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THE USER'S ROLE IN A SIMULATION BASED SCHEDULING SYSTEM

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ABSTRACT

This paper focuses on the role of the production scheduler in developing and using a computer simulation based scheduling system. As the scheduling system end user, the production scheduler is responsible for developing schedules which support the business goals of the manufacturing facility. To do so, he must balance many conflicting objectives relating to work-in-process inventory levels, resource utilizations, and customer service. During any single scheduling period, the desired balance may vary with time or across production resources. Simulation based scheduling does not provide an optimum solution, but provides visibility into the effects of decisions. The production scheduler uses this information to perform analyses and to identify opportunities to improve the plan. His participation during system development ensures that the model and reports fully support these activities. While the schedule generation and revision process can be automated, the final analysis of the value of the resulting schedule requires human involvement. A FACTOR scheduling software application is reviewed to illustrate the role of the user in this dynamic environment.

1. INTRODUCTION

Over the last decade, American industry has faced increased competition from foreign competitors. This increased competition has forced U.S. companies to improve quality and become more efficient to maintain their presence in the marketplace. As manufacturers strive to drive out the waste and excessive cost in their manufacturing systems, they increase the interdependence of the variables in their systems.

For example, inventory has traditionally been used as a buffer between departments in order to decrease their dependence on one another. As the sizes of these buffers are reduced, departments become more closely coupled. If buffers are sufficiently reduced, it becomes impossible to consider departments as separate if effective flow through the facility is to be achieved More efficient manufacturing methods and reduced manufacturing costs involve the purchase of new capital equipment and more effective utilization of companies' existing resources.

The drive to improve the utilization of existing resources has brought increased emphasis to the importance of production scheduling. Scheduling involves complex decisions which directly impact a company's business objectives. The production scheduler must balance the effects of decisions against tangible and intangible measurements to realize production goals which may be somewhat mutually exclusive. In addition, he must address the dynamics of the manufacturing environment and business objectives.

As an example, during "normal" production, it may be desirable to process jobs at a specific work center in such a way as to minimize the time spent in setting up the work center. However, an instance could easily arise in which the decision would be made by the production scheduler to incur a relatively large set up time to process a job defined as a high priority by customer service. In this situation, processing jobs based on minimum set up conflicts with high customer service levels for some jobs.

The production scheduler must also manage the dynamic nature of these conflicting objectives. As an example of the dynamic nature of production objectives, consider a facility with strong seasonal demand exceeding capacity for some products. During seasons with lower demand, the production scheduler should attempt to carry minimal inventory to reduce costs. However, as the busy season approaches, the production scheduler must build inventory in either semi-finished or finished goods to satisfy the demand above capacity. If possible, inventory should be increased in the lowest value added form which will still allow the seasonal demand to be satisfied. Coupling the dynamics of objectives with the existence of conflicting objectives results in an extremely complex problem.

The production scheduler must perform in this environment. Not only is the scheduler required to make complex decisions which impact operating strategies, but usually he must do so within a relatively short time period.

2. SCHEDULING APPROACHES

Historically, the production scheduler relied upon manual methods to develop schedules for the shop floor. Using the simplest method, the scheduler (usually the department foreman or machine operator) selected the next job to run on each work center from the jobs waiting for the work center. The criteria used in selecting the next job were often based on the measures used to evaluate the foreman or operator and were often inconsistent with the overall business objectives.

The availability of manufacturing software brought more wide spread use of analytical approaches to scheduling. One method is sequencing by dispatching rules, such as weighted shortest processing time. These rules prioritize the jobs waiting for processing at each work center. The effectiveness of schedules generated using dispatching rules varies greatly, depending on the particular rule selected, the type of production facility, and the mix of jobs. In addition, rules are typically limited in the scope of what they consider and are not sufficiently flexible to address the dynamics which prevail on the shop floor.

Material Requirements Planning (MRP) has been widely used by manufacturers for factory management. Schedules generated by these products are based upon a bill of materials and estimated production time requirements. In many environments, these techniques are effective for long term planning but lack sufficient detail and accuracy for effective short term scheduling.

Recently, simulation has been applied to develop production schedules. Simulation based scheduling tools permit the scheduler to predict the future performance of the production system with great accuracy. Scheduling using computer based simulation requires the development of a model of the production facility. This model incorporates the physical constraints such as work-in-process inventory storage space and work center capacities and the operating strategies such as just-in-time or build-to-stock inventory management policies. Simulation as a tool allows both the physical and operational characteristics of the facility to be modeled to the appropriate level of detail. This accuracy allows the scheduler to evaluate the effects of his decisions prior to implementing them, reducing the risk of each decision and allowing the scheduler to select the lower cost option.

Simulation languages and tools have been applied to solve problems in a variety of industries. However, these tools have been either too slow and complex or have lacked the user interfaces needed to provide effective decision support for shop floor scheduling. Within the last four years, products have become available in the marketplace to provide simulation based scheduling which are robust and complete for use in manufacturing environments. They have efficient user interfaces to simplify model development and provide logical data presentation formats consistent with the needs of shop floor personnel.

3. DEVELOPING THE SCHEDULING MODEL

The process for applying simulation to production scheduling involves developing a model of the production facility and integrating it with information systems necessary to provide shop status and new demand. In addition, the interfaces required to support the production scheduler must be defined and developed. As the end user, the production scheduler should be involved in the development of the model and in the specification of the user interfaces.

There are three reasons for active involvement of the scheduler in model development. First, the scheduler is typically most familiar with the existing production facility and has extensive experience to draw upon. His knowledge of the interrelationships among departments and work centers will ensure that important constraints, variables and procedures are properly considered. Second, the scheduler is likely to be unfamiliar with simulation capabilities and limitations. The development process can serve as a valuable educational tool to familiarize him with new scheduling philosophies and how to use his new tools. Finally, by participating in the development, the scheduler has ownership of the scheduling system, greatly increasing his commitment to making the system a success after installation.

Simulation's power to address virtually any level of detail combined with the scheduler's thorough understanding of the facility often create the temptation to capture every minute detail in the scheduling model. It is important to balance the completeness and detail of the model against its complexity. Specifically, development time and money should be focused only on well defined areas with potential to add significant value to the system. As a key element in the system, the scheduler can handle problems which are not well understood, technically difficult to solve with software, or offer low returns.

The result of a less complex scheduling model is a faster implementation at a lower cost with higher user acceptance. After implementation, the impact of the remaining problems is often reduced as a direct result of the improved planning capability. After gaining experience with the new scheduling system, these problems can be evaluated from a position of strength and understanding to determine effective resolutions.

4. USING THE SCHEDULING MODEL

After the model of the facility is developed and installed, the scheduler uses it to evaluate the predicted performance of the facility for a given level of demand. If performance is not satisfactory based on the objectives for the scheduling period, he provides feedback to the model reflecting opportunities for improvement and runs another simulation to validate his feedback. When performance is satisfactory, the scheduler then generates schedule reports for distribution in the shop. Figure 1 shows the steps typically performed to generate a schedule.

As indicated in Figure 1, simulation as a scheduling tool requires an iterative approach. Simulation does not provide a direct means for optimization. Instead, the balance among cost and service measures comes from the scheduler and his ability to evaluate the predicted performance using his experience, judgement and intuition, and provide feedback to the scheduling model to capitalize on opportunities for improvement. Simulation allows him to predict the future and to test hypotheses about which approaches result in the most effective schedules.

Initially, the scheduler should focus on overall performance summaries. Typically, he begins by examining a report indicating the performance to due date for each work order. If all orders are predicted to finish on time, then possibly no further simulations are necessary. If one or more orders are predicted to be significantly late, the next step is to look for trends indicating possible causes for the lateness.

The scheduler might determine that most of the late orders are of the same part family and therefore use many of the same resources. If each of these orders also had a significantly longer waiting time, then the scheduler could review a report of resource statistics, focusing on the mean and maximum queue lengths for resources used by these orders. The utilizations of resources would also give insight as to possible remedies. One hypothesis that the scheduler may test is whether changing the release dates of some portion of the late orders would provide a more level load on the highly utilized resources. Another option would be to evaluate using alternate work centers or routings to reduce the burden on highly utilized resources.

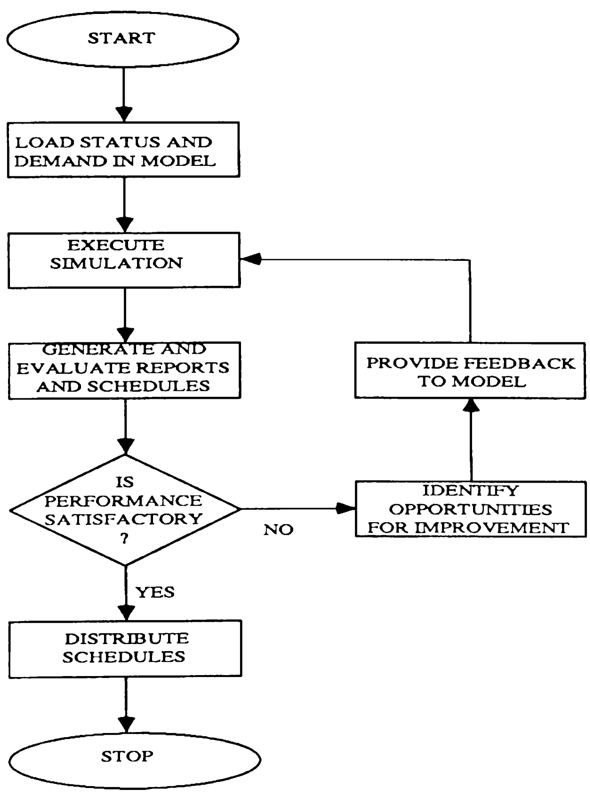

Figure 1: Scheduling Steps

It is possible that the initial simulation will indicate that all orders will be completed by their due dates, but the performance of the system could be unacceptable by other measures. For instance, some work centers might have very high utilizations early in the period and very low utilizations late in the period. This imbalance in capacity utilization might be undesirable, especially with regard to labor. The scheduler would identify this problem either through plots of resource utilization or by examining Gantt charts for each resource. Again, orders could be released at different times to distribute the load more evenly over the scheduling period.

When developing hypotheses for improving expected performance, it is vital that the user re-simulate rather than simply modify the schedule produced by the initial run. Given the complexity of manufacturing systems, it is quite possible that modifying the schedule could create an unachievable schedule. Re-simulating would identify infeasibilities prior to attempting to implement the schedule on the shop floor.

In extremely complex production environments or in environments in which the number of orders within a scheduling period is extremely large, the time required to perform multiple iterations may be too great a burden on the scheduler. In these instances, the burden may be reduced by automating a portion of the analysis or hypothesis development. Expert system tools offer an opportunity to extend the range of simulation based scheduling systems to these time consuming applications. The knowledge of the scheduler is captured in the expert system, which manages the iterations required to generate the desired system performance. The scheduler then reviews the plan before submitting it to production.

Active participation by the scheduler yields significant benefits. During development of the scheduling system, it ensures a more complete solution and provides an excellent opportunity for education. During regular operation of the system, the scheduler provides tremendous flexibility in analysis of and responses to the dynamic problems in the manufacturing facility, alleviating the requirement to address all scheduling issues within the simulation model.

5. A SCHEDULING APPLICATION

A simulation based scheduling system was implemented for an automotive engine cooling unit final assembly line. This assembly line supplied automobile assembly plants. Late shipments of cooling units to the assembly plants resulted in assembly plant down time, incurring costs of about $100,000 per hour. Minimal amounts of finished goods inventory could be held, so a missed ship date often required the use of premium shipping modes. The costs in premium shipping to satisfy delivery dates ran as high as $100,000 per month.

The objective of the scheduling system development was to provide scheduling decision support that would allow the scheduler to produce achievable, capacity constrained schedules which:

1. meet customer requirements on ship dates;
2. minimize final assembly inventory levels; and
3. maximize final assembly throughput.

Engine cooling units typically consist of a fan, an electric motor, a bracket or shroud, and various fasteners. Plastic parts (fans, brackets, and shrouds) are injection molded and motors are manufactured and assembled in house. The flow of parts through the assembly process is depicted in Figure 2. Assembly of the engine cooling units is done in conventional assembly line fashion with each component stored as work-in-process, brought to the line in hampers, and assembled by a crew of 18 to 24 assemblers performing serial operations.

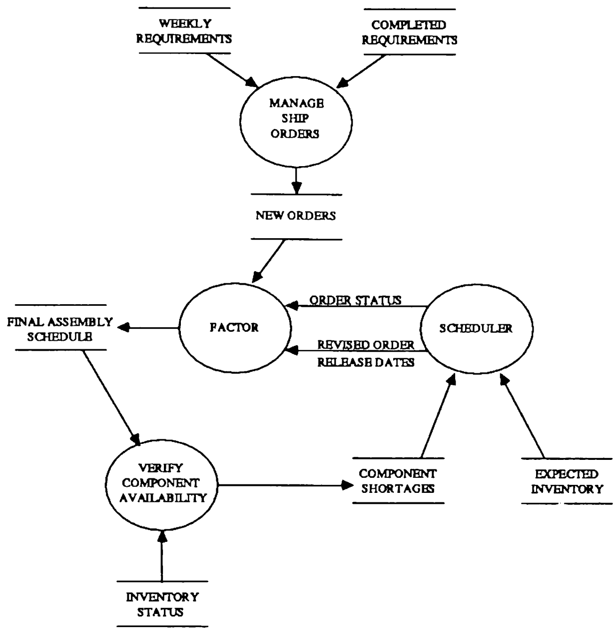

Figure 3: Scheduling Information Systems

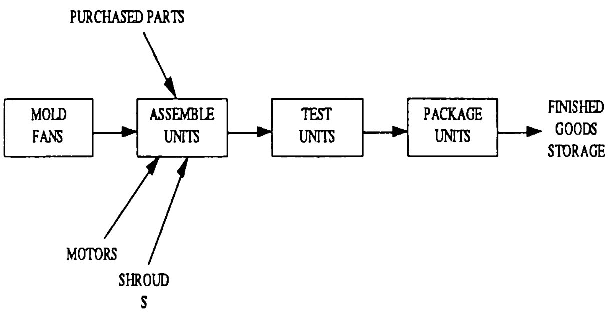

Figure 2: Engine Cooling Unit Assembly Flow

The information systems which support scheduling are depicted in Figure 3. The scheduler was active in defining his role in this new scheduling environment and in identifying the information systems needed to support daily operations and scheduling.

5.1 Development

The production scheduler participated during requirements definition and system development. Specifically, his participation was critical to developing the scheduling philosophies which met the needs of the business and found user acceptance. An understanding of the current scheduling method was obtained by interviewing the scheduler. The current method was analyzed for its efficacy relative to the project goal and the additional capabilities of FACTOR, and a new scheduling philosophy was developed. This new philosophy was captured in the simulation model. Because the scheduler made significant contributions to the development of the new philosophy, he understood its benefits and agreed to its implementation. User acceptance was also enhanced by tailoring FACTOR reports to present data to the scheduler in a format consistent with his objectives and approach.

Prior to implementing FACTOR, production was scheduled using manual techniques. To manually manage the task, the scheduler would examine the requirements for the week for each end item, aggregating them as "lots". He then assigned each lot to an assembly line, attempting to minimize the requirements for change over of the line during the week. In order to avoid a change over during a shift, the scheduler "padded" a given lot to fill the shift and scheduled the change over for the end or beginning of a shift. Typically, a lot was actually composed of multiple customer requirements, each with a different ship date. In order to meet requirements on ship dates, the entire lot was usually scheduled to be completed by the earliest ship date in the lot. Padding lots and using earliest ship dates had two negative effects. Often, the lot size was so large that performance to ship date was compromised. In the event that the entire lot was actually completed by the earliest ship date, excess finished goods inventory was created.

It was determined through the analysis that it was highly desirable to minimize the number of change overs performed on each line but that change overs should not be minimized at the expense of meeting ship dates. In addition, combining multiple customer requirements into a single lot conflicted with the overall objectives of meeting ship dates and reducing inventories. FACTOR provided the capability to consider each customer requirement, or order, as a separate set of demand. Orders of the same product type could be run in sequence to emulate lots, or orders could be run individually if needed to satisfy ship dates. A scheduling rule was implemented to encourage like orders to run in sequence, minimizing change overs. If however, an order for a different product was waiting for a resource and had potential to be late, the rule would break the previous sequence of orders, incur the change over, and start the potentially late order.

Although a new scheduling system was implemented with the capability to provide significantly more data to the scheduler, it was determined that the existing format and level of detail were effective for supporting the scheduler. FACTOR reports were tailored to be as similar to the existing format as possible, providing information on product type by lot while maintaining references to each customer ship order. This format provided the scheduler with summary information allowing him to readily investigate his inventory position and requiring minimal changes in communication with the shop floor.

5.2 Scheduling

The process for producing schedules with FACTOR in this application is consistent with the steps depicted in Figure 1. The scheduler uses the system to produce schedules for the engine cooling assembly line. Schedules are evaluated based on their ability to meet demand for finished goods and on the availability of critical components needed to assemble the cooling units. When the requirements are predicted to be completed on their ship dates, the scheduler can then evaluate options to improve the utilizations of resources or to increase throughput. He provides feedback to the scheduling simulation either by adjusting order release dates to account for material availability and to level the load on his resources or by overriding a decision made during the simulation which he feels could be improved.

The evaluation of component availability and satisfaction of requirements are quite interrelated. The scheduler runs an initial simulation assuming that all components required to build the needed engine cooling final assemblies are available. Initially, he evaluates the overall performance to ship date and generates a report summarizing the required component quantities for each day. Using an analysis program developed for this application, this report is then compared to reports provided by the existing information systems which summarize the current and expected component inventory levels. The result is a list of exceptions indicating components predicted to be consumed before they are expected to be available.

The scheduler then evaluates the material shortages and, using his knowledge of the production environment (and the telephone), determines when the shorted materials will be available. He then revises the release dates for the orders affected by the shorted components so that they are not released to the shop until the required materials are expected to be available. The simulation is then executed again to verify that the requirements for the period will be completed on their ship dates.

Alternatively, the simulation could have been designed to automatically avoid scheduling assemblies for which components were not shown as available. The "exception" method above was selected to provide visibility to component material problems, thereby affording an opportunity to react rather than hiding the problem. The responsibility for this decision was conciously assigned to the scheduler.

When the scheduler has developed a plan with good expected performance to ship date based on material availability, he evaluates the performance to identify opportunities to process orders at specific work centers in a more efficient sequence. He provides feedback to the simulation to capitalize on these opportunities through a tailored interface which provides direct control of the allocation of resources to orders. This interface allows the scheduler to specify time intervals during which a resource may only process specific product families and gives him the control needed to pursue local optimums without modifying the scheduling philosophy of the entire facility. Again, before schedules are generated and distributed to the shop floor, the simulation is run to verify the feasibility and performance to ship date.

As the scheduler gains familiarity with the scheduling system and proceeds up the learning curve, the hypotheses he develops will improve. As his experience increases, the number of iterations required to generate effective, capacity constrained schedules decreases. In addition, the track record of achievable schedules will result in still further user acceptance and continued improvements.

6. CONCLUSION

Increased competitiveness in many industries has caused manufacturers to renew their emphasis on increasing efficiencies in their operations. The result reinforced the importance of production scheduling as a means to reduce inventories and more effectively utilize production resources. Simulation based scheduling tools well suited to addressing the dynamic and often conflicting objectives of production environments which provide efficient and flexible user interfaces for use by shop floor personnel are available.

Simulation based scheduling systems do not provide a direct means to an optimal schedule. Rather, they offer an iterative approach in which the judgment and expertise of the production scheduler are an integral part of an efficient and achievable solution. The role of the scheduler within such a scheduling system is to evaluate the performance of the facility as predicted by the simulation model and to capitalize on opportunities to improve the performance using his knowledge and the visibility of the future that the simulation model provides.While tools such as expert systems should be used to reduce the burden on the scheduler, his experience and flexibility offer significant benefits during system development and operation.

By involving the scheduler in development and making him a key component of the scheduling system, the efficacy of the system is enhanced. During development the scheduler learns the capabilities of the new system and develops ownership of the solution. His experience and understanding ensure that scheduling issues are addressed in the proper detail and that the appropriate balance between complexity and completeness is achieved.

An application using FACTOR illustrated the benefits realized when the scheduler participated in scheduling system development. In addition, the specific analysis and the tools which were made available to support the scheduler's decisions were discussed. The results of the application have included improved ship date performance and increased capability to pursue inventory reductions.

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