# FabTime Cycle Time Management Newsletter

Volume 13, No. 2 April/May 2012

## Information

**Mission:** To discuss issues relating to proactive wafer fab cycle time management

**Publisher:** FabTime Inc. FabTime sells cycle time management software for wafer fab managers. New features in the software this month include support for integrated windows authentication (including support for automatic login to FabTime using domain credentials).

**Editor:** Jennifer Robinson

**Contributors:** Bob Kotcher (Simitar, Inc.); Scott Mason (Clemson University); Michael Hair

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## Welcome

Welcome to Volume 13, Number 2 of the FabTime Cycle Time Management Newsletter! In this issue, we have a community announcement about the new issue of Future Fab International (and an article within it about cycle time and variability by one of our newsletter subscribers). We also have a call for papers for the e-Manufacturing & Design Collaboration Symposium 2012. Our FabTime user tip of the month is about using the new average WIP lines on the Moves Trend and Pareto charts. We have subscriber discussion related to the economic benefits of cycle time improvement, the impact of engineers on cycle time, and the reasons that reentrant flow in fabs contributes to high cycle time and WIP.

Our main article this month is a guest article by Bob Kotcher of Simitar, Inc. Bob writes about choosing the appropriate level of capacity planning (from a simple static model to a highly detailed dynamic model) for each fab. He discusses investment in additional capacity for cycle time improvement in general, and highlights the need to focus on the question that the capacity model is being asked to solve. He concludes that "Millions of dollars can be left on the table by building models that are too basic. On the other hand, even the most detailed model is useless if it's unfinished or resources are not available to keep it accurate." We hope you find this article of interest.

Thanks for reading – Jennifer

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# Community News/Announcements

## New Issue of Future Fab International

Issue 41 of Future Fab International was published in late April. You can download this PDF industry magazine from http://www.future-fab.com/welcome.asp. The following article may be of interest to subscribers of this newsletter:

J. Ignizio and H. Garrido, "Fab Simulation and Variability," *Future Fab International*, Issue 41, 41-45, 2012. This article questions the "conventional wisdom" by which variability is included in fab simulation models, as well as the required length of time to run a fab simulation model before achieving steady state.

## Call for Papers: e-Manufacturing & Design Collaboration Symposium 2012

e-Manufacturing & Design Collaboration Symposium 2012
September 4, 2012
The Ambassador Hotel HsinChu, Taiwan

Abstract Submission due date: June 1, 2012

**Scope**

The Symposium attends to recent technological advancements to align the needs of designers, manufacturers, equipment suppliers, software vendors, solution providers and researchers. It offers a public arena for the exchange of up-to-date experiences among manufacturers for adoption of technological developments. With green notions of supply/engineering/value chains, coverage of the joint symposium includes, but is not limited to, the following topics of interest (list edited by FabTime):

- Benefits and Justification (ROI, CoO, OEE ...)
- Data Collection/Quality/Storage/ Management
- e-Diagnostics, e-Manufacturing, and EEC
- Engineering/Supply/Value Chains
- Equipment Control/Integration
- Fab Management/Scheduling/ Dispatching
- Factory Integration/Operations
- Factory Physics & Queueing Operations
- Manufacturing Control and Execution Systems
- Manufacturing Strategy and Operation Management
- Yield Enhancement and WIP Management

**Important Dates:**

Deadline of submission: June 1, 2012

Notification of acceptance: June 20, 2012

Final paper due: July 27, 2012

Deadline for early-registration: August 12, 2012

For more information visit: http://www.tsia.org.tw/seminar/eManufacturing2012/

FabTime welcomes the opportunity to publish community announcements. Send them to newsletter@FabTime.com.

# FabTime User Tip of the Month

## Use Average WIP on Moves Trend and Pareto Charts

As a new feature in Patch 101 (released in Q4 of 2011), the WIP line on the Moves Trend and Pareto Charts in FabTime no longer shows the WIP at the start of each time period. Instead, the WIP line now shows the average WIP, where the average is computed by dividing each period into sub-periods, and computing the average starting WIP for each sub-period within the period. If you wish to use starting WIP rather than average WIP, set the sub-period length equal to the period length – this will result in average WIP being the starting WIP (since it will be the "average" of a single value, the starting WIP for the period). An example of a Moves Trend chart with a 24-hour period length and a 12-hour sub-period length is shown below.

For example, suppose the first chart period is from 6am to 10am (4 hours) and sub-period length is set to 1 (hour). Suppose the starting WIP at 6am is 10 wafers, at 7am is 25 wafers, at 8am is 30 wafers, and at 9am is 50 wafers. The average WIP is (10+25+30+50)/4 = 115/4 = 28.75 wafers. Note that the WIP value at 10am (the ending time for the period) is not used in the calculation. If, on the other hand, the sub-period was set to 4 hours for this example, then the average WIP displayed would be the starting WIP from 6am, or 10 wafers.

Our goal with this change is to make the WIP line displayed on the moves charts more accurate, and less subject to distortion from start-of-period effects. This change also makes the Moves charts more consistent with the Turns charts, which have been calculated based on average WIP for some time now.

If you have any questions about this feature (or any other software-related issues), just use the Feedback form in the software.

# Subscriber Discussion Forum

## Economic Value of Cycle Time

The following question arose from a cycle time management class that **Scott Mason** delivered for ISMI/ SEMA-TECH on FabTime's behalf. "Has FabTime done or know of any studies regarding the economic value of cycle time?"

**FabTime response:** As mentioned in our main article below, FabTime developed a spreadsheet model for exploring the dollar benefits from cycle time improvement several years ago. The model can be downloaded here. There are a number of paths that can lead from cycle time reduction to improvements in the bottom line (both on the revenue side and the cost site). However, any analysis of specific numbers depends heavily on the assumptions entered into the spreadsheet. This makes it very difficult to draw specific conclusions regarding the economic value of cycle time (though it is generally clear that the bigger dollar benefit to cycle time reduction probably lies more on the revenue side than on the cost side).

As was mentioned to Professor Mason during the cycle time class, we understand that ISMI/SEMATECH has done work in this area in recent years, and that some of this work has entered the public domain. For example, we found a presentation by Marcus Lenz on this topic, from 2011, here: here.

It has been a number of years since we wrote about this topic in the FabTime newsletter (Issues 2.06, 3.05, and 7.07). Perhaps it is time to revisit the economic value of cycle time improvement. Do any other subscribers have any thoughts to share, or any public domain results that you can point us towards?

## Impact of Engineering on Cycle Time

Another question that arose out of Scott Mason's cycle time class at ISMI/ SEMATECH was: "Does FabTime have any experience or knowledge of companies who have found a way to hold engineering accountable for/to cycle time goals and/or found a way to convey to engineering how they can positively (or more often negatively) impact fab cycle time by their work/actions?"

**FabTime response:** Usually when we deliver our cycle time management class it's at a company site. We do encourage those companies to include people from the engineering organization in the class, so that engineers can learn more about the part that they play in overall cycle time (particularly through single path operations). Our general impression is that there is increasing awareness of this as an issue, and that it may be affecting approval processes for process restrictions. However, we have not seen anything published on this topic. Readers, do you have any thoughts to share on this?

## Cycle Time, WIP, and Reentrant Flow

**Michael Hair** sent us the following question: "I know that one of the many reasons that it is hard to manage CT and WIP in a fab is because the flows are reentrant flows. Do you know of a clear way of explaining why this is so? I have looked at the FabTime newsletters (but my copies don't go back very far) and the Factory Physics text and have not found anything specific."

**FabTime response:** We actually think that this is such a good question that we've decided to hold it for next month's main article. But the short answer, as with most everything in a manufacturing environment, boils down to the impact of the reentrant flows on arrival and process time variability.

FabTime welcomes the opportunity to publish subscriber discussion questions and responses. Simply send your contributions to Jennifer.Robinson@FabTime.com.

# What Level of Capacity Planning is Right for My Fab?

**By Bob Kotcher – Simitar, Inc.**

## Introduction

The world's wafer fabs are expected to spend US $38 billion on fab equipment this year, increasing to US $45 billion in 2013 [1]. Equipment spending comprises a big chunk of many chipmakers' expenses and therefore can have a significant effect on profitability. For example, in 2011, Intel spent an amount equal to 20% of its worldwide revenues on new fab equipment [2]. Yet methods being used for capacity planning vary widely from company to company. Some fabs use relatively simple manual spreadsheets. Others use dedicated simulation software to build detailed models linked to company MES's that run automatically and even rebuild themselves as fab conditions change [3]. Which level of capacity modeling is right for your fab?

## You're Not Buying Capacity; You're Buying Cycle-Time Reduction

The first thing to acknowledge is that, in a wafer fab—or in any highly variable operation—it's a misnomer to talk about "capacity planning." If that's all it was, a simple spreadsheet would always be the solution: just plug in the numbers and buy enough equipment to keep all loading below 100%. In a highly variable environment, though, the decision becomes how much additional equipment to buy to reduce cycle time to an acceptable level:

> *Where should I invest in surplus capacity to reduce cycle time to the desired level at minimal cost?*

With a static model (i.e., one whose output is tool % loading—typically an Excel spreadsheet), one can "brute force" the attainment of a reasonable cycle time by limiting loading of all equipment to, say, 85%. The November 2001 FabTime newsletter describes this method in more detail [4]. But a potentially lower-cost way of achieving the same cycle time is through dynamic modeling. You will sometimes hear dynamic modeling referred to as stochastic modeling, Monte Carlo simulation, or discrete-event simulation (DES), but for our purposes these all mean basically the same thing: they incorporate random variability. In a dynamic model, upon the "run" command, an internal clock is started, individual wafers start in the model, tools start breaking down and getting repaired, wafers start occasionally requiring rework or are scrapped, operators start going on break or calling in sick—all the pleasures of the real world.

All of the above events occur randomly (triggered by random-number generators), but in accordance with their real-world probabilities. When the run is finished, we now have a critical new statistic: time. We can see a sample of what every product's queue time was in front of each tool. Rerunning the same model with different random numbers gives us another sample of the possible dynamic behavior of the fab. Rerunning the model with different quantities of tools, we can see the correlation between various tool-purchase options and cycle time. Taking into account the purchase and operating costs of each tool, we can then "buy down" cycle time to the desired level by buying those tools that provide the greatest cycle-time reduction per dollar. Thus we achieve a desired capacity and cycle time at less cost than with the "brute force" method employed by static models. Savings might be 5-10%. Given SEMI's forecast of US $45 billion in worldwide fab equipment spending next year [1], perhaps US $2-4 billion savings is possible worldwide each year.

Jennifer Robinson coauthored a paper that describes dynamic capacity modeling in detail [5], and this topic was discussed and

summarized in the December 2001 FabTime newsletter [6]. Simitar Consulting made a poster presentation at December 2011's Winter Simulation Conference describing how to take this further by estimating what the "target" cycle time should be. See [7] for the details of this method in graphical form.

## Estimating the Profit-Maximizing Cycle Time

How, exactly, is the "target" cycle time estimated? This is a tricky subject because there is so much subjectivity in the benefits of low cycle time. Fortunately, FabTime's Dr. Frank Chance developed an extremely handy benefits-of-cycle-time-reduction calculator in Excel that is downloadable at FabTime's website: http://www.fabtime.com/bottomline.shtml [8]. Or you could build your own calculator. The trick in using such a tool, though, is determining what values to enter. Insights for setting values for your particular company can be gleaned from a number of sources. (See [9] [10] [11] [12], for example).

With a calculator for estimating the benefits of cycle time reduction, a cost-of-ownership calculator for evaluating tool purchases, and a dynamic model, it's possible to decide whether tool acquisitions for cycle time reduction are likely to be cost-effective. Here is a sample procedure:

1. Use a full fab simulation model to estimate the percent cycle time reduction that adding a particular tool (or set of tools) would give.

2. Use a calculator (such as the one mentioned above) to estimate the total annual benefit that would stem from such a cycle time improvement.

3. Use a cost-of-ownership calculator to estimate the annual cost of adding the tool(s) (including acquisition and ownership costs).

4. Compare the potential benefit from (2) to the cost from (3). Only buy tools for cycle time reduction that show a decent profit margin.

Repeat the above process until diminishing returns are reached. The resulting tool set and cycle time will be the ones that—based on your assumptions—optimize your company's profitability.

## The First Question One Should Ask Before Building A Model

Before diving into a procedure like the above, however, it's important to ask: "What specific question do I want answered by this model?" The reason that this question matters is that there is an unlimited amount of detail that could be put into a model. Let's face it: engineers tend to be perfectionists. As engineer-turned-comedian Don McMillan put it: "I went to an engineering university. Our football stadium scoreboard went to six decimal places." Posing The Question puts a boundary on detail, so the modeler knows where to stop in the accuracy-vs.-time tradeoff.

Let's look at some examples of The Question: Given next year's forecast volume and product mix….

1. What capital equipment should I buy to keep static loading below 85%?

2. In what capital equipment and direct labor staffing should I invest to keep average cycle time below thirty days?

3. In what capital equipment should I invest in order to maximize my profits?

The latter two questions would require a more labor-intensive model than the first because they're dynamic. Adding in all the factors that make for accurate cycle-time modeling is a lot of work. For example, you can't be content to just know the percent of time that each tool spends in each state; you instead need to know the MTBF (mean time between failures) and

MTTR (mean time to repair) for off-line incidents, as well as the statistical distributions for each of these. You need to know the dispatching rule (FIFO, e.g.) and setup rules for each tool. And if you want to model operators, well, we diverse, quirky humans are much more difficult to model than machines. Also, validation of dynamic models can take much longer than with static models.

Without The Question in mind ahead of time, a modeler could spend a lot of time modeling details that are not important to management at the moment. Keeping The Question in mind throughout the model-creation process will keep the modeler on track. Avoid the temptation to say, "Just build a simulation model of our whole facility; we'll figure out what to use it for later." Keep in mind that building the model to answer a specific Question does not mean that the resulting model will only be able to answer that question—far from it. It just provides a practical guideline for the modeler during the build. More detail and capability can always be added later.

## Decision Factors in Choosing the Right Level of Capacity Planning for Your Fab

Now I will outline applicability and advantages of various levels of capacity planning, going from the simplest and roughest to the most complicated and accurate:

1. Static modeling with a spreadsheet
2. Static modeling using a capacity-planning module from ERP, MES, or dashboard software
3. Static modeling with dedicated modeling software
4. Dynamic modeling with dedicated modeling software

### 1. Static modeling with a spreadsheet

Do this if:

- Your operation is relatively simple.
- You have relatively low variability.
- You have minimal capacity-planning resources.

**Advantages:**

- Simple and inexpensive to create.
- Easy for all users to understand, modify, and conduct analyses.
- Essentially no software cost.
- Results of any scenario are seen instantly.

Caution: With much detail, "simple" spreadsheet models become intractably complex. I've seen Excel models that were thirty worksheets long, all tied together by labyrinths of Excel formulas that would stymie Commander Data from Star Trek. Only the person who created the model knew how it worked and how to maintain it. At this level of operational complexity, Excel starts losing its simplicity advantage to dedicated modeling software. Dedicated software has all its logic hidden behind the scenes, so model-building and maintenance becomes more fill-in-the-blanks, and it also comes with a user's manual and tech support.

### 2. Static modeling using model-building capability of ERP, MES, or dashboard software

Some ERP, MES, or dashboard software has the capability of rough capacity planning. These packages deduce process flows, tool sets, downtime percentages, processing rates per tool per product type, and the like from the actual fab data that they already contain, and use it to build a static capacity model.

Do this if:

- Your operation is relatively complex.
- You have relatively low variability.
- You have minimal capacity-planning resources.
- You do not continually have a lot of unknown new equipment and new processes to model.

**Advantages:**

- Collects data for you—reduced need for manual time studies or data mining.
- Can be much cheaper than dedicated modeling software when data collection costs are taken into account.
- Results of any scenario are seen almost instantly.
- Requires less expertise than dynamic modeling.

This type of software can save considerable time and money you'd spend on manual time studies or setting up a separate automated data acquisition system. But be prepared for a good amount of manual massaging of the model as produced. I've done modeling projects for companies that said things like, "Don't worry about collecting data—our software does all that." But when I've dug into the data, I've found lots of anomalies, such as tools that were decommissioned still contributing to downtime data, R&D tools grouped in with production tools, confusion between individual chambers in cluster tools vs. entire tools, and so on.

FabTime's capacity planning module (as I believe others do) addresses this by allowing users to override its tool quantities, availabilities, and UPH values to make sure that the end result does in fact represent the real fab. This feature can be used not only to tweak the raw automatically built model, but to enable the automatically built model to be used as a starting point for a more detailed stand-alone model. In fact, in the 1990s, before the founding of FabTime, Dr. Frank Chance helped me build a stand-alone model of a fab by setting up queries that pulled product, route, and tool data from the MES, which I checked and massaged as necessary, then incorporated into a stand-alone model. In a similar fashion today, FabTime's automatically built model (or models from other products) could be used as a starting point in your construction and updating of a more detailed stand-alone model.

A final point to keep in mind about this type of software is that, since it relies wholly on past performance, it cannot model future processes and equipment—those will still need to be modeled manually.

**3. Static modeling with dedicated modeling software**

Do this if:

- Your operational complexity and/or desired level of modeling detail is higher.
- You have relatively low variability.
- You have higher capacity-planning resources available for build and maintenance.

**Advantages:**

- Can accommodate more detail and accuracy than a spreadsheet or the capacity planning modules in ERP, MES, or dashboard software.
- If operation is complex, and/or model is detailed, can be less cumbersome to build and maintain than a spreadsheet model.
- Results of any scenario are seen almost instantly.
- Requires less expertise than dynamic modeling (no need for multiple runs, statistical analysis, etc.)

I believe that the most popular dedicated modeling software among wafer fabs is Applied Materials' AutoSched AP. Though designed for dynamic analysis, AutoSched AP can be used for static analysis if variability is switched off. I have also used Wright, Williams & Kelly's Factory Explorer, which is similar to AutoSched AP but is designed for both static and dynamic analysis. Comparing the two, my experience has been that AutoSched AP has more features, enabling more detailed modeling, while Factory Explorer runs

faster and has somewhat more responsive customer service.

**4. Dynamic modeling with dedicated modeling software**

Do this if:

- Your operations are complex.
- You have high variability.
- You have large amounts of resources available for modeling.

**Advantages:**

- Can see the correlation between capacity loading and cycle time.
- Can show how to reach a given capacity and cycle-time level by spending 5-10% less on capital equipment than with static methods.
- Can also help with process improvement, in that you can see the effect on cycle time of changes in dispatching rules, setup rules, batching rules, WIP rules, tool dedication, cross-training, and dozens of other things.

In addition to AutoSched AP and Factory Explorer mentioned above, dozens of flowchart- and object-based simulation software packages exist. These are not good for wafer-fab capacity planning, however, because of wafer fabs' great numbers of process steps and reentrant flow, which makes such models impossibly complex. These types of software packages are great, though, for detailed modeling of small sections of wafer fabs to assist in process improvement.

Also note that, where dedicated modeling software can be run in either static or dynamic mode, a less-detailed model could be built up front and run in static mode, then later, as resources allow, details could be added to make the model accurate for dynamic modeling.

**Hybrids**

The above four options are not mutually exclusive; some companies use combinations of them, such as a dedicated dynamic model for detailed analysis, and Excel spreadsheets (which draw from the same database) for quick static analyses.

## Conclusion

When buying capacity beyond the number of tools strictly needed to meet throughput targets at 100% utilization, one is really buying cycle time reduction. It's possible to use dynamic modeling in the capacity planning process to identify the profit-maximizing cycle time for your fab. However, the answer to that question may not be what your particular fab is looking for at a given point in time.

The appropriate level of capacity planning is determined by a fab's complexity and variability and the amount of modeling resources available. Millions of dollars can be left on the table by building models that are too basic. On the other hand, even the most detailed model is useless if it's unfinished or resources are not available to keep it accurate.

## Closing Question for FabTime Subscribers

What method of capacity planning do you use? Do you use different methods for answering different questions?

## Author Bio

Bob Kotcher is President of Simitar, Inc. (http://www.SimitarConsulting.com ), which helps clients improve their capacity planning and operations efficiency via computer modeling. Contact him at http://www.simitarconsulting.com/Contact_us.html or 1-877-365-9997 (U.S. or Canada) or 1-408-213-7454.

## References

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# Subscriber List

**Total number of subscribers:** 2738, from 443 companies and universities.

**Top 20 subscribing companies:**

- Maxim Integrated Products, Inc. (148)
- Intel Corporation (147)
- Micron Technology, Inc. (113)
- Carsem M Sdn Bhd (84)
- Texas Instruments (83)
- Western Digital Corporation (69)
- X-FAB Inc. (67)
- ON Semiconductor (66)
- International Rectifier (63)
- STMicroelectronics (60)
- TECH Semiconductor Singapore (60)
- GLOBALFOUNDRIES (59)
- Fairchild Semiconductor (53)
- IBM (53)
- Analog Devices (52)
- Freescale Semiconductor (51)
- Skyworks Solutions, Inc. (47)
- Infineon Technologies (46)
- Telefunken Semiconductors (46)
- Seagate Technology (38)

**Top 5 subscribing universities:**

- Ecole des Mines de Saint-Etienne (EMSE) (12)
- Arizona State (8)
- Ben Gurion Univ. of the Negev (7)
- Nanyang Technological University (7)
- Virginia Tech (7)

**New companies and universities this month:**

- AUO Sunpower Sdn Bhd
- Avaya
- Center for Information Technology (CTI)
- Institute of Microelectronics (IME)
- MSEI/Biotronik
- Sanoifi Pasteur
- Teledyne DALSA
- Universität der Bundeswehr München

**Sampler Set of Other Subscribing Companies and Universities:**

- Actel (1)
- Arnstadt (1)
- CSMC (3)
- Cyberalert (1)
- Door King (1)
- Honeywell (30)
- Madras Semiconductor (1)
- New Jersey Institute of Technology (1)
- PerkinElmer (1)
- Polar Semiconductor (4)
- SanDisk (7)
- Siltronic Corporation (9)
- SPI Analysis (1)
- SSCM Consulting (1)
- SV Microwave (1)
- Syndex (1)
- University of Chicago (1)
- University of Ulsan - S. Korea (1)
- WaferTech (15)
- Woodgrain Millwork (1)

**Note:** Inclusion in the subscriber profile for this newsletter indicates an interest, on the part of individual subscribers, in cycle time management. It does not imply any endorsement of FabTime or its products by any individual or his or her company.

There is no charge to subscribe and receive the current issue of the newsletter each month. Past issues of the newsletter are currently only available to customers of FabTime's web-based digital dashboard software or cycle time management course.

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# FabTime® Cycle Time Management Training

*"It was helpful to see best-in-class methods for wafer fab cycle time management. Discussing these matters in-depth with you was quite valuable, as we could ask questions specific to our fab and processes."*

Shinya Morishita
Manager, Wafer Engineering
TDK Corporation

## Course Code: FT105

This course provides production personnel with the tools needed to manage cycle times. It covers:

- Cycle time relationships
- Metrics and goals
- Cycle time intuition

## Price

$7500 plus travel expenses for delivery at your U.S. site for up to 20 participants, each additional participant $300. Discounts are available for multiple sessions.

## Interested?

Contact FabTime for a quote.

FabTime Inc.
Phone: +1 (408) 549-9932
Fax: +1 (408) 549-9941
Email: Sales@FabTime.com
Web: www.FabTime.com

## Do you make the best possible decisions?

- Do your supervisors possess good cycle time intuition?
- Are you using metrics that identify cycle time problems early?
- Can you make operational changes to improve cycle time?

FabTime's Cycle Time Management Training is a one-day course designed to provide production personnel with an in-depth understanding of the issues that cause cycle time problems in a fab, and to suggest approaches for improving cycle times. A two-day version and a half-day executive management version are also available upon request. As of January 1, 2011, the course is only available for delivery at customer sites within the United States.

## Prerequisites

Basic Excel skills for samples and exercises.

## Who Can Benefit

This course is designed for production personnel such as production managers, module managers, shift supervisors, hot lot coordinators, and production control.

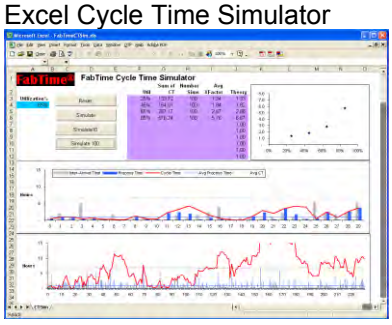
## Skills Gained

Upon completion of this course, you will be able to:

- Identify appropriate cycle time management styles.
- Teach others about utilization and cycle time relationships.
- Define and calculate relevant metrics for cycle time.
- Teach others about Little's law and variability.
- Quantify the impact of single-path tools and hot lots.
- Apply cycle time intuition to operational decisions.

## Sample Course Tools

Excel Cycle Time Simulator




Staffing Delay Simulator