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Theory and Methodology

Focusing material requirements planning (MRP) towards performance

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Abstract

This paper looks at the successes and disappointments of MRP. It studies numerous articles to determine what the key shortcomings of MRP are. Next, it investigates if these failures are correctable, and what the consequences of not correcting these deficiencies means. This article considers alternatives that have been discussed in the current literature. Last of all this article discusses whether the improvements these alternatives suggest are sufficient to make MRP worth salvaging, or whether MRP is a system that needs to be discarded in favor of systems such as JIT (Just-in-Time), Optimized Production Technology (OPT), Theory of Constraints (TOC), and Bottleneck Allocation Methodology (BAM).

Keywords: Material Requirements Planning (MRP); Manufacturing Resources Planning (MRP II); Bottleneck Allocation Methodology (BAM); Schedule Based Manufacturing (SBM), Just-In-Time (JIT)

1. Overview

Material Requirements Planning (MRP) has fallen into disfavor during the last ten years, as demonstrated by the extensive literature and conference material coming out of organizations like the American Production and Inventory Control Society (APICS) which discuss its shortcomings (Berger, 1987). MRP has received intense challenges of its effectiveness from Japan. This stems from the belief that there must be one best production planning and control system and that since the Japanese are out-performing the West in automobile and electronic components production, their system must be better. It is believed that the only thing that is still keeping so many manufacturers with MRP is the difficulty in converting to the JIT process, which requires the overhaul and reorganization of the entire factory (Plenert and Best, 1986; Plenert, 1990b).

The effectiveness and appropriateness of MRP, verses other production planning philosophies like the Japanese JIT, is determined by numerous criteria, as will be further discussed in this article. For

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example, some of the criteria are the depth of the Bill of Materials, the methods of buffering capacity, the existence of bottlenecks, the repetitiveness of the process, the repetitiveness and reliability of the forecast, etc. These types of criteria will be utilized to consider the appropriateness of each of the numerous production planning systems that exist.

A large number of alternative production control systems have jumped in and have been proclaimed as the new, best, leading edge philosophy. These include the Japanese Just-in-Time (JIT), Optimized Production Technology (OPT) which has been renamed, expanded, and repackaged as Theory of Constraints (TOC), and Finite Capacity Scheduling systems like Bottleneck Allocation Methodology (BAM) (Plenert, 1990a; Plenert, 1987) and Schedule Based Manufacturing (SBM). The objective of this paper is to analyze and identify the uses of MRP.

The Japanese Just-in-Time (JIT) environment seems to be the least-cost production control tool, reducing inventory levels and reducing manufacturing lead times. Most of the cost advantages of JIT occurred when large inflation increases resulted in large increases in the cost of carrying inventory (Plenert and Best, 1986; Plenert, 1993a). However, looking at MRP's basic philosophy, we should be able to focus our scheduling only on what materials are needed, and when they are needed (Plenert, 1990c; Ritzman et al., 1984; Chase and Aquilano, 1995; Lee and Schniederjans, 1994; Nahmias, 1997; Schroder et al., 1981). MRP allows greater flexibility in product customization. Even the Japanese realize this and use MRP in their Job Shops in Japan. From the author's experience during a one year research project in South-East Asia, he found that Japan rarely uses JIT outside of Japan, and uses MRP in more of its developing country factories than all other production systems combined, including JIT. For example, based on the author's one year research effort in South-East Asia, where Japan is the dominant investor, there are no JIT systems utilized in Japanese plants, including automotive and electronics components manufacturing. Rather, they use the MRP production scheduling process. What does Japan see in MRP? Let us start by looking at the differences between MRP and JIT. Then let us look at which of these differences are the inherent characteristics of the system, and which are the result of incorrect implementation of the MRP system.

2. The differences between MRP and JIT

There are differences between MRP and JIT that need to be characterized in two ways, design differences and usage differences. By design, MRP schedules and tracks every production or purchasing order (Orlicky, 1975). It works with the assumption that every order is potentially unique (Plossl and Wight, 1967). It does scheduling using a set of five key inputs, as shown in Fig. 1. It then goes through a scheduling process and creates a set of four key outputs. The tracking and status of these outputs then completes a feedback loop that inputs them back into the MRP scheduling process. It is this intensive data tracking and activity scheduling that gives MRP the reputation of being overburdened by data accuracy requirements and computing needs (Plenert, 1993b; Al-Hakim and Jenney, 1991; Al-Hakim et al., 1992; Chase and Aquilano, 1995; Lee and Schniederjans, 1994; Nahmias, 1997).

JIT, on the other hand, works on the assumption, that the production process is repetitive and that product variation is allowable only within a fairly narrow range, narrow enough to where the production process will not be adversely affected

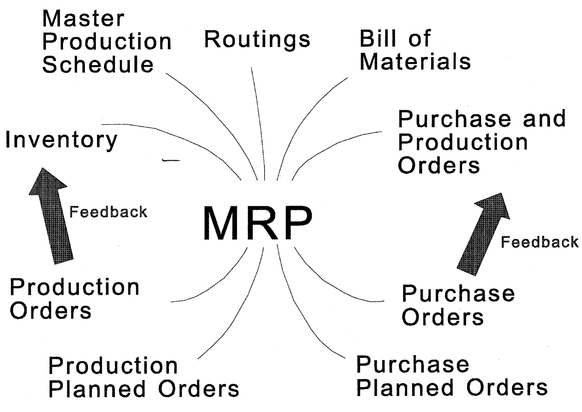

Fig. 1.

by the product change. JIT also works with production orders that are all the same size (KANBANs) at some minimal level. In effect, JIT is a very product inflexible, highly repetitive process (Plenert, 1990b).

JIT was developed by the Japanese during a time of limited resources, limited capital, and high unemployment. This resulted in the development of a production control system that focused on getting the materials in and out of the production process as quickly as possible (Materials Efficiency). However, this materials efficiency is only achieved at the expense of inefficiencies in other resource areas, such as labor.

Some companies are so resource inefficient that any improvement in any resource area is a net gain. However, if companies fall into the realm of being highly competitive, then there is generally a trade-off in resource efficiencies. For example, labor efficiency is increased by becoming more materials inefficient. In other words, in order to be labor efficient, we have to make sure that our workers have plenty of materials to work on. The result is that materials are stock-piled in front of the work station. This is caused by labor-based routings (rather than machine or materials based routings) which focus attention on labor efficiency and cause materials inefficiencies. Similarly, materials efficiency focused systems, as in the case of JIT, achieve their efficiency by creating inefficiency in other resources. For example, in a JIT line we have a series of workers each being fed materials, through the use of KANBANs. Unless you have an empty Kanban, you are not allowed to work or else you would be considered as someone who is generating waste. However, in a JIT line, it is impossible to balance the work load of all the workers equally. Since the employees are doing different functions, some employees will always be busier than others. The speed of the entire production process moves at the speed of the slowest worker. Therefore, most of the employees will have some wait time in the production process, which is the labor inefficiency that is generated by a drive for materials efficiency.

In looking at the usage differences of MRP, we find that even though MRP was not specifically designed to have labor based routings and a labor based production order tracking system, it almost always does. The production lead times are labor based, and the production traveler reports labor starts, stops, and efficiencies. Because of this, through its usage rather than through its design, MRP has become a labor efficiency oriented system, where production lead times are used to build buffer inventories in front of work stations so that labor efficiencies can be maximized (Berger, 1987). The shop floor data collection process reports labor performance based on what is tracked in these routings, and efficiency reporting is reported back against the standards that have been built into these routings. Other resources, like machine hours, could be used as the basis for these routing and also for systems like CRP and resource requirements planning, but labor is almost always used. Labor efficiency can only be achieved at the expense of inefficiencies in other resource areas, such as materials.

It is the Western obsession with labor efficiency that has taken MRP and focused it on labor-based lead time management. The MRP routings are scheduled based on labor lead time, and the data collection process is focused on labor efficiency and labor performance standards. These lead times are generally inflated to support labor based efficiencies to the point that 90–95% of the manufacturing lead time of a product is spent in wait, hold, queue, etc., which are all areas of staging inventory to support labor efficiencies. These inventory levels (stagings) do not support production throughput and inventory minimization, as MRP was designed for, rather, they make sure that there is always enough work in front of each work station in order to keep employees busy.

The following is a recap of the design differences between MRP and JIT:

Area	MRP	JIT
Product flexibility	High	Narrow range
Order tracking	High degree	None
Data accuracy	High	None
Computational needs	Lots	Minimal
Scheduling flexibility	High	Poor
Shop layout	Flexible	Restricted

Product flexibility refers to the range and variety of different products that the production process will allow. Order tracking means the degree to which each order is monitored through the production process. Data accuracy refers to the data accuracy requirements of the inputs to the production control system. Computational needs identifies the amount of computer power required. Scheduling flexibility allows a variety of products to be scheduled via any number of routings. Shop layout describes how restricted the organization of the shop floor is.

The following is a recap of the usage differences between MRP and JIT:

Area	MRP	JIT
Production lead time	Very long	Very short
Production batch size	Large	Small
Resource efficiency focus	Labor	Materials
Inventory levels	Large	Minimal
Set-up time	Averaged	Minimized

Production lead time defines how long the total manufacturing lead time for a product is. Production batch size compares the average batch sizes for each system. Resource efficiency focus looks at which resource this system is attempting to optimize. Inventory levels looks primarily at work-in-process inventories, but also includes raw materials and finished goods. Set-up time explains the priority placed on set-up time reductions.

In comparing MRP and JIT, we need to consider what elements make JIT more cost effective. Let us start by looking at the typical repetitive discrete manufactured product, like an electronic components or automotive product. A comparison of the value added breakdown is interesting. In both the JIT and the MRP case, the labor component is about 7–9% of the product's value added component. Similarly, in the case of the materials component, we find comparable product value added effects in the range of 50–60%. What is interesting is that in the value added effect of inventory, the JIT calculation of the value added effect includes the cost of financing inventory, but in the MRP case, the cost of financing inventory is included in the overhead component and is not in the inventory component. This is strictly an accounting difference between the two systems; in the case of MRP, inventory financing is not a cost of the inventory itself whereas in the Japanese version of JIT it is. This makes the inventory cost contribution (book value) higher in the case of JIT.

If the carrying cost of inventory were to be included as part of the cost of materials in the MRP evaluation, we see from 10% to as much as 25% increase (depending on the level of inventory) in the value added component effect of materials (the 60–85% range). Therefore, the inventory carrying cost has a larger effect on the value added component of our end product than does labor. Understanding this, and also understanding that labor efficiency improvements can only be done at the expense of materials inefficiency, we now realize that a 10% improvement in labor efficiency (less than 1% overall) usually costs us much more in materials inefficiencies. Therefore, improving labor efficiency can actually hurt our profitability. This point is also brought out in the OPT/TOC philosophies (Goldratt and Cox, 1986; Goldratt and Fox, 1986).

If, as is true in the case of most discrete manufacturing, the largest value-added resource is materials, and we focus our efficiencies on labor, then we can have the situation where increasing labor efficiencies can decrease profitability. For example, in automobile manufacturing, the value added content of labor is about 7–8%, and the value added content of materials is around 50–55%. If we increase labor efficiency by 10% (0.7–0.8% overall), but if this increase costs us a drop in materials efficiency (this trade-off was discussed earlier in the paper) of 2% (1–1.1% overall) we have a net loss of profitability of about 0.2–0.4% overall.

3. The differences between MRP and OPT/TOC or BAM

In a similar comparison we find the design differences between MRP and OPT/TOC:

Area	MRP	OPT/TOC
Product flexibility	High	High
Order tracking	High degree	Fairly high

Data accuracy	High	High in limited areas
Computational needs	Lots	Some
Scheduling flexibility	High	Good
Shop layout	Flexible	Flexible

To recap the usage differences between MRP and OPT/TOC we have:

Area	MRP	OPT/TOC
Production lead time	Very Long	Medium
Production batch size	Large	Vary
Resource efficiency focus	Labor	Bottleneck
Inventory levels	Large	Medium
Set-up time	Averaged	Adjusted

The distinguishing characteristic of OPT/TOC is that the operation needs some form of bottleneck around which to focus its efficiencies. This bottleneck usually takes the form of some type of machine with limited capacity. Driving this bottleneck to efficiency optimizes the usage of the bottleneck which, according to OPT philosophy (but not satisfactorily proven), optimizes the throughput and profitability of the entire plant (Plenert and Lee, 1993).

In the case of BAM (Plenert, 1990a; Plenert, 1987), we also focus on achieving overall profitability and assume that there are some constrained or limiting resources within the facility.

BAM is a process that starts with capacity, and then attempts to fit production schedules into the available resources. It uses MRP's lead times as the minimum lead times available and schedules out from there. MRP's lead times cannot be inflated with wait, hold, and queue times that unnecessarily stretch the total manufacturing lead time. BAM is an attempt to merge MRP and Capacity Requirements Planning (CRP) into one integrated optimization routine.

The BAM process then optimizes the schedules within these parameters. In a comparison with MRP, we find the design differences between MRP and BAM to be:

Area	MRP	BAM
Product flexibility	High	High
Order tracking	High degree	Low
Data accuracy	High	High in limited areas
Computational needs	Lots	Some
Scheduling flexibility	High	Good
Shop layout	Flexible	Flexible

To recap the usage differences between MRP and BAM we have:

Area	MRP	BAM
Production lead time	Very long	Variable
Production batch size	Large	Smaller
Resource efficiency focus	Labor	Constraint
Inventory levels	Large	Medium
Set-up time	Averaged	Minimized

At this point we need to look at the inappropriate applications of MRP that have occurred in its usage. These incorrect uses, not the design differences, turn out to be the primary elements behind the deficiencies of MRP.

4. The incorrect uses of the MRP system

The focus of this discussion now shifts to an analysis of the uses (or abuses) of the MRP environment. To start with we can look at production lead times. It has already been thoroughly demonstrated in the research that the majority of the lead time, over 95%, is non-productive time. Lead time includes elements like queue time, waiting time, transfer time, etc., all of which are much larger than the actual production time. These lead times cause a batch of one to take almost the same amount of time to produce (schedule through the production process) as a batch of 100. We establish these long lead times as a buffer for labor efficiency. We plan to have several days worth of work in front of each work center in order to help the employees keep their efficiencies up. In other words, as stated earlier, we are sacrificing our inventory efficiency in order to gain labor efficiency. The error is not in our lead time development only, the error is in our being so focused on labor efficiency that we are negatively effecting ourselves. This directly affects our fourth MRP usage topic, inventory levels. By looking at the competitive systems, it would appear that we should throw out labor standards and labor performance measures, and institute measures of inventory performance. For example, a measure of inventory levels or a measure of scrap and rework, would be more helpful in reducing overall production costs. This focuses on our third usage difference, resource efficiency focus.

The next topic, production batch sizes, ties in with the previous topics of production lead times, inventory levels, and resource efficiency focus. We will soon see that all the misuses of the MRP systems tie together. When we look at batch sizes we see that the MRP uses the Economic Order Quantity (EOQ) cost minimization curve as a given, without thinking that it has any control over what the optimal batch size should be (see Fig. 2). However, the other production control systems don't take the batch size (Q) as a given. See the JIT example in Fig. 3. In Fig. 3 we see how JIT focuses on reducing ordering cost (1 – OC shift) and by so doing reduces total cost (2 – TC shift) and shifts the curve to the left, which in turn reduces order size (3 – Q shift). This directly effects the fifth MRP usage topic, the set-up times. However, as long as lead time is badly inflated as already discussed, a reduction in set-up time, and therefore in batch quantity, will not significantly reduce lead time. This occurs because, as stated, the majority (90–95% percent) of the manufacturing lead time in the MRP production process is composed of wait, queue, hold, transfer, etc. times, and not of set-up and production times. Therefore, the focus should be on the 90–95%, and not on the remaining 5%, of which less then half is set-up time. The lead time reductions have to occur first. We can see that the usage of MRP, not the design of MRP, is causing it to be less than competitive.

Figs. 2 and 3 utilize the fact that the intersection point of carrying cost and ordering cost is also the point of least Total Cost. Recognizing this makes the analysis process easier and removes a lot of the mathematics. The relationship between the intersection and the low point was the subject of the author's dissertation and was proven using Geometric Programming. A discussion of this finding can be found in his article "Bottleneck Scheduling for an Unlimited Number of Products".

In order to cash in on some of the benefits of JIT, while not letting go of the labor efficiency MRP focus, we have established U-lines. These are mini JIT lines that are set up in some of the de-

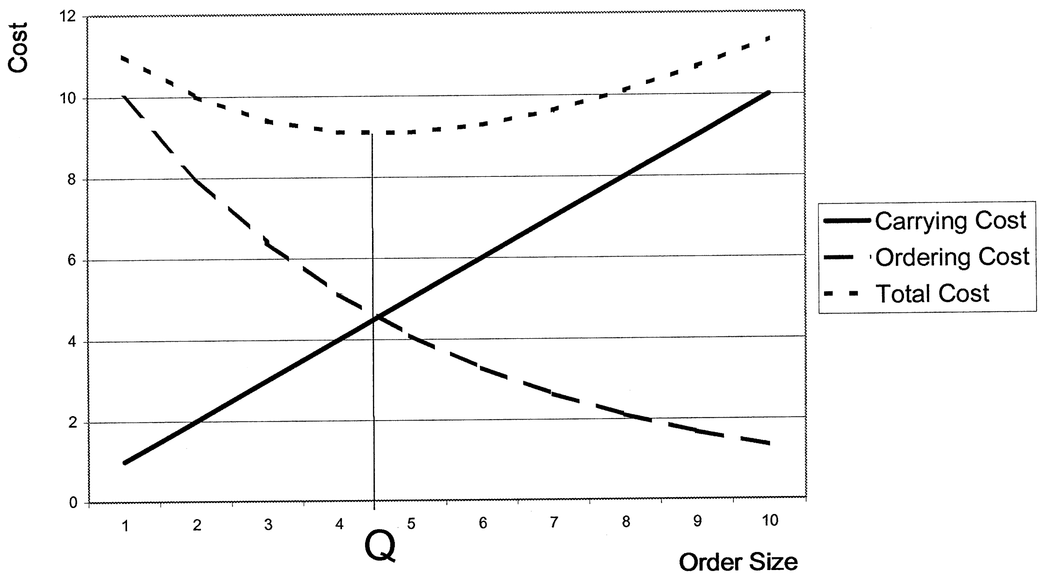

Fig. 2.

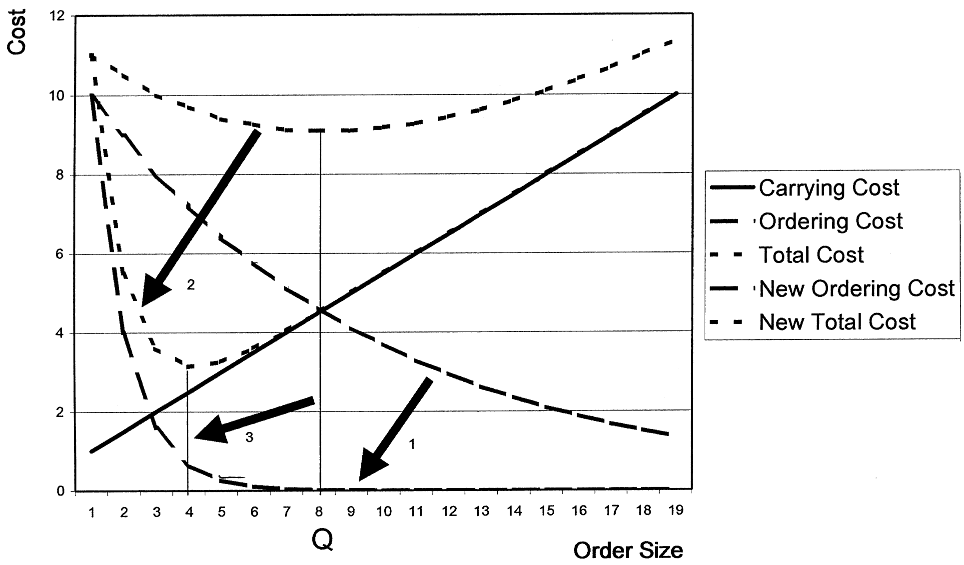

Fig. 3.

partments in an attempt to gain some of the inventory reduction benefits. These U-lines are generally efficient in their usage, unfortunately, they are usually buffered at each end with inventory so as to fit into the batch size needs of the MRP system that feeds into and/or out of the JIT line. In effect, we have two conflicting production priorities – materials efficiency vs. labor efficiency. Although there are inventory reduction benefits available in this type of system, there are greater benefits still attainable with a coordinated focus.

5. Can MRP be competitive with JIT, OPT/TOC, or BAM?

MRP does not need to be competitive with any other system. It is unique, and can stand on it is own in environments that would benefit most from its features. MRP focuses on:

Product variability/non-standardization,
Product customizability,
Flexibility in the production process,
Careful order tracking capability.

Japan is using MRP in its job shops because of the need for flexibility. Japan is also using MRP in most of its overseas installations because of its need for order tracking. If we attempt to run MRP head-to-head with a highly repetitive product that has a simple, sequencable production process, MRP will lose out every time. Additionally, if we try to use MRP in a process manufacturing setting where there is a central focus machine that is a dominating bottleneck, MRP will always lose out to a system like OPT/TOC or BAM. However, if we use MRP to compete with these systems in a highly customized product, we will find MRP to be the winner hands down. In the end, we need to realize that there is no perfect production control system that will fit all situations. We need to be selective when we decide which system we use, and MRP will satisfy many of these situations.

6. MRP clean-up

From this discussion we have learned that it is the usage, not the design of MRP that is causing its competitive shortcomings. The most obvious shortcoming in MRP usage is its focus on labor efficiency. Labor is not the resource that we need to be efficient at, especially since it causes inefficiencies in our most critical resource, materials. We need to minimize our routings, shortening lead times as much as possible. We need to do our buffering using safety capacity (labor and machine capacity buffers), not safety stock (materials capacity buffers). This does not mean that we only include the value-added steps, rather, it means that we should minimize the non-value-added steps to make them as efficient as possible. We need to rebuild the routings focusing on actual, rather than estimated and buffered lead times. This is the basic focus of Finite Capacity Scheduling tools, like SBM and BAM, which have become extremely popular enhancements to the MRP process. The difficulty with these enhancements is that MRP needs to be running correctly and efficiently for these tools to be effective since they add another layer of complexity to the process. These changes in operational parameters might effect the shop layout, product flexibility, and scheduling flexibility of MRP (Zaremba and Prasad, 1995).

By rebuilding the routings we can greatly reduce total manufacturing lead times. We need to move away from labor standards and efficiency measures, and look at lead time as a combination of all the time effects that influence the production time. We need to consider non-productive time elements in lead time as "waste", and we should focus on eliminating this waste. There are some excellent systems that have made these focus and measurement shifts, for example Schedule Based Manufacturing (SBM), developed in Australia has demonstrated tremendous, JIT-like improvements in lead time and inventory reductions (Black and Barker, 1993; Barker, 1993; Hastings et al., 1982), while keeping the flexibility advantages of MRP (Chang et al., 1992). SBM was developed at Bond University in Gold Coast, Australia. It utilizes capacity to define available resources and backward schedules production based on actual value-added manufacturing lead time only.

In refocusing on materials efficiency, we need to focus on the other two big builders of inventory (the first being lead time). These are safety stock and large batch sizes. If our protective buffer is safety capacity, then we should be able to reduce, and even eliminate safety stock in most areas. This would be a tremendous savings in inventory in a category that is now considered "Fixed Inventory Cost" and is not normally evaluated for inventory reductions.

The last of the big inventory builders that needs to be reevaluated is the batch size computation. Reconsidering Fig. 3, we see how JIT reduced batch sizes by reducing set-up times (ordering cost curve). We can do the same in MRP, thereby reducing our batch sizes, and thereby reducing our average inventory levels. Another area that causes large batch sizes is the incorrect definition of lot sizing policies. It is generally recommended that all production products should only use lot-for-lot as the lot sizing policy. Otherwise we are building inventory. Additionally, it is generally recommended that all the 'A' items (ABC analysis based on purchase cost), and most of the 'B' items that are purchased should be lot-for-lot. However, special case situations exist where this general guideline is not always true. For example, Ho and Lau have demonstrated that the Silver Meal rule performs significantly better than the lot-for-lot rule under levels of lead time uncertainty (Ho and Lau, 1994).

The last MRP clean-up item that needs to be focused on is the measurement system. The measurement system (like the job traveler) is not some accounting tool or costing tool, it is an operations tool used to motivate employees. An inappropriate measurement system will motivate employees to do the wrong things. Since we are refocusing employees towards materials efficiency, we need a measurement system that motivates inventory reductions and scrap reductions, not labor efficiencies.

MRP is not a failure, nor is it out-of-date. The MRP concept is alive and valuable. It is our usage of MRP that is out of date, and with the appropriate "clean-up" we can revive MRP by taking advantage of its benefits while at the same time making it more competitive.

7. The future of MRP

MRP has its strength in job shops that require flexibility in the production sequence, in the quantity of production, and in the timing of the production process. That is why the Japanese are looking to MRP in their own job shops. MRP does not need to run head-to-head in competition with any other system on their area of strength. However, even in a repetitive environment, MRP can be made to be much more competitive by adjusting the usage errors that are now incorporated into the MRP environment. That is one of the reasons why the Japanese are using MRP in most of their developing country plants. By refocussing MRP, we can cash in on its strengths, while still remaining competitive against materials focused systems like JIT.

References

Al-Hakim, L.A., Jenney, B.W., 1991. MRP: An adaptive approach. International Journal of Production Economics 25, 65–72.

Al-Hakim, L.A., Okyar, H., Sohal, A.S., 1992. A comparative study of MRP and JIT production management systems. Working Paper, Monash University, Clayton, Australia.

Barker, J.R., 1993. SBM – A working example: An integrated solution of materials and resources for manufacturers. Working Paper 1993-3-088B, School of Information Technology, Bond University, Gold Coast, Australia.

Berger, G., 1987. Ten ways MRP can defeat you. APICS Conference Proceedings, APICS.

Black, W., Barker, J.R., 1993. SBM – A working example: A comparison of schedule based manufacturing (SBM) and MRP II. Working Paper 1993-3-106B, School of Information Technology, Bond University, Gold Coast, Australia.

Chang, C.L., Hastings, N.A.J., White, C., 1992. A very fast production scheduler. International Journal of Operations and Production Management.

Chase, R.B., Aquilano, N.J., 1995. Production and Operations Management. Irwin, Chicago.

Goldratt, E.M., Cox, J., 1986. The Goal. North River Press, Croton-on-Hudson, NY.

Goldratt, E.M., Fox, R.E., 1986. The Race. North River Press, Croton-on-Hudson, NY.

Hastings, N.A.J., Marshall, P.H., Willis, R.J., 1982. Schedule based MRP: An integrated approach to production scheduling and material requirements planning. Journal of the Operations Research Society 33 (11), 1021–1029.

Ho, C.J., Lau, H.S., 1994. Evaluating the impact of lead time uncertainty in material requirements planning systems. European Journal of Operations Research 75, 89–99.

Lee, S.M., Schniederjans, M.J., 1994. Operations Management. Houghton Mifflin Company, Boston.

Nahmias, S., 1997. Production and Operations Analysis. Irwin, Chicago.

Orlicky, J., 1975. Material Requirements Planning. McGraw Hill, New York.

Plenert, G.J., 1987. MRP, JIT, OPT: A study. Proceedings of the Third International Conference on Advances in Production Management Systems (APMS 87), pp. 729–734.

Plenert, G.J., 1990a. Bottleneck scheduling for an unlimited number of products. Journal of Manufacturing Systems 9 (4), 324–331.

Plenert, G.J., 1990b. Three different concepts for JIT. Production and Inventory Management Journal 31 (2), 1–2.

Plenert, G.J., 1990c. International Management and Production Methods; Survival Techniques for Corporate America, Tab Professional and Reference Books. Blue Ridge Summit, PA.

Plenert, G.J., 1993a. An overview of JIT. International Journal of Advanced Manufacturing Technology 8, 91–95.

Plenert, G., 1993b. The Plant Operations Handbook. Business 1 Irwin, Homewood, IL.

Plenert, G.J., Best, T., 1986. MRP, JIT, or OPT, What's best? Production and Inventory Management Journal 27 (2), 22–29.

Plenert, G.J., Lee, T., 1993. Optimizing theory of constraints when new product alternatives exist. Production and Inventory Management Journal 34 (3), 51–57.

Plossl, G.W., Wight, O.W., 1967. Production and Inventory Control: Principles and Techniques. Prentice-Hall, Englewood Cliffs, NJ.

Ritzman, L.P., King, B.E., Krajewski, L.J., 1984. Manufacturing performance – Pulling the right levers. Harvard Business Review, pp. 143–152.

Schroder, R.G., Anderson, J.C., Tupy, S.E., White, E.M., 1981. A study of MRP benefits and costs. Journal of Operations Management 2 (1), 1–9.

Zaremba, M., Prasad, B. (Eds.), 1995. Modern manufacturing information control and technology. Advanced Manufacturing Series. Springer, Berlin.