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ABSTRACT

Material requirements planning (MRP) systems are described as management tools for planning and controlling production operations. A wide variety of industries and production organizations are credited as reporting significant operating improvements in such areas as inventory control, production scheduling, delivery performance, and production costs when MRP systems are used. MRP systems are cited as making significant improvements in the management of plant operations by automating many of the routine decisions involved in scheduling the production of component parts and controlling the inventory levels of these items. This paper points out some of the areas in which additional knowledge would be useful for designing and implementing MRP systems, indicates promising areas of research to gain this knowledge, and reports some initial efforts in research on MRP systems. (Author/MLF)

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The MRP Crusade has been officially closed and pronounced successful. Evidence of this success is found in the growing number of MRP systems that are being installed in industry and the diverse nature of the companies making these installations. Successful MRP system applications have been reported by APICS members from a wide variety of industries and production organizations.[3] These reports describe significant operating improvements in such areas as inventory control, production scheduling, delivery performance, and production costs. Many of these new MRP installations, and the general increase in awareness of MRP system advantages, can be attributed to the MRP Crusade's success in communicating how these systems improve the management of complex fabrication and assembly operations.

MRP systems have made two significant improvements in the management of plant operations. First, they have proven to be an effective tool for production planning. That is, MRP focuses

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management attention on the critical problem of planning at the end-item assembly level, rather than on the multitude of detailed operating problems such as scheduling machines at the shop floor level or controlling the inventory levels of component parts and sub-assemblies. Once these production plans have been formalized, as master assembly schedules, the MRP system computer programs can be used to translate these schedules into detailed operating plans, which show the timing of requirements for purchased and manufactured components.

A second important contribution of MRP systems is in automating many of the routine decisions involved in scheduling the production of component parts and controlling the inventory levels of these items. One example of this contribution is the ability of an MRP system to routinely calculate manufacturing priorities for component parts and sub-assemblies. This enables management to communicate changes in the final product master schedules directly to the shop floor level in the form of revised scheduling priorities for the production of component parts, thereby keeping shop attention centered on the high priority items.

These important contributions provide some of the impetus for the increasing number of MRP system installations noted during the MRP Crusade. There is a risk, however, in declaring the crusade closed. The impression conveyed, by declaring the crusade closed, is that it is no longer necessary to focus attention on MRP systems.

In fact, there are still areas where our knowledge about MRP systems is incomplete, and MRP system effectiveness could be improved by focusing research attention on these areas. The purpose of this paper is to point out some of the areas where additional knowledge would be useful for designing and implementing MRP systems, to indicate promising areas of research to gain this knowledge, and to report some initial efforts in research on MRP systems.

Motivations for Research

While MRP systems do offer the advantages of improving the production planning process and communicating up-to-date priorities for manufactured component parts, one source of difficulty in using MRP systems is in the day-to-day control of lower level component production. In situations where final product demand is known with complete certainty, for several months or more into the future, the master schedule can be used to forecast the usage of lower level components with complete certainty. However, in other situations, where the firm faces uncertainty in the demand for its final products and the master schedules are revised frequently, the MRP forecasts of lower level component usage are subject to forecast errors. In these cases some modification of the MRP system is needed to handle the uncertainty in final product demand.

There are several ways in which MRP systems are modified to accomodate uncertainty in final product demand. Safety stock and safety lead time have been used as devices to compensate for the errors in MRP forecasts of component part usage. Alternatively, master schedules are sometimes frozen for a sufficient period of time to cover the production lead time of lower level components. Finally, the frequency with which MRP systems are run is sometimes increased to allow a more frequent updating of component requirements. Since the computational costs of running MRP systems are often substantial, more frequent runs necessitate techniques such as Net Change Requirements Planning to reduce the computational effort. The use of these devices for improving the performance of MRP systems in controlling production operations suggest the need for a better understanding of the applicability of MRP systems to different operating environments.

Research Needs

Given the promise of MRP systems as a management tool for planning and controlling production operations, further research that is directed toward gaining additional knowledge of MRP systems and their operations, seems desirable. Moreover, given the substantial costs involved in installing an MRP system and the associated risks of system failure, research that is devoted to improving the design of MRP systems and to identifying the critical factors in achieving successful applications seems worthwhile. Some promising directions in which such research could proceed are:

1. The investigation of formal techniques for the decision-making aspects of MRP systems

2. The development of efficient computer software for processing data in MRP systems

3. The analysis of management problems encountered in installing MRP systems.

The first two of these directions deal with the overall design of an MRP system while the third involves conducting field research to study the implementation process among the users of MRP systems. We shall describe several potential areas for research on decision-making techniques for MRP systems and then offer several examples to illustrate the general nature of the remaining two research directions.

<u>Decision-Making Technique Research</u>: A number of the decisions required in MRP systems are made routinely through the application of formal decision-making techniques. A substantial amount of work has already been accomplished in developing techniques for making lot size and timing decisions for lower level components and sub-assemblies in an MRP system.[1,4] Yet, one is able to find very little guidance to help the system designer in choosing among the available lot sizing techniques. As an example, one of the trade-offs faced by the designer in choosing a lot sizing procedure, is the trade-off between the computational efficiency offered by lot sizing heuristics, such as the Part Period Balancing procedure, and the solution quality provided by optimizing procedures, such as the Wagner-Whitin Algorithm. Very few comparative evaluations which would aid the system designer have been reported to date.

Another related decision that is faced by the system designer has to do with determining which product components should be included in an MRP system. Basically, this choice has to do with the selection of a forecasting technique for each of the low level product components. The designer must decide whether MRP forecasts should be prepared for each of the lower level components or, since there are substantial costs associated with bill of material explosions, whether forecasts that are prepared using statistical forecasting techniques such as exponential smoothing would provide satisfactory results for these product components. When the system designer is working in a manufacturing environment where very little uncertainty exists in the demand for final products, and the master schedules are good predictors of the assembly requirements, MRP forecasts of component usage and optimal lot sizing procedures are obvious choices. Yet, such choices are not as obvious in manufacturing environments where substantial uncertainty exists in the demand for final products. Thus, one useful area of research on decision-making procedures for MRP systems is that of providing better guidelines for the system designer in choosing among the decision-making techniques that are presently available for MRP systems.

A second area for research is that of setting safety stock levels for individual product components. The problem of setting safety stocks for product components in an MRP system is not yet well understood and relatively few techniques exist for this problem. In reading the literature describing MRP systems and their application one frequently finds the recommendations that, "safety stocks should either be carried at the end product level or for raw materials."[2] This recommendation implies that the uncertainty which exists in the demand for final products should not be passed down to lower level components from the firm's master schedules. In situations where errors can occur in the MRP forecasts, because of changes in the firm's master schedules, some investment in safety stocks for components might provide a beneficial trade-off against the costs associated with restricting the use of safety stocks to the highest or lowest level in the system. Thus, research that is centered on the problems of determining the amount and location of safety stock in an MRP system may well provide lower overall production costs by enabling a better trade-off to be achieved between inventory carrying and expediting costs.

A final area of research on the development of decision-making procedures for MRP systems concerns the preparation of master schedules. Although many practioners agree that the master schedule is a critical input to an MRP system, the problem of (and techniques for) preparing master schedules remains largely unexamined. One recent analysis of the master scheduling problem has been reported by Tom Vollmann[5]. Vollmann reports a mismatch between the analytical techniques which are presently available for production planning and the master scheduling problem that actually exists in industry. In addition, he reports the development of computer models for preparing master schedules that have been implemented at the Ethen Allen Furniture Company. Because of the critical nature of the master scheduling inputs to an MRP system, this area of research would appear to be very productive in improving the design and operation of MRP systems.

MRP System Software Research: Thus far we have directed our attention to the decision-making techniques for MRP systems. The performance of MRP systems can also be influenced, however, by the design of efficient computer software for processing data in MRP systems. An example of some computer software that can consume considerable computer time is the bill of material processor which explodes the master schedule into time-phased requirements for the low level product components. The design of bill of material processors has attracted important attention during the past decade as more firms have installed MRP systems. Yet, relatively few studies have been reported that describe the problem of designing efficient software for conducting bill of material explosions. Research indicating the impact of product structure features such as the number of component levels, the number of components at each level, or the average number of components per sub-assembly may well be helpful in stimulating work on improved computer software for MRP systems.

Implementation Research: Another area for research, that is virtually unexplored, concerns the analysis of the management problems encountered in installing MRP systems. These problems include the question of whether or not to install an MRP system for a particular manufacturing situation and the determination of the best approach for administering the implementation process. As an example, such research may profitably focus on the development of criteria for deciding whether or not an MRP system is an appropriate planning and control technique for a specific manufacturing process. For example, is the fact that a level by level product structure exists, a sufficient justification for the installation of an MRP system or should factors such as the level of uncertainty in final product demand be considered in determining whether an MRP system should be installed? There is a relationship here with our previous suggestions, in that the development of techniques for improving the utility of an MRP system when there is demand uncertainty would reduce the importance of that factor in deciding whether to move ahead on the installation of an MRP system. It also seems likely that a systematic analysis of successful and unsuccessful MRP applications would be a useful step in analyzing the management problems encountered in implementing MRP systems.

Initial Research Efforts

Our own work on MRP systems focused initially on the design and evaluation of decision-making procedures. In the course of this work we found that very little teaching material exists for introducing university students in business and industrial engineering to the design and operation of MRP systems. Therefore our efforts have expanded to incorporate two main objectives: 1) to develop guidelines for selecting demand forecasting and lot sizing procedures for MRP systems, and 2) to develop teaching material to acquaint and to involve students with the problems of designing MRP systems.

One aspect of our work consists of developing a simulation model to compare the performance of alternative forecasting and lot sizing procedures for MRP systems under different demand conditions, product structures, and cost parameters. This simulation model permits the comparison of forecasts produced by statistical procedures, such as exponential smoothing, with MRP forecasts for component parts which are derived from production master schedules. It also allow the performance of lot sizing heuristics, such as the Part Period Balancing and the Silver & Meal procedures, to be compared with the performance of optimizing procedures such as the Wagner-Whitin Algorithm. The simulation model cutput permits performance comparisons to be made with regard to any of four different types of criterion; forecast accuracy, inventory related costs, service levels, and computing time.

A second aspect of these efforts involves preparing teaching material so that students can work with the simulation model, thereby enabling them to become involved in the process of designing an MRP system. In its present form the teaching package includes several business cases. One case presents the concept of time-phased material requirements planning and introduces the use of lot sizing procedures. Several other cases form a computer augmented case series which presents the problem of designing an MRP system. The students' task is one of choosing a forecasting and a lot sizing procedure for each of the firm's product components. The computer simulation program enables them to investigate a wide range of design alternatives, and to make recommendations regarding the best overall MRP system design for the firm.

We have had an opportunity to begin to use the simulation model and cases with both undergraduate and graduate students of industrial management. Our preliminary observations indicate that the simulation model is a valid research vehicle for exploring MRP system performance and that determining the answers to the research questions may, indeed, be more complex than would appear on the surface. The students themselves have made some valuable contributions to our thinking about these questions and have provided insights into conducting the analysis through their responses to the material in the classroom. We are convinced that continued research on MRP systems will provide useful data for those firms contemplating MRP systems installations, as well as firms that have been using MRP for some time.

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