Simulation-based Planning and Scheduling with Risk Analysis

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Executive Summary

Traditional planning and scheduling methods are unable to account for unavoidable variations, making it difficult for them to remain of value in the long term. In contrast, simulation-based planning and scheduling can incorporate variation into the model, providing long-term value. However, this requires a new set of simulation tools specifically designed to focus on planning and scheduling, including the ability to account for the underlying risk imposed by variations in the system. These new tools go beyond the traditional use of simulation for comparing alternative designs and directly support the use of models within an operational setting to improve the everyday production, operational, and business level decisions that are key drivers to the overall success of an organization.

Simulation-based Planning and Scheduling with Risk Analysis (SPSRA) is the application of simulation methodology to operational planning and scheduling. The basic concept is to leverage the predictive power of simulation models to improve the daily operations of a system.

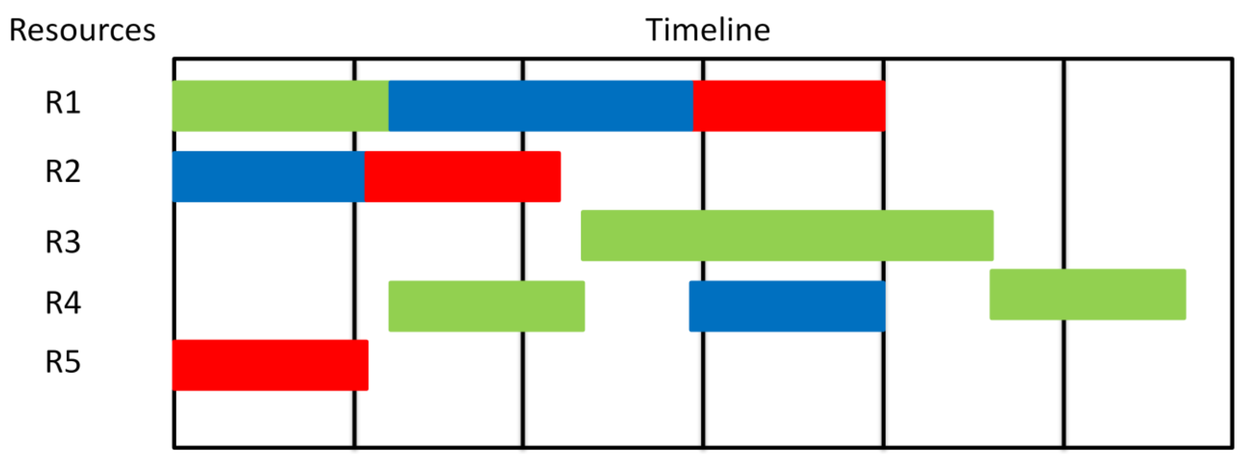
In a traditional simulation application we use the model to make improvements to the system by comparing alternative system designs. For example in a manufacturing application we might use the model to determine the number and type of each machine in our production line, as well as buffer sizes, material handling designs, and production strategies. Once we have designed our production system we are done with the model until we revisit the design at some point in the future. In traditional simulation applications we only make use of the model on an occasional basis when evaluating fundamental changes to the underlying system design.

SPSRA provides value in day-to-day planning and scheduling

In contrast, with simulation-based planning and scheduling, we use our model on a daily basis to help plan and schedule our system operations. Hence the model delivers value on a continuous ongoing basis. The basic purpose of the model is to determine the best sequence for a set of tasks across a limited set of resources. In a manufacturing system, we might use a simulation model to plan and schedule the actual production of orders in our facility. Likewise, in a healthcare system, we might use a simulation model to plan and schedule activities for our operating rooms. In either case our model is used on an ongoing basis to plan and schedule the actual work to be performed by the system.

In an operational setting the model works with actual data for individual transactions. In a manufacturing application, the model would process a specific list of production orders, using actual routings and expected processing times, expected material arrival dates, etc. This data is typically downloaded to the model from the ERP system. Although there is typically variation in things like processing times, material arrival dates, etc., the planning and scheduling is done with all deterministic values. All randomness that is normally present in the simulation model is removed, and all times are assumed to be their expected values. Likewise all unplanned events such as machine breakdowns, workers calling in sick, etc., are eliminated from the model execution. This is necessary because it is not possible to develop a detailed plan or schedule that incorporates variation and unplanned events.

The output from the traditional planning and scheduling simulation model is often viewed in the form of a Gantt chart that shows individual transactions across resources over time. In the following simple example we have three manufacturing orders (green, blue, and red) that are processed across five resources (R1, R2, R3, R4, and R5). Our red order is first processed on R5, then R2, followed by R1. The simulation model generates this production plan by simulating the actual movement of these three orders through a detailed model of the limited resources in the system. The model logs the start and stop time for each order on each resource, and these times are then used to display the schedule in the Gantt chart.



To generate this schedule the model assumes all deterministic times and no unplanned events. However in actual systems there are many sources of variation and unplanned events. For example if resource R1 is a machine it might break and need repair, or the actual task time for the red order on resource R5 might be 10% longer than planned.

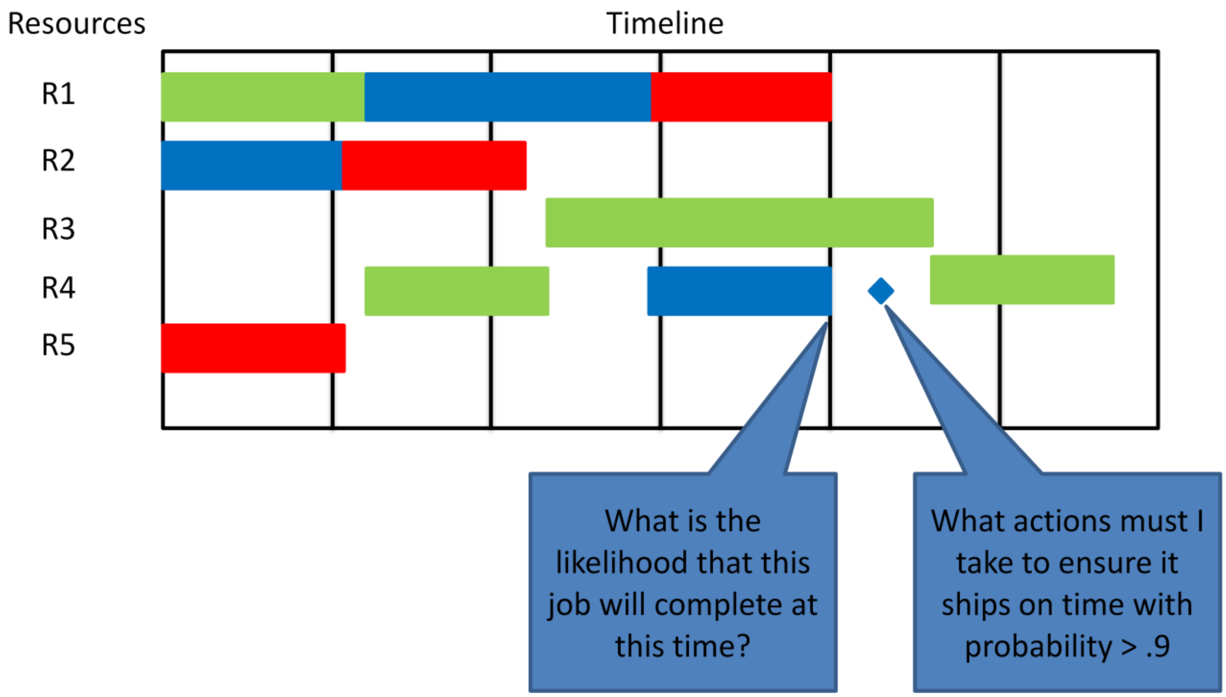
The challenge: How do you account for variation and unplanned events?

A deterministic plan is by nature optimistic, and it is rare that the plan is actually met. In typical applications the actual system performs worse and worse over time compared to the plan, and then at some point the plan is either ignored or regenerated to reflect the variations that have occurred. It's important to realize that this does not mean that the plan was faulty from the start; it's just the basic nature of any deterministic plan, no matter how "optimal" the plan appears from the start. A "good" deterministic plan will migrate overtime towards a "bad" plan as actual variations occur in the real system relative to the deterministic plan.

There are many sources of variation in most real systems that cause this migration from a good plan to a bad plan. Task times typically vary from their expected times, resources will often not be available as planned, and required materials may not arrive on their expected dates. In addition, machines may break, workers may not show up, or they may perform poorly because they are sick or distracted. Although these are not things that go into the plan that we generate with our simulation model, they directly impact the ability of our real system to meet our plan.

In planning and scheduling applications we often have targets that we wish to meet for individual transactions being processed by our system. In a production system, for example, we might have targets related to ship dates for each order, as well as activity based costing assigned to each order. A feasible plan or schedule is defined as one where all targets are met by the plan/schedule. When we run the model, we generate our operational plan -- and this plan may or may not be feasible relative to the targets we have set. We can then use the model to try "what if" scenarios such as adding overtime, changing/splitting production batches, etc. to achieve a feasible plan.

Because of variation in the system, what starts off as a feasible plan may turn infeasible over time. Although we may plan our production in such a way that all orders are shipped by their due date, variation in the system may cause one or more orders to ship late. As a decision-maker, I would like to know in advance the risk associated with each transaction meeting each of the planned targets. In our previous example, I might have a target ship date for my blue order indicated by the blue diamond, and I might want to know the likelihood that my order will ship by this date. Hence having a feasible plan is not adequate; what I want is a feasible plan that falls within my risk tolerances for meeting my critical targets.



Risk measures enable more complete evaluation

Although traditional planning and scheduling methods cannot provide any assessment of risk, with simulation-based planning and scheduling with risk analysis we can incorporate variation and unplanned events into the same base model that we use to generate the plan to also generate risk measures for each transaction relative to its targets. Hence a given plan can be judged by the decision-maker not just on its feasibility at the time that the plan is generated, but also the robustness of the plan over time in terms of the underlying risk associated with hitting each target that has been defined for each individual transaction that we are planning. This provides the decision maker-with the ability to plan critical operations while fully accounting for the underlying risk imposed by variations in the system.

New simulation tools bring speed, ease-of-use and risk analysis to operational applications

To implement simulation-based operational planning and scheduling with risk analysis a new set of simulation tools are required that are focused on this general application area. Simulation tools of the past are not designed or equipped to work in this environment. These new tools must support rapid modeling and easily and flexibly interface to a wide range of enterprise data that is typically held in spreadsheets, data bases, or ERP systems. These tools must also make it easy to define and properly evaluate alternatives without requiring sophisticated modeling skills or knowledge of statistics. And finally, these tools must go beyond the traditional use of simulation for comparing alternative designs and directly support the use of models within an operational setting to improve the everyday production, operational, and business level decisions that are key drivers to the overall success of an organization.

One such set of tools is simulation-based operational planning and scheduling with risk analysis from Simio LLC. SPSRA has been implemented in multiple, commercial production environments. Prior to these commercial implementations, a U.S. provisional application was filed by Dr. Pegden, founder and chief executive officer of Simio LLC, and the invention has a patent pending.

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About the Author: C. Dennis Pegden, Ph.D. Simio LLC founder and chief executive 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. cdpegden@simio.com.

