Risk-based Planning and Scheduling: Why Variation Matters

By C. Dennis Pegden, Ph.D.

The role that variation plays in creating congestion and delays in manufacturing is well documented in the literature but is typically ignored in the day-to-day planning and scheduling of production. Advanced Planning and Scheduling (APS) tools generate schedules by completely ignoring the variation in the system. In some cases hours of computation are expended to generate a schedule; however, the basic assumption of deterministic times makes this schedule unrealistic and optimistic from the start. By ignoring variation APS tools generate schedules that promise more than can be delivered.

To illustrate this point we will take a very simple scheduling problem comprised of a single machine. On the average, jobs arrive to our machine every hour and require 55 minutes to process. They are picked up two hours after they arrive. Let's look at a simple deterministic schedule for processing the first three jobs in our simple system. The Gantt chart for our schedule based on our deterministic times is shown in Figure 1.

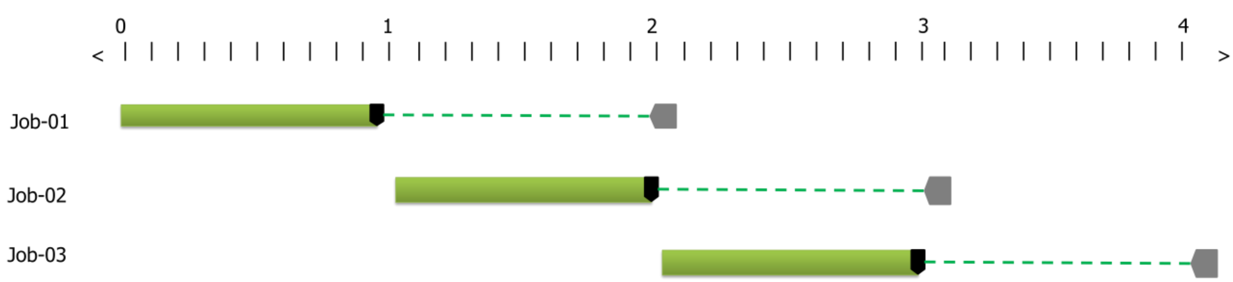

Figure 1 - Gantt Based on Deterministic Analysis

Note that our schedule looks good; we have 92% utilization of our machine, a 5-minute break between each 55-minute job, and all jobs have a 65-minute slack time (indicated by the dashed line) built into the schedule between the planned completion time and their due date. Since we have a slack that exceeds our makespan to buffer to account for any unforeseen problems, from initial appearance this looks to be a robust schedule for our planned three jobs.

Although we have created this schedule by assuming away all variation, real-life systems have many sources of variations. For example the processing times typically vary from job to job, purchased or manufactured components may arrive late and hold up the start of an operation, machines may fail, and crew may not show up. These are things that are often beyond our control and degrade the schedule and cause our performance to fall short of our plan.

Let's now examine what happens to the long-term behavior of our simple one-machine system when we add variability in the arrival and processing times. We will now assume that our data represent expected values, and the actual times vary around these values. To simplify the mathematical analysis, we will assume both the time between job arrivals and the processing time on the machine are exponentially distributed. Given this assumption we can use basic queuing theory to compute the long-term behavior for scheduling on this single machine.

With the variation factored into our system a simple queuing analysis shows that our system performs very poorly. Although our long-term machine utilization remains 92%, our machine usage is highly variable. The machine operator is frequently working long periods without a break, and at other times is starved for work with long periods of idleness. Each arriving job **waits an average of 10 hours** before it starts processing, and only **16% of our orders are ready on time**. We have exactly the same physical capacity as before, except our inventory levels and on time performance are terrible. What appears to be a feasible (good) plan based on deterministic values becomes infeasible (terrible) when variation is considered.

This phenomenon explains the gap between existing APS tools and the reality of scheduling work in a complex manufacturing system that is full of variation and uncertainty. The schedules that are generated by deterministic tools cannot properly deal with the realities of the factory floor.

Simio Risk-based Planning and Scheduling (RPS) is the next generation of APS that is specifically designed to account for risk and uncertainty. RPS uses a purpose-built discrete event simulation model of the system to fully capture both the detailed constraints and variations in the system. RPS then uses this model in two ways. The first is to generate a detailed schedule/plan. In this case the model is executed in a purely deterministic mode; machines do not break, process times are always constant, materials arrive on time, etc. This is the optimistic view assumed by all APS systems and produces a deterministic plan/schedule. Once the schedule has been generated RPS then replicates this same simulation model with variation turned on and performs a probabilistic analysis to estimate the underlying risks associated with the schedule. The risk measures generated by RPS include the probability of meeting user-defined targets, as well as expected, pessimistic, and optimistic schedule performance. With RPS we generate a similar Gantt chart (Figure 2) as before, except now we add color-coded risk measures that show our substantial risk of missing our planned due dates.

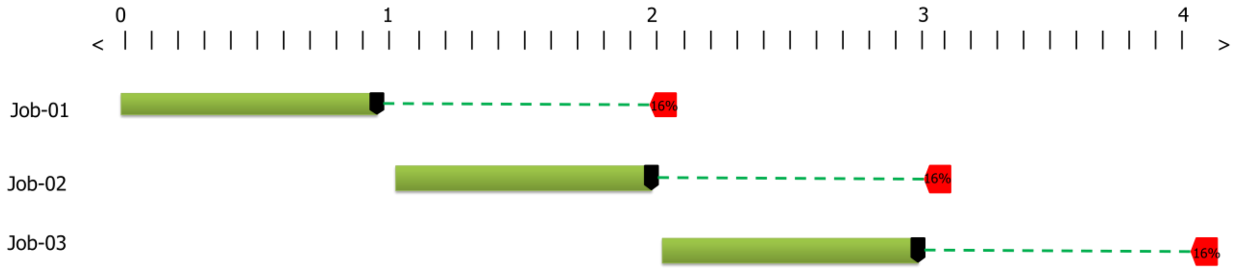

Figure 2 - Gantt with Stochastic Risk Analysis

Although a schedule slack that exceeds the makespan may seem "safe", we see in this simple example that our jobs are at high risk of being late (only a 16% chance of being ready on time).

By providing up-front visibility into the inherent risk associated with a specific plan/schedule, Simio RPS provides the necessary information to take early action in the operational plan to mitigate risks and reduce costs. Simio RPS provides a realistic view of expected schedule performance. Specific alternatives such as overtime or expediting external material/components from suppliers can be compared in terms of their impact on both risks of meeting schedule targets, and costs of mitigating those risks, thereby providing a customer-satisfying operational strategy at a minimum cost.

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About the Author: C. Dennis Pegden, Ph.D. Simio founder and chief product officer. Dennis led the development of the SLAM, SIMAN, Arena, and Simio simulation tools. He co-authored three simulation textbooks and has published papers in a number of fields including scheduling and simulation.