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*Stellar Performance in Planning and  
Scheduling for Multi-Plant Manufacturers*

# Automated Scheduling Methods

Advanced Planning and Scheduling Techniques



# Table of Contents

Introduction	3
The Basic Theories	3
Constrained and Unconstrained Planning	4
Forward, Backward, and other methods	5
Rules for Sequencing Tasks	6
Conclusion	7
For Further Reading	7



# Automated Scheduling Methods

## Introduction

Many theories and commercial software solutions for Advanced Planning and Scheduling, known as APS, have appeared over the years. Ultimately, scheduling systems strive to answer the question of “When should this task be scheduled, and what resources should accomplish the work?” This paper examines the available methods for quickly creating production plans and schedules for manufacturers to meet their business objectives.

## The Basic Theories

Most APS software uses either:

1. “Rules-based” methods for assigning tasks to resources. These methods are also sometimes called “heuristic” or “deterministic” methods. One advantage of these methods is that the calculated results will be the same for a given input state, making it easier for software users to understand the decision-making process of the rules-based engine. These methods are also well-suited to complex scheduling problems which have many constraints that need to be followed. Rules-based scheduling also allows for “incremental change” of schedules, for example enabling a given task to be manually repositioned by the program user. A downside to rules-based solutions is that they do not guarantee the best possible solution. Also, they often rely on experimentation to determine which rules would deliver the best results for a given set of inputs.
2. “Optimization” based methods seek to minimize or maximize a mathematical objective, with the idea that the “best” results are output for each planning run. Typically, cost or penalty factors must be assigned for use by the optimization function. It can be difficult for users to understand why individual decisions regarding tasks and resources are made, so results can seem counter-intuitive at a detailed level (though in theory the “big-picture” is optimized.) Furthermore, only known variables can be optimized, and the exclusion of an important factor can give unusable results in the real-world. If conditions in the real-world fluctuate, it is common to have to adjust the cost-factors for the optimization engine – resulting in more work for the end user. In practice, optimization-based techniques such as linear programming may be better suited to more static situations where the factors are easily understood. There are other important limitations to using optimization techniques such as linear programming for scheduling problems. It can be very time consuming to



build and maintain constraint models and require a high degree of expertise. In addition, there are a wide variety of real-world scenarios that simply cannot be handled by this approach such as sequence-dependent setup times and continuous-time scheduling.

## Constrained and Unconstrained Planning

By definition, an APS system creates capacity and material plans, primarily based on either of two dynamic inputs:

1. Supply and Demand Inputs, netted within the APS system
  - a. Supplies, such as available inventory, purchase and transfer orders
  - b. Demands, such as sales orders and forecasts
  
2. Net Requirements calculated from an MRP or DRP engine (manufacturing orders). In this case, the APS system is mainly used for capacity planning, with the assumption that the MRP process manages the material plans. These engines ideally are linked together, forming an iterative loop.

These tasks can consume capacity and materials in a constrained or unconstrained manner. Sometimes the term “finite” is used to describe constrained planning, especially with regards to capacity. Likewise, “infinite” is commonly used to refer to unconstrained planning. In constrained planning, resource capacity and material availability are treated as having limits that cannot be violated during the planning process. In unconstrained planning, these same limits are treated as threshold levels that generate exception messages when levels are violated.

Constrained planning offers these advantages and disadvantages:

1. Sequencing of work through a given resource can be performed. For example, by recognizing that only a limited number of tasks at a time can proceed through a resource, products with similar characteristics can be grouped, resulting in efficiency gains.
  
2. Plans are always feasible if the given data is accurate. Even if no action is taken, the timing of work and lead-times are realistic for a given situation. For example, if a critical purchased material will not arrive by a given date, the software recognizes this constraint and plans accordingly.
  
3. Software can make alternative decisions based on availability of a constraint during its scheduling run. For example, if a preferred constrained resource is unavailable, the next best resource can be selected automatically by the software logic.
  
4. A common issue cited with constrained planning is that orders will be scheduled late, beyond their due-dates. Although that can happen, this information is useful because it gives feedback to the user that either capacity must be increased, sequencing decisions



must be altered, or that inputs must be changed.

Unconstrained planning offers these advantages and disadvantages:

1. For longer term capacity planning, required levels are shown, giving the company feedback on what appropriate levels of capacity should be.
2. “Management by exception” is still promoted by many industry organizations – expecting the human planning team to make the best decisions for material shortages and capacity overloads. This can work well when there is flexibility in capacity and material lead-times, and when there are not a lot of exceptions to manage.
3. Unconstrained planning generally cannot sequence work through a resource because the resource is allowed to be “overloaded”. Likewise, alternatives for reducing the given load on a resource must be manually evaluated by the end-user in most cases.

A modern APS system recognizes that a manufacturer may have legitimate uses for both constrained and unconstrained planning in the same planning model, and provides flexibility to model materials and resources as appropriate.

## Forward, Backward, and other methods

With the appropriate constraints or lack of constraints on materials and resources set, whether to “forward” or “backward” load the orders is a common question. What are these methods, and what other methods have developed?

Forward scheduling attempts to keep resources utilized by pulling available tasks “forward” in the schedule, and completing them as soon as possible. For companies that desire to ship orders as soon as possible and keep resource utilization high, this is the recommended method. There is the risk of building too much finished goods inventory if shipping as soon as possible is not an option.

Backward scheduling, sometimes called “just-in-time” or JIT scheduling, was developed for companies that have inventory reduction as a primary goal. By attempting to start each task at the latest possible moment to ensure successful on-time completion, inventory can be purchased later, and WIP items and finished goods are produced no sooner than needed. In practice, it is recommended to allow a buffer ahead of the actual requirement date to account for the variability in the production and purchasing processes. In some cases, if a JIT schedule is executed precisely and there is excess capacity, this planning method would result in gaps in the schedule where a resource may be required to stand idle before beginning the next task “just-in-time”.

“Drum-buffer-rope” scheduling is based on the Theory of Constraints by Eli Goldratt. In this method, a constraining resource is set as the “drum”, setting the pace of production. This is ideal where the “bottleneck” is known and does not tend to vary. A “buffer” of inventory is



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determined to keep the drum utilized as much as possible, with the theory that if the drum is starved, overall production (and profit) will suffer. The “rope” is the demand set by the orders and/or forecasts that are setting the sequence of work through the drum. For environments where different resources may be constraints depending on product mix, this method may be an oversimplification, since in modern APS systems each resource could potentially be a “drum” based on the work to be done.

## Rules for Sequencing Tasks

“When should this task be scheduled, and what resources should accomplish the work?” With constrained planning, this question can be answered quickly, intuitively, effectively, and predictably with a method based on what are commonly called “simulation rules” or “dispatch rules” for resources. These rules give each resource a routine for selecting the best available task to work on next, while recognizing constraints. During the process, you might think of time being “simulated” as passing during the planning run, from the beginning of the planning horizon to the end (or a subset of that time range). How does this work?

1. The resource needs to be available to work on a task at a given time. If the resource is “busy” at that time, the simulated timeline must pass until the resource is available.
2. Only tasks that are “ready” to be worked on can be considered by that resource. This requires:
  - a. A method for selecting which tasks can be assigned to a resource, based on skill sets or production capabilities.
  - b. A task will be “ready” based on the expected availability of materials at that moment in time, as well as any preceding constraints based on subassemblies or other operation steps within a routing or process flow.
3. If a resource has several “ready” tasks to choose from at a given point in time, it needs to have a “rule” for selecting the best choice.
4. The resource applies its rule, loads the task, and must wait until the expected completion time of that task before beginning again at Step 1.

A simple rule for selecting a task might be “choose the task with the earliest due-date”, or “select the task with the highest priority code”.

Simulation rules are applied for every resource in the model, and each resource could potentially have its own rule. With modern memory-resident applications, these step-by-step calculations are completed in a matter of seconds even with large volumes of data and constraints.



Modern simulation-based APS systems recognize that simple selection rules for tasks based on due-dates and priorities are insufficient for many manufacturers. Many variables might need consideration, but how can they be factored into the plan intuitively? One method is to allow users to decide how important these factors are to their business, and assign them weights. For example, both due-date and priority can be considered, while striking the right balance between high-priority orders and orders with tight deadlines. Beyond that, multiple factors can be considered, such as product attributes and groups, profitability, costs, and industry-specific factors – all within a single rule. Multiple rules can be stored and compared easily, primarily through generating “what-if” schedule scenarios, each with their own Key Performance Indicators important to that business.

## Conclusion

For an APS system to have any use to a manufacturer, how it automates the scheduling process must be considered. These are key factors to evaluate:

1. Can the system model my resources and materials in a way that makes it easy for me to easily create effective schedules?
2. Does the APS have methods which will help meet the business objectives for our company? Objectives can include cost reduction, on-time performance, profitability, resource utilization, output maximization, cash flow, product safety guidelines (such as cross-contamination), customer preferences, and other objectives.
3. How self-explanatory and immediately useful are the results of a planning run?
4. Can the end user easily adjust the “rules” when real-world conditions change?
5. Is the process fast enough to shorten and automate the planning cycle?

An APS helps to automate the decision process, so beyond the actual methods outlined here, the ability to store and compare different scenarios and track Key Performance Indicators is valuable in its own right.

## For Further Reading

1. **Theory of Scheduling** by Richard W. Conway, William L. Maxwell, and Louis W. Miller.
2. **The Goal** by Eliyahu M. Goldratt and Jeff Cox
3. **Producing for Profit** Jim Cerra and Tanya Menendez

