Improving Production Scheduling: Integrating Organizational, Decision-Making, and Problem-Solving Perspectives

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Abstract

Production scheduling activities are common but complex. This leads to many different views and perspectives of production scheduling. Each perspective has a particular scope, its own set of assumptions, and a different approach to improving production scheduling. This paper covers three important perspectives (the problem-solving perspective, the decision-making perspective, and the organizational perspective) and discusses the methodologies that these perspectives use. Finally, this paper presents an integrative strategy that can be used to select, in a particular setting, an approach for improving production scheduling.

KEYWORDS: Production scheduling, decision-making, optimization

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 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.

Production scheduling can be difficult and time-consuming. 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.

Because production scheduling activities are common but complex, there exist many different views and perspectives of production scheduling. Each perspective has a particular scope and its own set of assumptions. Different perspectives lead naturally to different approaches to improving production scheduling. Three important perspectives are the problem-solving perspective, the decision-making perspective, and the organizational perspective.

The problem-solving perspective is the view that scheduling is an optimization problem that must be solved. 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 [1], Pinedo [2], or similar introductory texts on production scheduling. Researchers will find references such as Leung [3] and Brucker [4] useful for more detailed information about problem formulation and solution techniques.

The decision-making perspective is the view that scheduling is a decision that a human must make. Schedulers perform a variety of tasks and use both formal and informal information to accomplish these. Schedulers must address uncertainty, manage bottlenecks, and anticipate the problems that people cause [5].

The organizational perspective is a systems-level view that scheduling is part of the complex flow of information and decision-making that forms the manufacturing planning and control system [6, 7]. Such systems are typically divided into modules that perform different functions such as aggregate planning and material requirements planning [8, 9]. In this paper, production scheduling refers to the low-level, shop floor control function.

The paper will discuss the methodologies that these perspectives use and show the relationships between them. In addition, the paper will present an integrative strategy that can be used to select, in a particular setting, an approach for improving production scheduling. The remainder of this paper is organized as follows: Section 2 discusses the problem-solving perspective. Section 3 describes the decision-making perspective. Section 4 addresses the organizational perspective. Section 5 discusses an integrative strategy for improving production scheduling. Section 6 concludes the paper.

2. Problem-solving: Finding Optimal Schedules

When viewed from the problem-solving perspective, production scheduling is a fascinating puzzle to be solved by moving tasks around a Gantt chart, searching for the optimal solution. MacNiece [10] gives a beautiful example of using a Gantt chart to solve a scheduling problem. The problem is to determine if an order for an assembly can be completed in 20 weeks. The Gantt chart has a row for each machine group and bars representing already planned work to which he adds the operations needed to complete the order. He argues that using a Gantt chart is a much quicker way to answer the question. More generally, the ability to formulate the problem rigorously and to analyze it to find properties of optimal solutions has attracted a great deal of research effort. In addition to exact techniques [4], there are a variety of heuristics and search algorithms used to find near-optimal solutions to these problems. Although there exists a significant gap between scheduling theory and practice, some researchers have improved real-world production scheduling through better problem-solving (see, for instance, Dawande et al. [11]).

However, the optimization approach relies upon the ability to formulate the problem. Its feasibility depends upon the ability to collect the data needed to specify the problem instance. More importantly, its relevance depends upon whether or not someone will use the schedule that is generated. The relevance problem is not new and predates the academic research on scheduling. Reacting to situations that he observed ninety years ago, Gantt [12] warned that the most elegant schedules created by planning offices are useless if they are ignored.

3. Decision-making: Planning for Trouble

Decision-making is a slightly broader perspective on production scheduling. Decision-making is, in general, a process of gathering information, evaluating alternatives, selecting one, and implementing it. Schedulers must perform a variety of tasks and use both formal and informal information to make scheduling decisions. A number of authors have documented the activities that schedulers must perform, including [13, 14]. McKay and Wiers [5] provide an excellent discussion of the decision-making perspective, starting with the tasks that schedulers perform each day:

1. Situation assessment: what is where;
2. Crisis identification: what needs immediate attention;
3. Immediate resequencing and task reallocation: reactive decisions;
4. Complete scenario update: remapping the future;
5. Future problem identification: what problems can be foreseen;
6. Constraint relaxation and future problem resolution: discounting future problems; and
7. Scheduling by rote: dealing with the rest of the problem.

Two important points should be highlighted. One, in this perspective, the production scheduling objective is “to see to it that future troubles are discounted” [15]. 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. Problems can be caused by sources outside the shop floor, including labor agreements and the weather. It is unlikely that such a wide variety of possible problems can ever be considered automatically, implying that computers will never completely replace human schedulers. Moreover, improving production scheduling requires that the schedulers manage bottleneck resources effectively, understand the problems that occur (whether caused by others or by themselves), and take steps to handle future uncertainty [5].

Scheduling decision support systems can be useful as well. As suggested by McKay and Wiers [16] and Wiers [17], the design of a scheduling decision support tool should be guided by the following concepts: (1) the ability of the scheduler to directly control the schedule (called "transparency"), (2) the amount of uncertainty in the manufacturing system, (3) the complexity of the scheduling decison, and (4) how well-defined the scheduling decision is. (An ill-defined scheduling decision is characterized by incompleteness, ambiguity, errors, inaccuracy, and possibly missing information [16].)

The second point is that there is a place for problem-solving. The scheduling by rote task requires creating a schedule for the work that is not in process, assigning work to resources, and sequencing the operations subject to the constraints that the scheduler imposes to avoid future problems. Schedule generation algorithms can be useful in this step to reduce the workload of the scheduler and find solutions that are better than those a human can find (due to the size or complexity of the problem).

4. The Organizational Perspective: Sharing Information

The organizational perspective, which is the most complete, views production scheduling as a system of decision-makers that transforms information about the manufacturing system into a plan (the production schedule) [6].

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.

Representing decision-making systems is a difficult task. Herrmann and Schmidt [18] 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 [19] are a special type of flowchart that adds more detail about who does which activities, a key component of a decision-making system. Herrmann [6] uses 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. Swimlanes are not the only possibility. Work by Guinery and MacCarthy [20] on improving production scheduling systems used modified GRAI modeling techniques [21] for representing decision centers.

A scheduler is only one node in the production scheduling system network. The scheduler's tasks (listed in Section 3) describe the activity within that node. The information that the scheduler needs arrives from other nodes, and the schedules that are created go to other nodes in the network.

5. An Integrative Strategy

Based on the above discussion, it is clear that these three perspectives form a hierarchy, with the the problem-solving perspective at the lowest level, the decision-making perspective in the middle, and the organizational perspective at the highest level. Figure 1 illustrates this relationship in a conceptual way. Moving among these three perspectives corresponds to shifting one's focus from the production planning organization to one person to one task. Thus, this hierarchy of perspectives does not correspond to a temporal or spatial decomposition. Instead, it is related to a task-based decomposition of the production scheduling system.

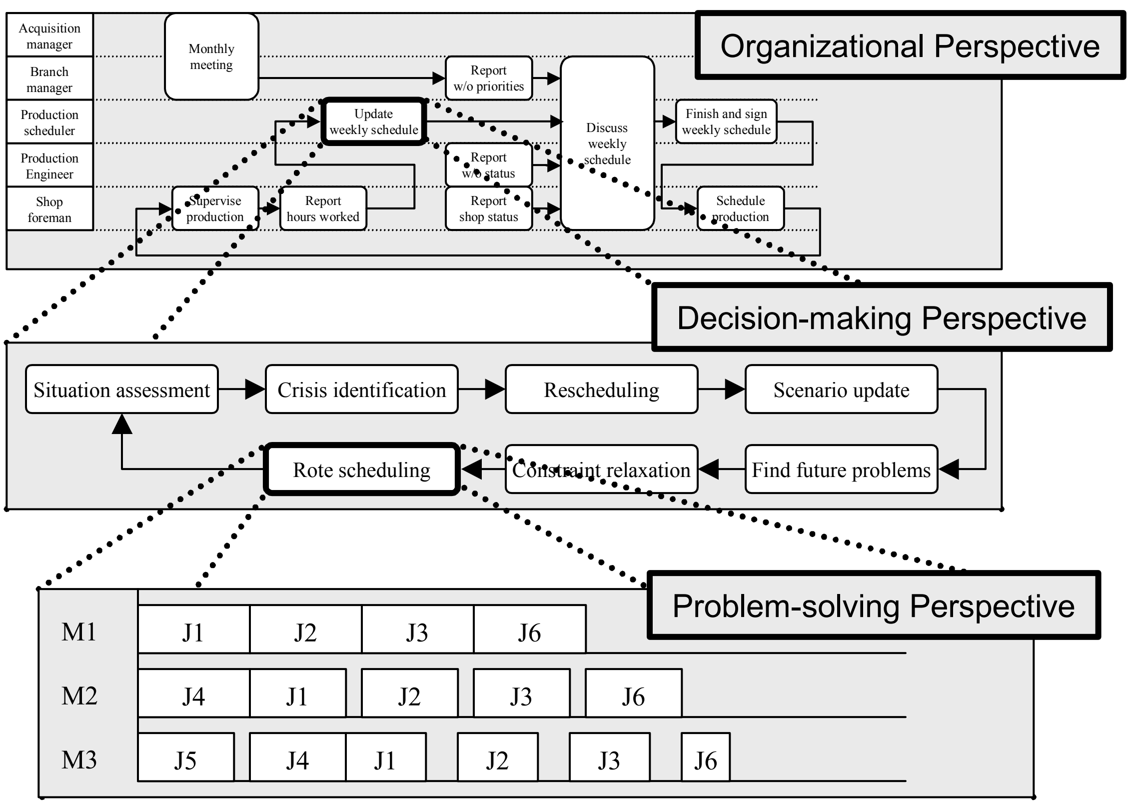

Figure 1. Perspectives on Production Scheduling

This hierarchy suggests the following integrative strategy for improving production scheduling.

1. Study the production scheduling system. Create a model (using swimlanes, GRAI modeling techniques, or some other method) of the persons in the production scheduling system, their tasks and decisions, and the information flow between them.

2. Analyze this model and determine if changes to the information flow, task assignments, or decision-making responsibilities are desirable and feasible. For instance, it may be useful to restrict persons (other than the scheduler) from updating the schedule. If changes are needed, go to Step 6.

3. Given that the patterns of information flow are satisfactory, consider the decision-making process that the scheduler uses. Determine if the scheduler is able to manage bottleneck resources effectively, understand the problems that occur (whether caused by others or by themselves), and take steps to handle future uncertainty. If not, changes in these areas are suggested. If changes are needed, go to Step 6.

4. Consider dividing the workload between the human scheduler and a decision support tool. If a new or improved decision support tool is needed, go to Step 6.

5. Finally, consider improving production scheduling problem-solving by developing a more appropriate problem formulation or installing more powerful algorithms that can find better solutions faster. Consult the enormous literature on scheduling problems for different approaches to these challenges.

6. Implement the changes that were selected.

7. Assess the impact of the implemented changes and repeat the above steps as necessary.

The steps of this strategy are straightforward, though the references cited in the previous sections provide more information about the techniques and give examples. It is clear that the ability to use this strategy requires a wide range of skills that go beyond useful talents in analyzing optimization problems and programming decision support tools.

6. Summary and Conclusions

The three production scheduling perspectives discussed here are distinct but related. Moreover, an analysis of these perspectives suggests that they form a hierarchy. This, in turn, motivates an integrative strategy for improving production scheduling that begins with considering the production scheduling system, then looking at the scheduler's decision-making process, and finally addressing the problem-solving algorithm.

Discussing the location of this integrative approach in the context of the wide variety of systems approaches [22], especially those that mix methodologies [23], is beyond the scope of this paper. This paper introduces a pragmatic strategy that stresses the need to be familiar with and consider a set of approaches to improving production scheduling. A complete theoretical analysis of the methodology remains to be done.

In practice, production scheduling is a complex system of information flow, decision-making, and problem-solving. It is not simply an optimization problem. It is hoped that the strategy presented here will help engineers, analysts, and managers recognize and understand this complexity and successfully improve their production scheduling systems.

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References

1. Pinedo, Michael, and Xiuli Chao, *Operations Scheduling with Applications in Manufacturing and Services*, Irwin McGraw Hill, Boston, 1999.

2. Pinedo, Michael, *Scheduling: Theory, Algorithms, and Systems*, Prentice Hall, Englewood Cliffs, New Jersey, 1995.
3. Leung, Joseph, *Handbook of Scheduling*, Chapman & Hall/CRC, Boca Raton, Florida, 2004.
4. Brucker, Peter, *Scheduling Algorithms*, Fourth Edition, Springer-Verlag, Berlin, 2004.
5. McKay, Kenneth N., and Vincent Wiers, C.S., *Practical Production Control: a Survival Guide for Planners and Schedulers*, J. Ross Publishing, Boca Raton, Florida, 2004. Co-published with APICS.
6. Herrmann, J.W., 2004, Information flow and decision-making in production scheduling, 2004 Industrial Engineering Research Conference, Houston, Texas, May 15-19, 2004.
7. 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.
8. Hopp, Wallace J., and Mark L. Spearman, *Factory Physics*, Irwin/McGraw-Hill, Boston, 1996.
9. Vollmann, Thomas E., William L. Berry, and D. Clay Whybark, *Manufacturing Planning and Control Systems*, fourth edition, Irwin/McGraw-Hill, New York, 1997.
10. MacNiece, E.H., *Production Forecasting, Planning, and Control*, John Wiley & Sons, Inc., New York, 1951.
11. Dawande, M., J. Kalagnanam, H.S. Lee, C. Reddy, S. Siegel, and M. Trumbo, "The slab-design problem in the steel industry," *Interfaces,* Volume 34, Number 3, pages 215-225, 2004.
12. Gantt, Henry L., *Work, Wages, and Profits*, second edition, Engineering Magazine Co., New York, 1916. Reprinted by Hive Publishing Company, Easton, Maryland, 1973.
13. Webster, Scott, "A case study of scheduling practice at a machine tool manufacturer," in *Human Performance in Planning and Scheduling*, B.L. MacCarthy and J.R. Wilson, eds., Taylor & Francis, London, 2001.
14. Crawford, Sarah, "Making sense of scheduling: the realities of scheduling practice in an engineering firm," in *Human Performance in Planning and Scheduling*, B.L. MacCarthy and J.R. Wilson, eds., Taylor & Francis, London, 2001.
15. Coburn, F.G., "Scheduling: the coordination of effort," in *Organizing for Production and Other Papers on Management* 1912-1924, Mayer, I., Ed., Hive Publishing, pages 149-172, 1981.
16. McKay, Kenneth N., and Vincent C.S. Wiers, "The human factor in planning and scheduling," to appear in *Handbook of Production Scheduling*, J.W. Herrmann, ed., Springer, New York, 2006.
17. Wiers, V. C. S., *Human–computer interaction in production scheduling: Analysis and design of decision support systems for production scheduling tasks*, Ph.D. Thesis, Eindhoven University of Technology, 1997.
18. 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.
19. Sharp, Alec, and Patrick McDermott, *Workflow Modeling*, Artech House, Boston, 2001.
20. Guinery, J.E., and B.L. MacCarthy, 2005, The Prochart Toolkit for the re-design of production planning, scheduling and control processes, Proceedings of the 18th International conference on Production Research (ICPR18), Salerno Italy, July 2005.
21. Doumeingts, G., D. Chen, and F. Marcotte, Concepts, models and methods for the design of production management systems, *Computers in Industry*, **19**(1):89-111, 1992.
22. Jackson, M.C., *Systems Approaches to Management*, Kluwer Academic/Plenum Publishers, New York, 2000.
23. Nicholls, M.G., S. Clarke, and B. Lehaney, eds., *Mixed-Mode Modelling: Mixing Methodologies for Organisational Intervention*, Kluwer Academic Publishers, Dordrecht, 2001.