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Obstacles that Limit the Application of Quantitative Scheduling Techniques

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For quantitative scheduling techniques found in journals, their wider use in applications has been retarded by a variety of obstacles. This article will first list a number of these obstacles and then suggest ways to overcome them.

Let us begin with a situation encountered in 1972 by one of the authors in devising a computerized quantitative production scheduling system for a tire production plant. The schedule produced by the system was constrained by the machines available, the sequencing of the machines for each type of job, the flow of materials, the demand of make-to-order jobs, the demand of make-to-stock jobs, the job due dates, and the personnel available. The corporate MIS department commissioned the system, which was designed to be updated on their mainframe computer once a week. After the system was completed, the MIS department said the system was a success because it demonstrated to the company that the computer could be used to schedule production, which was the entire purpose of the project. However, the system would not be used to actually schedule production, which was a shock to the author. After much thought, there were many reasons for the non-implementation.

1. Job control. The production schedulers did not want the MIS department to take control. Basically, they did not want someone else doing even part of their job.

2. Efficient schedule. The production schedulers felt that a computer program could never produce a schedule as efficient as their schedule and the company would lose money.

3. Short-term priority changes. The computer schedule could not respond to short-term changes in the priorities such as marketing or corporate headquarters requesting that a particular customer receive top priority today.

4. Tradeoffs. Production schedulers did not agree with, or more importantly, even know how the computer schedule made the myriad of tradeoffs necessary to produce a schedule. For example, a production schedule must trade off decreasing total setup time versus increasing the chance that some due dates will not be met. In addition, if all due dates cannot be met, the computer schedule internally chooses which jobs are late, and the production schedulers may not agree with the tradeoffs used to make that choice.

5. Preference and knowledge input. The computer schedule did not reflect the preferences and knowledge of the production schedulers or any other department such as marketing.

6. Using the computer schedule as a tool. Most production schedulers don't understand or even want to understand how the quantitative scheduling algorithm determines the computer schedule. Therefore, any real or perceived problem with the computer schedule is cited as proof that the quantitative scheduling algorithm should be scrapped as it is clearly inferior to a schedule produced by a production scheduler. In other words, a production scheduler is not trained to use the computer schedule as a tool to help them do their job but instead view it as a competitor.

7. Incomplete information. The data used to produce the computer schedule did not completely mirror the real world situation and by necessity left out some information including political nuances. Thus, any computer schedule will usually be seen by someone as having serious shortcomings.

Priority Class Scheduling

Most of the problems listed above are present in all applications of quantitative scheduling techniques, but there has been very little work in the literature to try and solve these problems. One study by the authors (Brown & Ozgur, 1997) suggested using priority class scheduling to reduce due date conflicts between marketing and the production schedulers by replacing due dates with production periods and priority classes. The priority classes are used by the production scheduler as constraints on what can be scheduled in a production period. If any job in priority class i is started in the production period, then all jobs in priority class $i-1$ must be completed within the production period. This is the only constraint on the production scheduler and allows the scheduler to concentrate on optimizing manufacturing efficiency within the production period. The constraint is so simple that its consequences are easily understood by those who assign jobs to priority classes, but at the same time allows manufacturing some flexibility in scheduling. Indeed, the production scheduler can schedule a priority three job to be completed early in the production period as long as all priority one and priority two jobs are completed within the production period. In addition, if only some priority three jobs can be completed in the production period, the selection of which jobs to produce is made entirely on the basis of production efficiency. This gives some flexibility to manufacturing to optimize production efficiency. Indeed, the production scheduler only considers the priority classes when scheduling and does not even need to know the due dates of the jobs. This means that marketing alone without any help from the production schedulers could determine the priority

class for each job and let the production schedulers concentrate on increasing production efficiency. Theoretically, priority class scheduling would greatly reduce the conflict between marketing and manufacturing.

However, getting the production schedulers to agree to even try priority class scheduling would be very difficult because of some of the problems listed above. The production schedulers would perceive a loss of job control because they would feel that marketing would be dictating to them. With marketing in control of the "due dates," manufacturing would think that getting an efficient schedule would be impossible and the company would lose money.

Short-term physical changes could cause the violation of the priority class scheduling rules. For example, suppose a priority class 3 job was lumped together with a priority class 1 job early in the production period to reduce setup time and cost. If later in the production period a machine broke down and caused a priority class 2 job to not be run, then at the end of the production period, a priority class 3 job was completed while a priority class 2 job was not completed. Since this is a clear violation of the idea of priority classes, the production schedulers would be blamed for the violation and marketing would be furious.

Scheduling Parks Maintenance

Although many quantitative scheduling techniques are designed for production scheduling, other types of scheduling problems have been studied, but they have some of the same obstacles listed above for production scheduling. For example, consider the problem of scheduling jobs in a governmental agency where the amount of work to be done almost always exceeds the resources available. In this case, the scheduling problem is deciding how much of each job to do and not do given the amount of resources on hand.

Anderson and Brown (1978) devised the Parks Maintenance Management System (PMMS), a quantitative parks maintenance scheduling system that avoided some but not all of the obstacles

listed above. Using the resources available (mainly personnel and machines), parks maintenance must determine how much of each job to do to keep the parks in as good condition as possible. For example, in the summer, a parks maintenance district must trade off how the number of times jobs like tractor mowing (mowing large open areas), trim mowing (mowing small areas around trees, sidewalks, buildings, etc.), litter removal, and ballfield dragging are done in each park. The main problem is to determine the correct balance between the jobs, given the resources available. This is clearly a case where a balance is necessary because doing a lot of litter removal and ballfield dragging while doing no mowing would not be acceptable to the taxpayers.

For each parks district and scheduling period, the PMMS used as data a list of the parks, estimates of the time for a parks maintenance crew to complete each job in each park, the personnel and equipment available, and what personnel and equipment constituted a parks maintenance crew for each job. In addition, the model was driven by a maximin value function collected from the parks maintenance management that showed what they considered the best balance of the jobs at various levels of resources. For example, they might feel that for a low level of resources, relatively more mowing should be done while for a higher level of resources, the amount of litter removal and ballfield dragging relative to mowing should be increased. A computer schedule was run every two weeks and gave a district maintenance supervisor an amount of each job the district could accomplish in the next two weeks with the resources predicted to be available. This computer schedule represented the best balance between the jobs as it maximized the maximin value function given the resource constraints.

A very simple example will be used to illustrate PMMS. Suppose a parks manager (PM) is trying to decide how many times the jobs trim mowing, tractor mowing, litter removal, and ballfield dragging should be completed this summer for the parks in his district. First, the PM's perfect complements preference

structure is determined by having him complete a table. Table 1 contains a completed table where initially the Desirable Quantity column as well as columns 1, 2, 3, 4, and 6 are empty except for the Totals and UTILITY rows. The PM is asked to give how many times each job should be done to keep the parks in good condition (these amounts should represent the upper end of the PM's range of interest). The PM's response is shown in the Desirable Quantity column of Table 1. Next the PM is asked to complete column 1 with percentages of the corresponding desirable quantity that sum to 80. The response of 10 for trim mowing corresponds to 10 percent of the desirable quantity of 20 or 2 trim mowings. These percentages reflect the PM's tradeoffs between the four attributes and contain what he considers the best balance between them given the percentages can only sum to 80. The attribute values corresponding to the percentages in column 1 are 2

trim mowing, 10 tractor mowing, 2 litter removals, and 0 ballfield draggings over the summer. These attribute values are then entered in column 1 of Table 2. In a similar manner, the PM then fills in columns 2, 3, 4, and 6 so the percentages for each column sum to the amount listed in Totals row. Finally, the attribute values corresponding to the percentages are entered in the appropriate columns in Table 2. This collects data on what the PM thinks is the best balance between the attributes over a range from doing nothing (column 0) to the desirable quantities (column 5) and beyond (column 6).

Since each column in Table 2 is a point in the attribute value space, a linear line between these points approximate what the PM considers the best balance over the entire attribute value space. To keep it simple, suppose the only limiting resource needed to accomplish the jobs is labor measured in hours. The PM estimates that one trim mowing requires 50

labor hours, one tractor mowing requires 40 labor hours, one litter removal requires 150 labor hours, and one ballfield dragging requires 10 labor hours. These estimates are entered in the LABOR HOURS column of Table 2. The labor hours needed to accomplish the attribute values in columns 0, 1, 2, 3, 4, 5, and 6 are computed and entered in the TOTAL LABOR HOURS row. Suppose the PM has 2074 labor hours available this summer. Then the amount of each attribute that provides the best balance while using no more than 2074 labor hours can be found by linear interpolation in Table 2. From Table 2, the best balance is 8.8 trim mowings, 15.6 tractor mowing, 6.2 litter removals, and 8 ballfield draggings for a utility of 48. Note that a non-integer amount such as 8.8 trim mowings is acceptable because that means every park would be trim mowed 8 times and get 80 percent of the way through the ninth trim mowing.

ATTRIBUTES	DESIRABLE QUANTITY	PERCENT OF DESIRABLE QUANTITY						
		0	1	2	3	4	5	6
1.Trim Mowing	20 Mowings	0	10	40	50	80	100	100
2.Tractor Mowing	20 Mowings	0	50	70	90	100	100	100
3.Litter Removal	10 Removals	0	20	50	80	90	100	120
4.Ballfield Dragging	100 Draggings	0	0	0	20	50	100	160
Totals		0	80	160	240	320	400	480
UTILITY		0	20	40	60	80	100	120

Table 1: Constrained choice table for parks maintenance example.

ATTRIBUTE	LABOR HOURS	ATTRIBUTE VALUES								
		0	1	2	3	4	5	6		
1.Trim Mowing	50	0	2	8	8.8	9.6	10	16	20	20
2.Tractor Mowing	40	0	10	14	15.6	17.2	18	20	20	20
3.Litter Removal	150	0	2	5	6.2	7.4	8	9	10	12
4.Ballfield Dragging	10	0	0	0	8	16	20	50	100	160
TOTAL LABOR HOURS		0	800	1710	2074	2438	2620	3450	4300	5200
UTILITY		0	20	40	48	56	60	80	100	120

Table 2: Attribute value table for parks maintenance example.

This system has many advantages. The PM's preferences are inputted to the model and are used to determine the best amounts of each attribute to accomplish given the resources available. The PM can easily understand how the quantitative scheduling algorithm determines the schedule. In addition, *what if* questions can be answered. Suppose city council asked the Parks Department what it could accomplish if the labor hours were increased from 2074 to 2438. Using linear interpolation, Table 2 shows that 2438 labor hours would increase the trim mowing from 8.8 to 9.6, increase tractor mowing from 15.6 to 17.2, increase litter removal from 6.2 to 7.4, and increase ballfield dragging from 8 to 16.

PMMS also collected data on how much of each job was accomplished in the preceding two-week period. Although this actual job performance data was compared to what the computer schedule predicted could be done, it was not used in a punitive fashion but rather as a starting point for discussion of what changes would enable the parks department to do a better job of serving the public. The objective was to instill pride in the parks maintenance personnel and to motivate them into making continual improvements.

By design and by enlightened management, PMMS avoided many of the obstacles listed above. PMMS avoided the job control obstacle as parks maintenance management viewed the computer schedule as simply a starting point and was free to change it as conditions warranted. In addition, the computer schedule only gave the amounts of each job that could be accomplished and did not tell a manager what personnel should be assigned to which crew or like priority class scheduling when the jobs should be done within the period. The managers were free to devise their own work schedule within the computer schedule framework so they were hopefully motivated to design an efficient schedule and could not blame any inefficiencies on the computer schedule. The managers were also free to respond to both short-term physical changes and priority changes as they saw fit. The preference and knowl-

edge input obstacle and the tradeoffs obstacle were for the most part avoided by using the maximin value function supplied by the parks maintenance management to drive the determination of the computer schedule. For the obstacle of using the computer schedule as a tool, every effort was made to enable parks management to use the computer schedule as a tool, but this was limited by the fact that the computer schedule was only produced once every two weeks and the parks maintenance managers could not use it to ask *what if* questions. In addition, although there was some minimal training on how the quantitative scheduling algorithm worked, hindsight says that more effort should have been directed into training. Finally, as with all applications of quantitative scheduling techniques, the incomplete information obstacle was present.

Overcoming Obstacles

Using the discussion above, some strategies and ideas on how to overcome obstacles to the application of quantitative scheduling techniques can now be stated. Probably the most important idea is to make the quantitative scheduling technique accessible to the managers as an integral tool in their day-to-day work. This requires three important changes in the way quantitative scheduling techniques are designed and implemented.

1. Managers must understand how the scheduling algorithm works so they know not only its strengths but its weaknesses. Much more time must be spent in educating the managers so they view the scheduling algorithm as an important tool that they can use.

2. Managers must have constant access to the scheduling algorithm so they can run what if analyses. This access was not possible in 1972 tire production system because only mainframe computers were available. However, today the power of laptop computers and the Internet make this access possible, but the designers and programmers of the scheduling system must make this access the top priority in the design and implementation of the computerized quantitative scheduling system.

3. Ways to measure a manager's value function and integrate that value function into his model must be invented. If this is done, the manager will feel ownership of the model and will not be afraid to use its results.

References

- Anderson, R. D., & Brown, J. R. (1978). Better parks maintenance. *Park Maintenance*, 31(10, 11, 12).
- Brown, J. R., & Ozgur, C. (1997). Priority class scheduling: Production scheduling for multiobjective environments. *International Journal of Production Planning and Control*, 8(8), 762-770. ■

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in top academic journals. Recognize that failures will come, but do not let them discourage you. Michael Jordan, one of the most accomplished professional basketball players of all-time, once observed, "I've missed more than 9,000 shots in my career. I've lost more than 300 games. Twenty-six times, I've been trusted to take the game-winning shot and missed. I've failed over and over and over again in my life ... And that is why I succeed." Indeed, strength and growth comes only through continuous effort and struggle, so do not be discouraged if you struggle and fail a few times. In most doctoral programs, students are surrounded by experienced faculty. Seek their help. Rely on them for advice. Remember they were once students, too. While there is no substitute for perseverance, in many cases, guidance can prove invaluable, saving time and unnecessary effort.

Good luck!

References

- Covey, S. R. (1989). *The 7 Habits of Highly Effective People*. New York: Free Press.
- Dierickx, I., & Cool, K. (1989). Asset stock accumulation and sustainability of competitive advantage. *Management Science*, 35, 1504-1511. ■