A Diagnostic Approach to Scheduling

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Several scheduling algorithms and methodologies have been proposed for a variety of scheduling environments. In this paper, we suggest a diagnostic approach to scheduling methodologies, which has been developed based on the diagnostic approach used by medical practitioners. We define symptoms of scheduling problems, discuss diagnoses for the problems, and suggest different solution algorithms proposed in the literature. The proposed approach is intended to help students of supply chain management gain an understanding of scheduling literature in a meaningful and understandable way.

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I. INTRODUCTION

The scheduling of jobs in manufacturing environments has attracted numerous research efforts from both academicians and practitioners. Scheduling is also known as shop floor control or production activity control in industry. The large amounts of data involved in scheduling and the large number of variables involved make the task of job scheduling in manufacturing facilities a challenging and complex problem. Recently, major software vendors, such as SAP, I2 Technologies, and Manugistics, have developed sophisticated and expensive software algorithms to support the industry with scheduling practice. Based on a survey of manufacturing firms (Olhager and Selldin, 2007), the authors concluded that the choice of a scheduling system has a significant impact on the performance of the firm.

A scheduling problem, such as job shop scheduling, involves scheduling several thousand jobs or orders, which require equipment and/or labor, over several weeks or months with the objectives of completing jobs on time, minimizing work-in-progress inventories, and achieving high utilization of resources (such as equipment and labor). These objectives are often in conflict with each other in that one objective is achieved at the cost of the other. Scheduling is typically a dynamic problem since some orders are completed while new ones are arriving everyday. Further, changes occur with orders in progress, such as cancellations and modifications of customer orders.

There are several variations in scheduling environments (Jacobs et al, 2010) based on industry, technology, and organization practices. Job orders may stem from independent demand or dependent demand; due dates for final products are important in the latter case. Typically the routing of jobs is fixed, but cases may exist where alternate routing is required. Overlapping and splitting of orders are other possibilities. Some scheduling problems require minimizing setup costs and setup times, the latter of which can be affected by the sequencing of jobs. Job routings may be the same, such as in a flow shop, or random, such as in a job shop.

It is therefore not surprising that such a large number of articles and books have been published for dealing with and managing such a large variety of scheduling problems. Typically a research article (Venkataramanaiah, 2008; Yang and Yang, 2010) defines a scheduling environment and proposes a new algorithm to find an approximate or optimal solution for that environment. A textbook on scheduling (Baker and Trietsch, 2009) is typically a collection of various algorithms. The objective of this paper is to develop an approach within which these algorithms can be viewed and understood for their relevance. The approach is based on the diagnostic framework developed for medical practice. Similar to medical practice, we start with the symptoms of scheduling problems in a manufacturing facility. Then, we investigate the underlying causes for these symptoms to reach a diagnosis. Based on the diagnosis, we arrive at a solution or prescribe a treatment for the symptoms. In the conclusion section, we propose that the approach can be used in an iterative loop; symptoms should be re-evaluated to determine whether or not a different solution or treatment is required. This approach is intended to help students of supply chain management understand and appreciate the significance of scheduling, allowing them to understand the symptoms of manufacturing problems, diagnose them, and apply suitable remedies and techniques. The approach also demonstrates linkages of scheduling with several other manufacturing subsystems. Finally, this paper attempts to suggest guidelines for selecting a suitable technique.

II. SYMPTOMS OF SCHEDULING PROBLEMS

Several symptoms indicative of problems in scheduling are highlighted in Table 1. If scheduling is not effective, problems may be brought to attention with customer complaints or if promised delivery dates are missed. Scheduling is also ineffective if the delivery dates take too long and are thus not acceptable to customers, who may be internal or external. A large work in progress and cluttered shop areas and aisles are also symptoms of problems. The need for many expeditors who have to follow up orders is a symptom of firefighting. If a work center requires overtime work in some periods but is starved of work in other periods, the scheduling system may require re-examination and corrective actions. An effective scheduling system is evidenced by a smooth flow of materials with satisfied customers and employees.

As in medicine, a symptom may be caused by different underlying problems. The symptoms described above may not reflect deficiencies in scheduling techniques; instead, the symptoms may be caused by capacity shortages, an unrealistic master production schedule, a due-date quotation procedure, or other deficiencies. The next section explores this concept further and suggests possible different areas which should be investigated.

TABLE 1: SYMPTOMS OF SCHEDULING PROBLEMS

SYMPTOMS
Failure to meet due dates
Large work-in-progress
Long manufacturing lead times
Too much firefighting
Too much overtime/undertime
Too many setup time changes
Too much splitting of batch sizes
High labor costs

III. DIAGNOSIS OF INEFFECTIVE SCHEDULING

Similar to medical practice, collecting data and running tests are required to diagnose scheduling problems. Symptoms of scheduling ineffectiveness may be attributed to different underlying causes. If problems occur in meeting due dates, it is important to first examine the existing procedure for quoting due dates. Delivery dates should be committed based on the master production schedule (MPS) and the production plans of the factory. Available to promise and existing commitments should be considered in setting due dates for new customer orders. New manufacturing software packages (such as SAP's Supply Chain Management [SCM] version 5.1 2008 software) offer several available to promise algorithms. Further, due dates need to be updated frequently as customer requirements change. Another obvious culprit is the shortages in capacities in one or more work centers. Unrealistic expectations regarding capacities and capabilities may become evident in capacity requirements planning reports that are prepared based on planned orders and orders in progress. There may be bottleneck work centers, which several researchers (Goldratt and Cox, 2004) have shown to be a major cause of scheduling and productivity problems. Several techniques and methodologies have been proposed to address this problem.

Researchers on material requirements planning (MRP) techniques have shown that a frequent cause for the ineffectiveness of production systems is that the planning modules of MPS, MRP, capacity requirements planning (CRP), and scheduling are not linked with feedback loops (Jacobs et al, 2010). Scheduling problems may be caused by ineffective MPS or CRP. When problems arise in scheduling or CRP, there may be a need to revise MPS. As mentioned earlier, the scheduling objectives of meeting due dates, utilizing capacity, minimizing work-in-progress (WIP) inventories, shortening lead times, and sequencing to reduce setup times are conflicting objectives. If a production manager is evaluated solely on capacity utilization, he/she may follow policies to meet that objective while sacrificing other scheduling objectives. Thus, a careful balanced approach must be used for setting objectives for managers. These and other possible issues to investigate are listed in Table 2.

TABLE 2: POSSIBLE CAUSES OF SCHEDULING PROBLEMS

DIAGNOSIS
Shortages of capacities as indicated in Capacity Requirements Planning
Procedure for quoting due dates
Updating of due dates
Matching of priority rules with objectives of scheduling
Linkages amongst MPS, MRP, CRP, and scheduling
Bottleneck or critical work centers
Major changes in products, equipment, and capacities
Setting of production objectives for managers

IV. SCHEDULING TECHNIQUES AND METHODOLOGIES

A careful diagnosis after an investigation of underlying causes should lead to the development of appropriate prescriptions. Some of those prescriptions and available solution methodologies are outlined in Table 3. Many of the solutions can be directly related to the causes found. Changes in capacities may be one solution. Setting due dates with new available to promise techniques may be another solution (SAP SCM software version 5.1, 2008). The optimization techniques that are covered extensively in Baker and Trietsch (2009) are generally limited to solving smaller scheduling problems with fewer machines or job orders and also have other restrictive assumptions. The larger scheduling systems that are typical in practice require computers and scheduling software. A number of powerful and sophisticated software packages such as I2's Factory Planner (2001), SAP's ERP version 6.0 (2008), and SAP's SCM version 5.1 (2008) are now available, and careful analysis and selection of appropriate scheduling software can be very helpful. The software package allows for the selection of a scheduling priority rule, finite or infinite scheduling, horizontal or vertical scheduling, and forward or backward scheduling amongst other options. Scheduling software also allows scheduling to focus on due dates or inventories or utilization by giving different weights to the objectives depending on priorities in a given situation.

One of the interesting approaches to scheduling has been an input-output control methodology, which is similar to scheduling incoming customers in a dine-in restaurant. Depending on the availability of chefs and waiters, a certain number of tables are open for service so that the customers inside the restaurant are served efficiently. Other customers wait in the lounge and are given an estimate of waiting time. Input-output control methodology in manufacturing environments attempts to achieve similar results with customer orders or jobs. Jobs are admitted to the shop depending on the completion or output of jobs in progress. Such a system avoids the build-up of inventories on the shop floor, and accepted jobs on the shop floor are completed efficiently. Another major success in scheduling has been Goldratt's (2004) philosophy of the theory of constraints. He has shown that the best approach to scheduling is to focus on constrained or bottleneck resources and to schedule other resources around the schedule of constrained resources. Most scheduling software now includes this approach as one of the options in the software package.

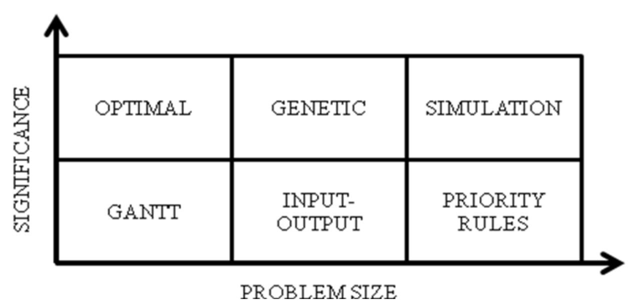
More powerful and significant scheduling approaches are simulation and genetic algorithms for larger scheduling systems, where the payoffs are substantial with improved scheduling. A computer simulation allows for the simulation and evaluation of several scheduling alternatives in complex environments. Genetic algorithms have been introduced more recently and have been incorporated into new software algorithms. The functions of selection, mutation, and crossover, which are well-described concepts in human evolution, are embedded in the genetic algorithms developed in scheduling. SAP's SCM software essentially builds schedules in large and complex environments with genetic algorithms. In these algorithms, the starting solution is gradually improved (by applying selection, mutation, and crossover rules) within the constraints of the problem and in the direction of the objective function of the scheduling problem. The quality of the solution obtained may depend on the computer time assigned for the problem (Knolmayer et al, 2002).

TABLE 3: POSSIBLE SOLUTIONS

TREATMENT
Due date setting or available to promise methods
Procedure for updating due dates
Review and selection of scheduling algorithm (Gantt chart, priority rules, or optimization techniques)
Computer-based information system for scheduling
Establishment or revision of linkages amongst MPS, MRP, CRP, and scheduling
Scheduling by bottleneck or critical work centers
Input-output control procedure
Clarification and setting of relevant production objectives for managers
Use of simulation algorithms
Use of genetic scheduling algorithms

Figure 1 below suggests a possible approach for selecting a solution based on the size of the scheduling problem and the significance or payoff potential from improved scheduling.

FIGURE 1: SELECTION OF A SOLUTION



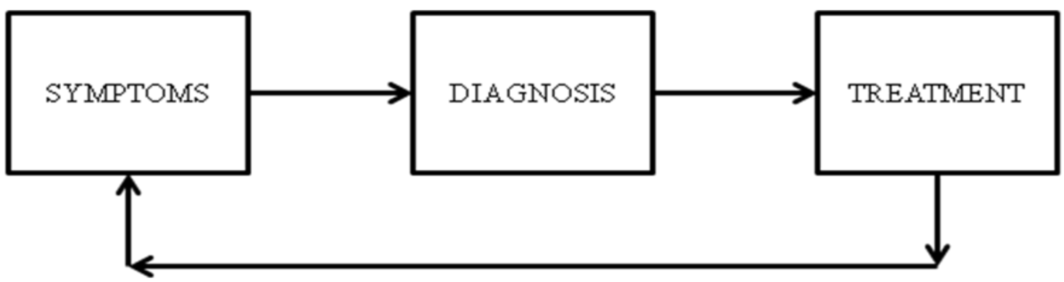
A manufacturing facility with a few work centers can schedule them simply with a Gantt chart. A large facility with many work centers involving complex scheduling (such as a large repair shop in a steel plant) will use priority sequencing rules in a computer-based scheduling system. Scheduling is complex in the latter case, but the payoff potential is not very high.

Scheduling in capital intensive industry (manufacturing aircrafts or ships) has a substantial payoff and can benefit greatly from genetic and simulation techniques.

V. CONCLUSIONS

We have discussed above an approach for scheduling techniques and methodologies that employs the same approach used by physicians. This approach of symptoms, diagnosis, and prescription provides a perspective for students of supply chain management so that they understand the contribution scheduling can make to improving productivity. This approach can be implemented in an iterative way as shown in Figure 2. After the solution has been implemented, the problem should be re-assessed; and, if necessary, the prescription should be revised. Currently, students are exposed to various scheduling techniques but lack a coherent approach. Learning scheduling methods within this approach can lead to an enhanced understanding of significance of various scheduling approaches.

FIGURE 2: A DIAGNOSTIC APPROACH FOR SCHEDULING METHODOLOGIES



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