**8 Manufacturing Performance Metrics within Simulation Models**

**By Brian Harrington, MTN-SIM, LLC**

Often the main objective of building simulation models is to test out the new proposed layout of your manufacturing facility. Simulations provide an opportunity to conduct “**What If Analysis**” on design layouts and compare scenarios against each other. Applying simulation studies upfront before actual implementation can save millions of dollars; opposed to making changes and updates on the shop floor after tooling has been installed. Often the bottom-line metric used in determining the capability of the proposed layout is overall system throughput, often referred as “**Parts per Hour**” or “Jobs per Hour”. Yet there are many other performance metrics that we can include within our simulation studies to help aid within the decision making process. For example, some of these metrics might give us further insight into the quality, flexibility, or reliability of the proposed layout. Let’s take a look at eight of the most common **manufacturing metrics** including the following:

1. **Throughput PPH**
2. **First Pass Yield**
3. **Rolling Throughput Yield**
4. **Time in System (Dock to Dock)**
5. **Schedule Adherence Percent**
6. **Overall Equipment Effectiveness**
7. **Change Over Time**
8. **Financial Costs**

**1) Throughput or Parts per Hour**

This is the most common base metric used on the shop floor and within simulation studies. It is the measure of how many units are being produced within a discrete time unit such as an hour. It can be measured at the station level, line level, or for the entire facility. Most companies will compare the simulation’s average net throughput value to their targeted market demand. Often the throughput distribution curve will follow a Beta Distribution. The Beta Distribution is a continuous distribution which is bounded by a min and max and has two shape parameters.

The hourly throughput values can also be easily displayed in the form of a X-Bar R-Chart, showing which values fall below your control limits.

**Why:** Throughput is “King”. It is the most important metric; it depicts the overall capability of the facility.

**2) First Pass Yield (FPY)**

**First Pass Yield** is defined as dividing the number of “Good Units” with *no rework or scrap* by the total number of units that were released over a discrete time interval. For example, if 100 units enter Line A, 5 are scrapped, 10 are reworked, and 95 leave as good parts.

FPY = (Good Parts-Scrap-Rework)/Total Parts

FPY = (95-5-10)/100 = 80/100 = 0.80

**Why:** Quality is always on top of the list when it comes to metrics. Reducing rework items and scrap not only improves throughput, but it reduces waste and saves money! Simulation can aid in determining the best locations for inspection, rework and scrap stations.

**3) Rolling Throughput Yield (RTY)**

FPY is usually measured at the segment or line level of the overall facility. If we multiple all the various FPY’s for the lines or sub processes together we get what is defined as “**Rolling Throughput Yield**”. For example, given three Lines A, B, and C with the following FPY’s:

FPYA = 0.80

FPYB = 0.95

FPYC = 0.90

Hence, the overall Rolling Throughput Yield is RTY = 0.80\*0.95\*0.90 = 0.684

The RTY is a good indication of how the entire system is working with respect to requiring no reworks nor scrapped parts. FPY & RTY are common manufacturing metrics that focus on the “Quality” aspect of production.

**Why:** Like the above metric FPY, RTY takes into account several rework and scrap points. It can show the impacts of the overall synchronous behavior of adjoining assembly lines.

**4) Time in System (Dock to Dock)**

Total time in system or commonly referred as “**Dock to Dock**” is a performance metric which captures the time to complete a single product from start to finish. Starting from the raw material docks to final shipping docks of the completed product. TIS or DTD can be measured at various points within the system; usually it is measured according to a specified “**Control Part**”. For example, the control part may be identified at some early on rendezvous station where a couple subcomponents get assembled; starting the creation of the overall product. The average time in system metric will be an excellent indicator on how long it takes to complete one finished unit. This metric can become distorted due to rework items, shift patterns, product variants, and lineside inventory.

The average TIS metric will usually form into a distribution with a skewed tail to the right capturing the lagging outliers. It will become important to investigate what is causing these longer build times. Furthermore, we can set limits on what is deemed as acceptable and what is considered out of control.

**Why:** Dock to Dock is the key indicator of the time it takes to complete a finished good. This metric especially is useful when running mixed products down flexible assembly lines. It can aid with determining best scheduling scheme such as Batch Build sizes, etc.

**5) Schedule Adherence Percent**

Most of today’s manufacturing facilities face many scheduling conflicts when it comes to building their family of products. It is most often desirable to build according to market demand, hence scheduling your products according to the actual placement of customer orders is common practice. Flexible manufacturing facilities allow for building multiple products down the same assembly lines. The manufacturing metric **“Schedule Adherence Percent”** measures how well your maintaining the original build schedule.

Schedule Adherence Percent = (Actual Production / Scheduled Production) x 100

Usually within large manufacturing facilities building complex product variants there are several ways to get out-of-sequence. Some common causes are the following: Rework loops, Parallel Lines, Quality Tests, Decouplers with Short-cuts, (Buffers, Mezzanines, and Storage Banks). Often distinguishing between “late units” and “early units” is also valuable insight as to the schedule build. Most companies want to minimize the number of late units, or see if they can use substitution of an early unit to reduce the effects of late units.

**Why:** The benefits of maintaining the original schedule is not always about meeting customer demand in a timely fashion, but also focus on how subcomponents arrive lineside to assure a timely rendezvous for assembly. Lineside inventory levels can be greatly impacted on variations with the original build schedule. For instance, labor searching for a specific subcomponent type can need critical seconds to the overall cycle time of a station.

**6) Overall Equipment Effectiveness**

**OEE** is a multidimensional metric that strives to get the most out of the plants planned production time by focusing on 3 key factors: **Availability, Performance, and Quality**. Depicted below are the various time segments that make up a plants production time.

Plants Operating Time (i.e. Shift)

Planned Production Time

Planned Downtime

Downtime Downtime

Operating Time

Net Operating Time

Performance Loss

Productive Time

Quality Loss

Loss

As we can see from the above bar graphs, a plants typical working shift can dwindle-down to a relatively small fraction of the shift know as *fully productive time*. This is after we factor out planned downtime which usually consists of breaks and lunch. The three other contributors are the loss factors that are associated with equipment downtime, performance losses, and quality losses. The **availability** factor includes equipment breakdowns and is often captured using “Mean Time Before Failures” MTBF and “Mean Time to Repair” MTTR. Equipment over-cycles and start-up losses are significant contributors for **performance** loss. Often operators can impact the performance metric by adding non-value added seconds onto the ideal or design cycle time. Lastly, scrap and reworked items count as defects creating the quality loss.

**OEE Calculations:**

**Availability** = Operating Time / Planned Production Time

**Performance** = [Total Jobs/Operating Time] / Design Rate

**Quality** = Good Jobs / Total Jobs

**OEE** = Availability\*Performance\*Quality

**Why:** OEE is often a metric most that large companies review on a weekly basis. Manufacturing engineers usually have to present ideas and concepts that will improve the OEE. Simulation can aid in determining which action items will improve Availability, Performance, and Quality.

**7) Change Over Time**

This is a simple metric to capture, but is a very critical factor to running multiple product variant’s down the same assembly lines. The change over time is the amount of time it takes to complete a change over or tool setup for a station, line, or facility to run a new product variant. Depending on your manufacturing facility and family of products; change overs can take minutes or up to days to complete.

Change overs rely heavily upon the build schedule; from running large batch sizes to small random mixes with minor tool setups. Most often capable flexible manufacturing companies are going to be very concerned with minimizing or removing the need for tool setups.

**Why:** Tool set-ups and change overs cause downtimes within the production schedule; thereby reducing overall production time. Simulation studies can address comparing different change over schemes, and determine optimal production schedules. Also, what impact will introducing a new product have on the overall capability of the system.

**8) Financial Costs**

Adding financial cost metrics to your model can easily show management the “**Rate of Return**” on the proposed investment. This is very useful when comparing between scenarios, since some might not fit into the affordable business plan. It is also helpful in pointing out if high cost technology stations are worth the return on investment.

The simulation model will prompt the user to enter in all associated capital costs and respective usage costs per station including labor. The results will be in the form of costs, revenue, and profit.

**Why:** Most companies will be operating within an “Affordable Business Model” when it comes to their assembly operations. Simulation studies can determine where to place key assets within the layout, and just as important… where not to.

**Benefits of Including Performance Metrics**

As we mentioned above… the biggest bang for your buck is performing a simulation study early on in the design phase, months ahead of implementation. Having performance metrics within your simulation model will give more insight into the factors of Quality, Availability, Customer Satisfaction, Flexibility, Reliability, Efficiency, and Cost. Once the simulation model has served its largest intent of leading the way for the new manufacturing facility design it still can be of great use of keeping the facility in control. Having performance metrics within your model which align to the shop floor metrics that manufacturing engineers use on a daily basis will prove to be useful for ongoing real-time performance.

It’s often considered to be the second largest benefit of conducting simulation studies as to monitor performance metrics and assure quality. Also, performing “**continuous improvement**” to the manufacturing processes. Therefore, the simulation model can evolve and continue its usefulness just ahead of the real-time data sources on the shop floor.