TECHNICAL PAPER

# TP07PUB5

# A Lean Analysis Methodology Using Simulation

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## abstract

The article outlines a methodology for using simulation modeling as a tool in lean improvement programs and as a complement to other techniques, such as value stream mapping and kaizen. Simulation refers to a software program, and there are different types and uses of it within manufacturing, such as for CNC. This methodology refers to "discrete simulation," which allows one to visually see and measure how processes perform over time, including materials, information and financial flows, and how probabilistic variables impact them.

## terms

Lean
Simulation
Process
Methodology
Six Sigma
Manufacturing

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# A Lean Analysis Methodology Using Simulation

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The article outlines a methodology for using simulation modeling as a tool in lean improvement programs and as a complement to other techniques, such as value stream mapping and kaizen. Simulation refers to a software program, and there are different types and uses of it within manufacturing, such as for CNC. This methodology refers to "discrete simulation," which allows one to visually see and measure how processes perform over time, including materials, information and financial flows, and how probabilistic variables impact them.

It is particularly valuable in operations where a mix of products share resources, and it is difficult to "get your head around" all the things that are happening asynchronously, even in an operation with only moderate complexity. The devil is in the details when it comes to designing a workable new process.

The case study described used simulation to plan and test the conversion from an MRP based push process to a demand driven pull process in a single plant operation. Each major set of equipment on the factory floor operation was simulated in this test process.

There are two important takeaways from this case study:

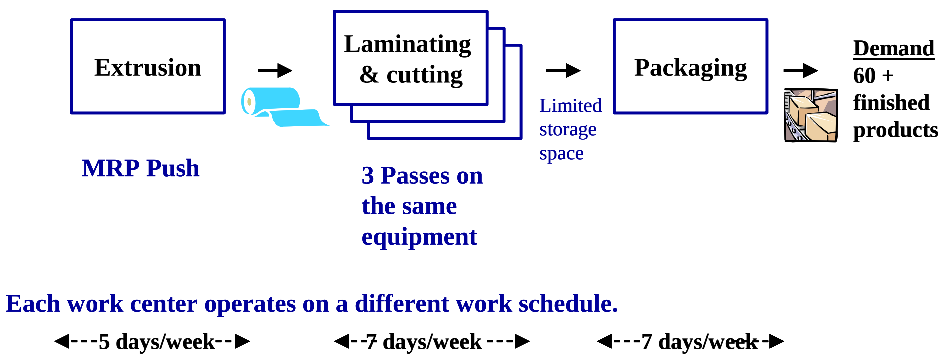
1. Simulation is valuable for evaluating things that other tools cannot, such as product mix, setups, variability in processes, downtimes, demand, etc.
2. Internal people can be trained to use and develop these models, particularly people that have been trained in six sigma analysis already. It becomes another key part of their toolbox.

There are sometimes objections in the lean community to using software solutions in lean manufacturing analysis. In this case, simulation modeling is a valuable complement, rather than replacement for the traditional tools. For example, value stream mapping is a key tool; it is a good beginning. But it is static, and typically only done for high volume products, or classes of products. Simulation allows the value stream map to become dynamic, and to model the range of probable values, not just averages. It also allows linkages to other tools such as those used by six sigma teams, to present results such as projected capacity utilization in a consistent manner.

In the project described, the project team had completed a value stream map, implemented 5S in the work centers, and conducted a kaizen event to identify possible solutions to identified issues. As in most value stream mapping exercises, there were data unknowns, especially values for things such as downtimes and extended setups. Developing a model can actually be a benefit to provide a structure for data collection for the missing information. It is possible to develop a range of likely values through a combination of limited sampling and input from factory floor staff to begin using simulation for bottleneck/constraint verification.

The team used a simulation model to set up pull process in a flow shop for laminated plastic manufacturing. It was a make-to-stock process beginning with manufacturing of rolls of extruded plastic. The basic unit in the operation is a lot (one roll). The figure below depicts the Before process. There are some unique things about it: namely, some set time is required before the laminated plastic is cut, and several passes on the same equipment, analogous to a job shop, is embedded in the middle.

**Manufacturing Process: Before**




The methodology for the project was as follows:

- The team consisted of a master black belt, operations supervisor, and planner/scheduler who worked together to develop ideas they and the work center staffs had for improvement.
- Issues in the before process had been identified as: poor service levels, labor cost over budget, and projected growth in volume that had to be accommodated.
- The group started with demand and worked back through the process to meet the pull objective.
- The master black belt configured and trained on a licensed simulation model that has preset templates for lean analysis, so the model did not have to be developed from scratch. The configuration and training took about one month.
- The three person team ran model scenarios and reviewed results over about three months to test alternative lean techniques and scheduling rules.

The analysis steps with model were:

1. First, replicate current process metrics to validate the model.
2. Analyze work shifts and responsibilities.
3. Test a make-to-order mechanism for finished goods.
4. Test kanbans for extrusion to replace the MRP trigger.
5. The packaging operation was the critical constrained resource in the flow. A Constant Work-in-Process (CONWIP) mechanism to keep the packagers busy was tested. Since there were a variety of finished products and setup rules, an Every Product Every Interval (EPEI) rhythm cycle was incorporated to deal with that. Quality testing after the packaging was not initially included in the process analysis. However, as tested progressed, and throughput was improved, quality testing became a bottleneck that also needed to be addressed.

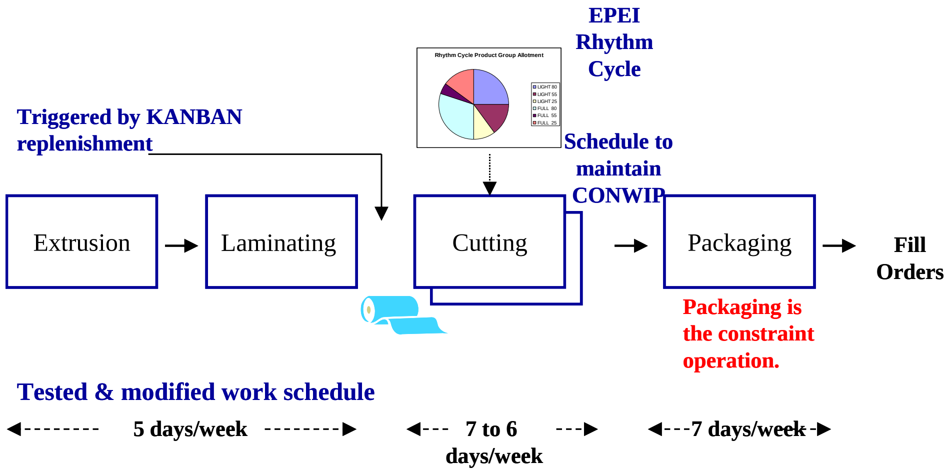
Interesting perspectives and learnings evolved as the team reviewed results. For example, the planner/scheduler noticed the impact of set time required after the 2nd step, lamination, before the plastic was cut, and proposed that it be done immediately after the 1st step of extrusion, rather than putting the rolls in inventory. The team then theorized that there was enough time to do it this way with the same work crew. This was then tested as a scenario, and reviewed with the work crew.

The model used in the analysis had capabilities for testing various lean techniques. Not all were used in the first phase, but the following summarizes those that were:

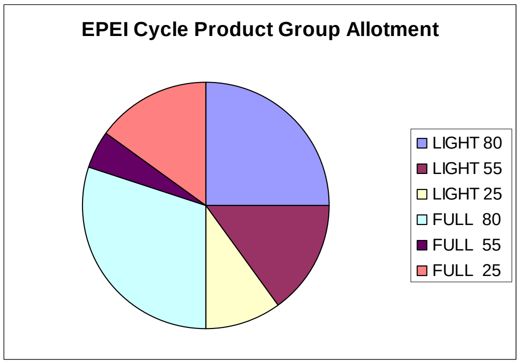
| CAPABILITY | USED |
|---|---|
| Kanbans | √ |
| Schedules | √ |
| EPE (every-part-every …) interval | √ |
| Campaign lengths vs. one lot flow | √ |
| Setup reduction | |
| Routing changes | √ |
| Shared resources | √ |
| Postponement | |
| Variability impacts | √ |
| Downtime impacts | √ |
| Yield & scrap | √ |
| Material lead time | |

The most challenging issue in the process was development of scheduling/replenishment rules for finished goods. There were 60+ finished products defined by specific combinations of lamination, cutting and finishing, and packaging. So converting to a demand pull with no finished inventory with the constraints of setups, and limited storage in front of packaging was tested with a variety of scenarios. The resulting process met the lead time requirements for finished orders, with the combination of an Every Product Every Interval (EPEI) rhythm cycle, and a Constant Work-in-Process (CONWIP) rule so that Packaging was not starved.

## Manufacturing Process : After



The Every Product Every Interval rhythm cycle maintains the CONWIP rule.




There are 60+ total products; in 6 product groups.

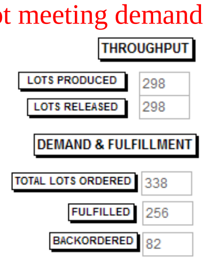
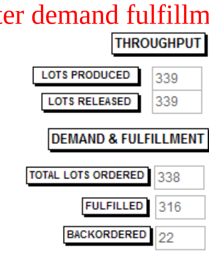
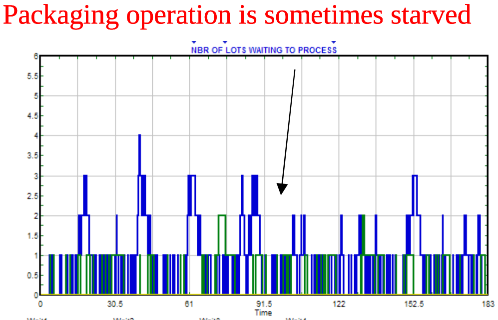
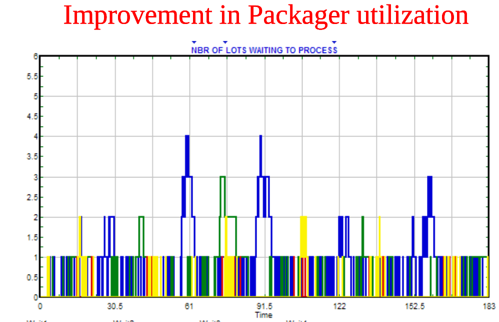
As demand arrives for each product, the production order is assigned to the next available cycle spot for its product group.

There are fairly complex setup rules between product groups.

Data required to populate the model include:

- Rules for equipment setup and processing
- Product routings
- History of equipment and staff utilizations
- Historical service levels for finished goods orders
- Root cause analyses for service failures.

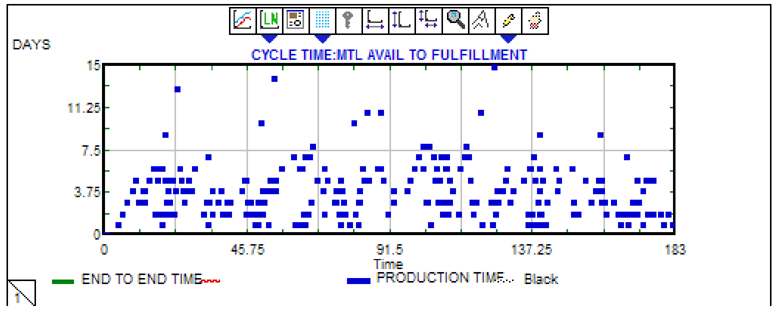
Metrics used in the actual operation are important in a lean design to compare alternatives. The model showed the difference between Before and After process designs.

| **Service levels: Before Process** | **Service levels: After Process** |
|---|---|
| Not meeting demand | Better demand fulfillment |
|  |  |
| Packaging operation is sometimes starved | Improvement in Packager utilization |
|  |  |

End to end cycle times are also computed, since they dictate order lead time commitments and EPE Interval.

**END TO END PROCESSING**

| | |
|---|---|
| MEAN CYCLE TIME (days): MTL AVAILABLE TO FULFILLMENT | 3.91 |
| STND DEV OF CYCLE TIME (days) | 2.27 |
| MAX CYCLE TIME (days) | 15 |

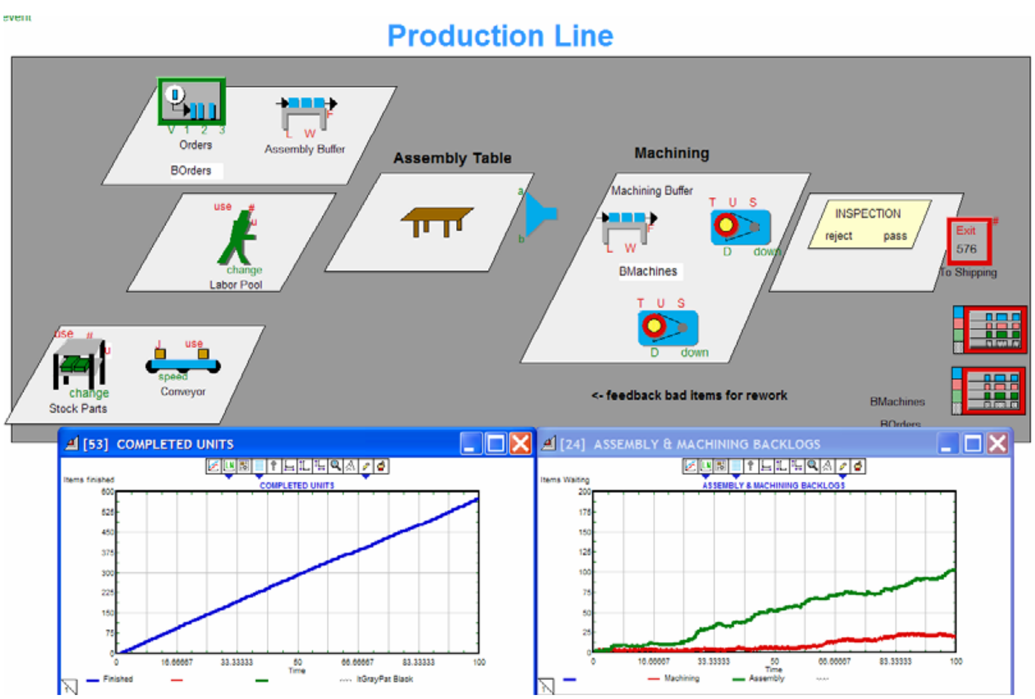



Specific lean metrics important to analyzing the throughput and utilization of resources to identify impacts of improvement efforts are takt times and overall equipment effectiveness (OEE). Following are examples of Takt times/rates and OEE for the Packaging operation:

| LOTS Completed | LOTS WAITING NBR | LOTS WAITING DAYS | | EQUIP UTILIZATION IN USE | EQUIP UTILIZATION CLEANOUT | EQUIP UTILIZATION DOWN | OEE |
|---|---|---|---|---|---|---|---|
| 141 | 0.574 | 0.745 | 1 | 0.5591 | 0.12969 | 0.13743 | 0.5032 |
| 49 | 0.289 | 1.058 | 2 | 0.50134 | 0.04287 | 0.15036 | 0.4227 |

| TAKT RATE & TIME | Takt Rate (Lots/Week) | | | Takt Time (Production Days) | | |
|---|---|---|---|---|---|---|
| | 13 | Act Rate | 12.891 | 0.54 | Act Time | 0.543 |

The examples in this case study are from models developed in Extend™, a discrete simulation program from Imagine That Inc. Following is one of many example models that come with Extend, for people to use in learning to model with it. Many undergraduate and graduate programs are now including instruction in Extend to their students, so the learning curves for employees may not be as long as they might have previously.



A model supported methodology such as is proposed includes a traditional continuous improvement program, where the multi-functional team uses the model to test scenarios, and evaluate the relative benefits of process changes. Models have also been shown to have continuing value for decisions about how to schedule an operation vs. leaving it up to work crews to use trial and error in the actual operation. In addition, they can be used in capacity planning for the operation, using a baseline set of volumes with incremental changes.

Some closing points about the training required for internal staff are appropriate to help manage expectations. I have been teaching students to develop Extend models as part of supply chain design and lean manufacturing courses for five years. The students get about 15 hours of classroom instruction and several model building exercises in a semester. Most of the students are capable of modeling a simple manufacturing operation after that, and some have fairly advanced skills. It takes a person about a year to develop the expertise to develop a model from scratch for the type of operation described in this case study. On-the-job training and doing it is the most important thing to gaining the experience.

An alternative to “from scratch” training and development is to use an available predefined model or template, and train people with analysis skills to configure it and change it. Some of those people will become super-users, and begin then developing models on their own. This approach works well, and people seem to become confident in their abilities fairly quickly. Whichever approach is selected, it does require planning and commitment to incorporate modeling as a tool in a lean program.