Compare ordinal and cardinal utility essay sample

Information Flow and Decision-Making in Production Scheduling Jeffrey W. Herrmann Department of Mechanical Engineering and Institute for Systems Research University of Maryland College Park, MD 20742 Abstract Although often studied as an isolated optimization problem, production scheduling in practice is a complex flow of information and decision-making. This paper discusses this perspective and presents ways to represent production scheduling systems. The paper uses a case study of a manufacturing facility to illustrate the concepts. KEYWORDS: Production scheduling, rescheduling, decision-making

1. Introduction

Many manufacturing facilities generate and update production schedules, which are plans that state when certain controllable activities (e. g., processing of jobs by resources) should take place. In dynamic, stochastic manufacturing environments, managers, production planners, and supervisors must not only generate high-quality schedules but also react quickly to unexpected events and revise schedules in a cost-effective manner. These events, generally difficult to take into consideration while generating a schedule, disturb the system, generating considerable differences between the predetermined schedule and its actual realization on the shop floor. Rescheduling is then practically mandatory in order to minimize the effect of such disturbances in the performance of the system. In practice, production scheduling is part of the complex flow of information and decision-making that forms the manufacturing planning and control system. Such systems are typically divided into modules that perform different functions such as aggregate planning and material requirements planning [1, 2].

In this paper, production scheduling refers to the low-level, shop floor control function. A great deal of research effort has been spent developing methods to generate optimal production schedules, and countless papers discussing this topic have appeared in scholarly journals. Typically, such papers formulate scheduling as a combinatorial optimization problem isolated from the manufacturing planning and control system in place. Schedule generation methods include most of the literature in the area of scheduling. Interested readers should see Pinedo and Chao [3], Pinedo [4], or similar introductory texts on production scheduling. Vieira et al. [5] present a rescheduling framework that can be used for classifying and describing rescheduling environments, policies, strategies, and methods.

As discussed in that paper, production scheduling theory has had limited impact on practice because most scheduling results do not consider important characteristics of the environment in which scheduling occurs. In particular, researchers have not considered fully the dynamic aspects of the manufacturing system, including the planning and control systems. McKay and Wiers [6] discuss the relationship between the theory and practice of scheduling and describe three principles that explain a practical production scheduling system. First, it generates partial solutions for partial problems. Second, it anticipates, reacts to, and adjusts for disturbances.

Third, it is sensitive to and adjusts the meaning of time in the production situation. McKay et al. [7] describe a hierarchical framework for production planning and discuss the flow of information in this framework. This paper presents a more general approach to understanding and representing production scheduling systems. The remainder of this paper is organized as follows: Section 2 introduces production scheduling systems and discusses the role of rescheduling. Section 3 discusses how to represent production scheduling systems. Section 4 presents a case study of a manufacturing facility to illustrate the concepts. Section 5 concludes the paper.

2. Production Scheduling Systems

Manufacturing facilities are complex, dynamic, stochastic systems. From the beginning of organized manufacturing, workers, supervisors, engineers, and managers have developed many clever and practical methods for controlling production activities. Although dispatching rules, kanban cards, and other decentralized production control policies are in use, many manufacturing facilities generate and update production schedules. In manufacturing systems with a wide variety of products, processes, and production levels, production schedules can enable better coordination to increase productivity and minimize operating costs. A production schedule can identify resource conflicts, control the release of jobs to the shop, and ensure that required raw materials are ordered in time. A production schedule can determine whether delivery promises can be met and identify time periods available for preventive maintenance.

A production schedule gives shop floor personnel an explicit statement of what should be done so that supervisors and managers can measure their performance. In a manufacturing facility, the production scheduling system is a dynamic network of persons who share information about the manufacturing facility and collaborate to make decisions about which jobs should be done when. The information shared includes the status of jobs (also known as work orders), manufacturing resources (people, equipment, and production lines), inventory (raw materials and work-in-process), tooling, and many other concerns. The persons in the production scheduling system may be managers, production planners, supervisors, operators, engineers, and sales personnel. They will use a variety of forms, reports, databases, and software to gather and distribute information, and they will use tacit knowledge that is stored in their memory.

The following are among the key decisions in a production scheduling system: • releasing jobs for production, • prioritizing jobs that require the same resources, • assigning resources (people, equipment, or production lines) to jobs, • reassigning resources from one job to another, • determining when jobs should be started, and • interrupting jobs that should be halted. The production scheduling system is a control system that is part of a larger, more complex manufacturing planning and control system. The production scheduling system includes but is more than a schedule generation process (be it manual or automated). The production scheduling system is not a database or a piece of software. The production scheduling system interacts with but is not the system that collects data about the status of open work orders (often called a manufacturing execution system). The production scheduling system is not an optimization procedure.

The production scheduling system provides information that other managers need for other planning and supervisory functions. Note that, after a schedule is generated, manufacturing operations begin. Managers and supervisors want the shop floor to follow the schedule. In practice, operators may deviate from the schedule. Ideally, the schedule is followed as closely as possible. Small deviations from scheduled start times and end times are expected and usually ignored. (The definition of small depends on the facility in question.) Larger deviations or changes to the sequence occur when unexpected events disrupt the initial schedule.

Even if the managers and supervisors do not explicitly update the schedule, schedule repair occurs as the operators react to the disruptions, delaying tasks or performing tasks out of order. Rescheduling is a key principle for understanding production scheduling systems. Rescheduling is the process of updating an existing production schedule in response to disruptions or other changes. (For more about rescheduling, see Vieira et al. [5].) There are many types of disturbances that can upset a production schedule, including machine failures, processing time delays, rush orders, quality problems, and unavailable material. In practice, rescheduling is done periodically to plan activities for the next time period based on the state of the system. It is also done occasionally in response to significant disruptions. Because time estimates are incorrect and unexpected events occur, precisely following a schedule becomes more difficult as time passes. In some cases, the system may follow

the sequence that the schedule specifies even though the planned start and end times are no longer feasible. Eventually, however, a new schedule will be needed. Figure 1 shows a conceptual diagram of a typical production scheduling system, modeled as a feedback control system. The input to the production scheduling system is the set of jobs that need to be completed. The order release function checks the status of the jobs and releases those that are ready to begin. The schedule update function takes an existing production schedule, any changes to state of the jobs, and information about the state of the shop (primarily the jobs and the resources) and creates a new production schedule, which the shop follows as best as possible in the face of disruptions.

Changes to jobs Disturbances

New jobs

Order release

Jobs

Schedule update

Shop

Production schedule State: jobs, resources

Figure 1. Production scheduling as a feedback control system Though this description is simple, production scheduling systems are complex because the mechanisms for sensing the state of the manufacturing system and generating updated production schedules cannot be expressed (except in very special cases) as mathematical functions. In addition, the randomness of disruptions and other uncertainties make scheduling difficult. The most realistic representation is to view a production scheduling systems as a

system of decision-makers that transforms information about the manufacturing system into a plan (the production schedule).

3. Representing Production Scheduling Systems

Representing decision-making systems is a difficult task. Herrmann and Schmidt [8] describe decision-making systems in product development. The most typical representation is an organization chart, which lists the employees of a firm, their positions, and the reporting relationships. However, this chart does not explicitly describe the decisions that these persons are making or the information that they are sharing. Another representation is a flowchart that describes the lifecycle of an entity by diagramming how some information (such as a customer order, for example) is transformed via a sequence of activities into some other information or entity (such as a shipment of finished goods). Swimlanes [9] are a special type of flowchart that adds more detail about who does which activities, a key component of a decision-making system. Control systems theory provides another way to represent a decision-making system (as shown in Figure 1).

The Viable System Model [10] is a cybernetics model that decomposes an organization into predefined subsystems. In an interpretive systems approach, Checkland [11] suggests building rich pictures to indicate the many components of a complex system and to encourage system-level thinking. Different representations capture different aspects of a decision-making system. There is no single representation that can capture all of the relevant aspects. In the next section, this paper will use swimlanes to represent a production scheduling system since the swimlanes model yields a structured model that describes the decision-making and information flow most efficiently and clearly shows the actions and decisions that each participant performs. One limitation is that the model does not show the structure of the organization. Also, representing a larger, more complex system would require swimlanes models at different levels of abstraction to avoid confusion.

4. CAD/PAD Production Scheduling

The Naval Surface Warfare Center, Indian Head Division (NSWC/IHD) serves the armed forces by developing, manufacturing, and supporting energetics products, including cartridge-actuated devices (CADs) and propellantactuated devices (PADs) that are typically found in aircrew escape systems and in other aircraft systems (see Figure 2). This section describes the production scheduling system for the CAD/PAD assembly facility, which assembles devices using cartridges, primers, and other hardware that are made in other facilities at NSWC/IHD or at contractors.

Figure 2. Typical devices. The production scheduling system includes the following persons. The branch manager directs the operation of the facility. The production controller maintains the production schedules. (There are two other production controllers who help with ordering and preparing hardware.) The shop foreman directly supervises the operators in the shop. There are about nine production engineers, who are each responsible for a range of products. The production engineers prepare everything needed for production and solve any problems that occur. Jobs are called workorders.

Workorders arrive from the acquisitions organization that is responsible for purchasing devices for the armed services. The branch manager logs the workorder. The production controller adds it to the long-range schedule. The production engineer determines if the key hardware will be ready on time and informs the branch manager if the required delivery date is feasible.

The branch manager accepts the workorder and informs the acquisitions organization. The production system operates with two schedules: a long-range schedule (discussed below) and a weekly schedule. The weekly schedule is a list of about 24 operations (for 13 workorders) that are currently in process or ready to start. For each operation, it lists the product, the responsible production engineer, the number required, the operation, the workorder, the hours needed, the hours completed to date, the due date, and the hours completed in the previous week. At the end of each week, the shop foreman tells the production controller how many hours were worked on which workorders. The production controller updates the weekly schedule (the one created at the beginning of the week) with this information and brings this interim schedule to the weekly meeting. The primary communication mechanism in the production scheduling system is a weekly meeting (first thing Monday morning) of all the participants. The participants discuss the workorders scheduled for that week, the work performed the previous week, and any other updates.

The primary objective of the meeting is to create an accurate picture of which workorders are ready for production and which have priority so that the shop foreman can determine what the shop will do. Production engineers state whether any new workorders are ready for production. Any such workorders are added to the weekly schedule at this meeting. Production engineers provide information about how much work was done last week and how much time is left to complete the workorder. Production engineers provide information about any changes to the status of their workorders. For example, a workorder is ready to be shipped to the X ray facility, hardware has been moved from storage to the production building, or a piece of necessary equipment may be unavailable. The shop foreman adds similar information.

The shop supervisor is aware of the shop status, including any equipment problems, from direct observation or reports by operators and production engineers (for instance, the hogout facility is down). Based on information from a monthly meeting with the acquisitions organization, the branch manager identifies the workorders that have priority that week. After the meeting, the production controller updates the schedule accordingly, signs it, and distributes to all personnel that day. The shop foreman makes decisions about which operators will work on which activities, and when during the week tasks will be done. The shop foreman records the hours worked. When changes occur during the week (to the status of equipment, hardware, or workorders), the production engineers, production controller, and shop foreman react appropriately without changing the weekly schedule. These events are discussed at the next weekly meeting, and the schedule is updated accordingly then.

The long-range schedule lists approximately 80 workorders. For each workorder, it states the quantity, the customer due date, the responsible production engineer, the predicted labor hours, the workorder status, and has columns for each month in the next year. In each column is the number of production labor hours scheduled for that workorder in that month. This is based on the production engineer’s estimate of when the necessary hardware and cartridges will be ready. The predicted labor hours on the schedule are rough estimates. Although the long-range schedule includes capacity estimates, satisfying the capacity constraints is not important since the requirements are not precise. Once a month the weekly meeting also discusses the long-range schedule.

The group discusses each workorder on the long-range schedule and its status. The production controller updates the long-range schedule accordingly and distributes this to personnel in the branch and elsewhere. Any changes during the month are discussed at this monthly discussion. Once a month the branch manager meets with the acquisitions manager and another production branch manager. At this meeting, the each branch manager discusses the status of critical workorders and receives a list of priority workorders. (These are used to prioritize workorders at the weekly meeting.) The minutes of this meeting are distributed to personnel across the manufacturing organization.

Figures 3 and 4 illustrate the production scheduling process using swimlanes. Each horizontal bar corresponds to a particular person and shows the activities in which that person participates. The links between the activities show the flow of information. Figure 3 represents the activities that receive workorders and update the long-range schedule. Figure 4 represents the activities that update the weekly schedule. Acquisition Branch manager Production controller Production Engineer Shop foreman Send workorder Log workorder Add w/o to long-range sch. Check w/o hardware Accept workorder Long-range schedule Report w/o status Report shop status Discuss long-range schedule Update long-range sch. Receive acceptance

Figure 3. Workorder receipt and long-range scheduling.

Acquisition manager Branch manager Production controller Production Engineer Shop foreman

Monthly meeting Update weekly schedule

Report w/o priorities Discuss weekly schedule Finish and sign weekly schedule

Report w/o status Supervise production Report hours worked Report shop status

Schedule production

Figure 4. Weekly scheduling. Interestingly, the weekly meeting performs the order release function, where production engineers report that workorders are ready for production, and these orders are added to the weekly schedule, which functions more as a dispatch list than a schedule. In addition, this meeting serves as an information filter for the shop foreman, who makes the actual scheduling decisions based upon the information discussed in the meeting. (The role of information filters is discussed in more detail by McKay et al. [7].)

5. Summary and Conclusions

This paper has described production scheduling systems, discussed the role of rescheduling, and presented a variety of ways to represent production scheduling systems. Moreover, the paper has illustrated these ideas with the description of a real-world production scheduling system and a model that can be used for portraying the system. The objective has been to show how, in practice, production scheduling is part of a complex flow of information and decision-making. It is not an isolated optimization problem. It is hoped that this material will help engineers, analysts, and managers improve their production scheduling systems by considering the structure and behavior of the system. This will encourage researchers to develop new representations and to employ innovative methodologies for studying and improving production scheduling. Acknowledgements The author appreciates the insights and help provided by many collaborators at the University of Maryland and at the Naval Surface Warfare Center, Indian Head Division, which supported this research.

References

1. 2. 3. 4. 5. 6. 7. 8. Hopp, Wallace J., and Mark L. Spearman, Factory Physics, Irwin/McGraw-Hill, Boston, 1996. Vollmann, Thomas E., William L. Berry, and D. Clay Whybark, Manufacturing Planning and Control Systems, fourth edition, Irwin/McGraw-Hill, New York, 1997. Pinedo, Michael, and Xiuli Chao, Operations Scheduling with Applications in Manufacturing and Services, Irwin McGraw Hill, Boston, 1999. Pinedo, Michael, Scheduling: Theory, Algorithms, and Systems, Prentice Hall, Englewood Cliffs, New Jersey, 1995. Vieira, Guilherme E., Jeffrey W. Herrmann, and Edward Lin, " Rescheduling manufacturing systems: a framework of strategies, policies, and methods,"

Journal of Scheduling, Volume 6, Number 1, pages 35-58, 2003. McKay, Kenneth N., and Vincent C. S. Wiers, " Unifying the theory and practice of production scheduling," Journal of Manufacturing Systems, Volume 18, Number 4, pages 241-255, 1999. McKay, K. N., F. R. Safayeni, and J. A. Buzacott, " An information systems based paradigm for decisions in rapidly changing industries," Control Engineering Practice, Volume 3, Number 1, pages 77-88, 1995. Herrmann, Jeffrey W., and Linda C. Schmidt, " Viewing Product Development as a Decision Production System," DETC2002/DTM-34030, Proceedings of the 14th International Conference on Design Theory and Methodology Conference, ASME 2002 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Montreal, Canada, September 29 – October 2, 2002. Sharp, Alec, and Patrick McDermott, Workflow Modeling, Artech House, Boston, 2001. Beer, S., Brain of the Firm, Allen Lane, London, 1972. Checkland, Peter, Systems Thinking, Systems Practice, John Wiley & Sons, Ltd., West Sussex, 1999.

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