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MRP in a job shop environment using a resource constrained project scheduling model

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Abstract

One of the most difficult tasks in a job shop manufacturing environment is to balance schedule and capacity in an ongoing basis. MRP systems are commonly used for scheduling, although their inability to deal with capacity constraints adequately is a severe drawback. In this study, we show that material requirements planning can be done more effectively in a job shop environment using a resource constrained project scheduling model. The proposed model augments MRP models by incorporating capacity constraints and using variable lead time lengths. The efficacy of this approach is tested on MRP systems by comparing the inventory carrying costs and resource allocation of the solutions obtained by the proposed model to those obtained by using a traditional MRP model. In general, it is concluded that the proposed model provides improved schedules with considerable reductions in inventory carrying costs.

Keywords: Job shop scheduling; Project management; Capacity; Optimization

1. Introduction

Material requirements planning (MRP) is extensively used in manufacturing to schedule dependent demand items based on the production schedule for the independent demand items (end items). Despite its wide spread use, several difficulties with the implementation of MRP systems have been reported, see, for example [1–4]. The main shortcoming generally mentioned is the lack of integration of capacity requirements into an MRP schedule. Typically an MRP schedule is followed by rough cut capacity planning and if a capacity problem exists the master production schedule (MPS) is modified. The MRP schedule is then re-run and this procedure is repeated until all capacity requirements are within acceptable limits. Many of the studies in the literature indicate that lead times are often extended to make it easier to satisfy capacity requirements [4–6]. This, however, will also lead to an increase in the amount of work-in-process. The use of discrete time periods (time buckets) in MRP systems further aggravates these problems. Often short lead times are rounded up to reach the length of a time bucket, and then doubled or tripled to ease capacity constraints, as well as provide for unanticipated occurrences such as maintenance downtime, supplier problems, and the like. This can then possibly lead to failures in meeting customer deadlines. Handling capacity limitations in this manner can greatly affect the quality of the MRP schedules, especially in a job shop, where customer orders cannot be satisfied through inventory when capacity is inadequate as scheduled.

In this study, we offer a model using an optimization approach to solving capacity constrained, continuous-time, multi-stage production scheduling problems, based on resource constrained project scheduling (RCPS) concepts. This model addresses capacity and material requirements planning in a job shop environment. It develops a production schedule by determining the latest possible times for all the activities, or by leveling resource usages, while taking capacity constraints into account.

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The paper is organized as follows: In the next section, we review the literature on incorporating capacity into MRP systems and on using resource constrained project scheduling for material requirements planning. Then we discuss the relationship between RCPS and MRP systems using an example from the literature. The fourth section is devoted to the formulation and the description of the RCPS/MRP model, followed by the computational considerations and results. The last section is devoted to conclusions.

2. Literature review

The integration of capacity limitations into the MRP planning process started in the early 1980s when many manufacturing companies started to use MRP as a primary planning tool. Several heuristic procedures for smoothing capacity usage while implementing MRP were proposed and evaluated. Schmitt et al. [7] study four capacity planning procedures, using simulation analysis to compare their on-time performance and their capacity utilization performance. The performance of a procedure is measured by testing it against the MRP requirements assuming that MRP provides feasible production plans. Harl and Ritzman [8] develop an algorithm to be used in conjunction with MRP to make planned order releases more sensitive to capacity limitations. The algorithm determines the lot sizes to smooth out the capacity problems at specific work centers. Again, here the general assumption is that the MPS is realistic and the average capacity at each work center over the planning horizon is sufficient. Billington et al. [9] suggest a mathematical programming approach for scheduling capacity constrained MRP systems. They propose a discrete-time, mixed-integer linear programming formulation. In order to reduce the number of variables, and thus the problem size, they introduce the idea of product structure compression. They demonstrate, with examples, several ways of compressing product trees and achieving up to 81% reduction in cases where only a few of the dependent parts use bottleneck resources. Sum and Hill [4] suggest a new framework, called IMPICT, for manufacturing planning and control systems to address capacity problems. In their framework, capacity constraints are explicitly considered and the planning horizon is assumed to be continuous. They present three heuristics for determining order sizes, rather than using an objective to evaluate schedules.

A recent study by Segerstedt [10] offers a mathematical formulation for capacity constrained multi-stage inventory and production control problem. The objective is to minimize inventory costs and shortage costs subject to capacity and inventory constraints. The practicality of both the formulation, and the accompanying dynamic programming procedure to solve it, are not tested. Brandimarte et al. [11] develop a general framework for finite capacity scheduling. It is a two step procedure which consists of a “reference trajectory” (an aggregate plan) and a scheme for shop floor schedulers to respond to local conditions. The procedure assumes the availability of a feasible reference trajectory.

There is also a great deal of interest in integrating finite capacity planning into ERP/MRP software systems. For example, the SAP R/3 production planning and control system tracks capacity and identifies bottleneck resources but is limited in providing revised schedules. IBM offers a software product called Production Resource Manager that provides the capability to obtain solutions for constrained and capacitated MRP.

In general, the studies in the MRP literature treat capacity constraints as an implementation issue rather than a component in the development of initial MRP schedule. The capacity constraints are enforced by relatively minor modifications of initial schedule, such as revising order release dates and lot sizes. For this approach to work well, the common assumption adopted is that a good initial schedule is available. However, methods of finding one are usually not addressed. This deficiency in the MRP literature motivated us to develop a model which integrates capacity into the planning process, using ideas for capacity management from the project scheduling literature.

Starting in the 1960s, studies in project scheduling suggested tools and techniques for managing limited capacity during the implementation of project activities and thus today there are many techniques which are widely used in practice and incorporated in the project scheduling software packages. The reader is referred to [12] for a review of the RCPS literature. Unfortunately, to date these techniques have not been tested for capacitated material requirements planning systems, although there is a close resemblance between resource constrained project scheduling and capacitated MRP.

Two studies in the project scheduling literature incorporate some material requirements planning concepts into resource constrained project scheduling. In 1980, Aquilano and Smith [13] developed a CPM/MRP algorithm for scheduling the activities of a project when they require material resources. Information on inventory levels and the material acquisition lead times are used in the algorithm to determine the availability of materials during the implementation of the activities. In their follow up work [14], a heuristic procedure is developed where the CPM/MRP algorithm is used to generate initial non-resource constrained schedules. A parallel scheduling scheme is then applied to this schedule to make it resource feasible. Both studies use input from an MRP system to develop early start schedules for projects that use materials and resources.

In the RCPS literature the model developed by Icmeli and Rom [15] has the required attributes to be an alternative approach for scheduling in MRP. In particular, it allows for the use of various objectives such as maximizing the value of a project or minimizing the project timeline. It also has flexibility in the way the capacity constraints can be expressed. The model we propose here is an extension of the one in [15]. The objective function and the constraints are