society dedicated to enhancing excellence in manufacturing through Just-In-Time practices.He is a member of APICS, having been certified in Production & Inventory Management (CPIM) at the Fellow level, and a member of the American Society for Quality Control.

Editor's Note: Nicholas Edwards is leading a JIT course for the Society on 7-9th November — see page 7 for details.