FabTime Cycle Time Management Newsletter

Volume 15, No. 2 March 2014

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 coming in the next patch (due out shortly) include instant-load for JavaScript charts and modifications to better calculate OEE for multi-chamber tools.

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Contributors: Mike Hillis

Keywords: Lot Size; Tool Availability; Dispatching; WIP Management

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Welcome

Welcome to Volume 15, Number 2 of the FabTime Cycle Time Management Newsletter! This month marks FabTime's 15-year anniversary. Many thanks to those who were with us at the beginning, and to everyone who has joined us along the way (employees, customers, friends, and, of course, newsletter subscribers). The time (most years, anyway) has really flown by. We remain especially grateful to Headway Technologies, who took the leap to become our first software customer. Today, we have 30 installed FabTime sites from around the world, and we look forward to continuing to grow.

We have two announcements in this issue, one about a promotion for Lara Nichols, now our Director of Engineering, and another with a call for papers for the MASM conference. Our FabTime tip of the month is about identifying the states in which your bottlenecks spend the most time, so that you can seek opportunities for improvement. We have two subscriber discussion topics, one from Mike Hills in response to our last issue, and one with a new question about maintenance staffing models.

In our main article this month, we revisit and generalize upon a topic first introduced in the newsletter in early 2000: the impact of changing a fab's lot size. Where previously (in Issue 2.02) we had looked at the question of whether a lot size reduction was likely to be beneficial overall, in this new article we discuss both lot size reduction and lot size increase. We welcome your feedback.

Thanks for reading – Jennifer

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Community News/Announcements

Promotion for Lara Nichols

FabTime is pleased to announce the promotion of **Lara Nichols** to **Director of Engineering**. Lara has been with FabTime since 2007. As Director of Engineering, Lara will provide leadership and solve technical challenges related to new installations, customer support, and internal research and development.

Call for Papers: MASM Conference 2014

The 2014 International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM) will be contained as a track within the Winter Simulation Conference, on December 7-10, 2014, in Savannah, Georgia. The call for papers notes:

"We are looking for high-quality research at all levels of semiconductor manufacturing. At the operational level, improved equipment and process control and optimized scheduling and transportation policies must be studied. At the tactical level, better capacity planning and qualification management are expected. At the strategic level, demand planning, factory economics and supply chain efficiency must be improved to support the business. Moreover, better integration of decisions taken at different decision levels is becoming a must. These various goals will be attained through new advanced control and statistical methods, computing techniques and operations research methods. We invite participants to present on all topics related to modeling and analysis that will help address these challenges. While the MASM conference is mostly focused on the current semiconductor industry state-of-the-art, neither presenters nor attendees need to be in the IC industry to participate. We are interested in any methodologies, research, and/or applications from other related industries such as TFT-LCD, flexible displays, bio-chip, solid state lighting (LED) and photovoltaic (PV) that might also share or want to share common and new practices."

You can find the full call for papers, and submission details, here. The deadline for paper submission is April 1, 2014.

FabTime welcomes the opportunity to publish community announcements, including conference notices and calls for papers. Send them to newsletter@FabTime.com.

FabTime User Tip of the Month

Identify the Downtime SubStates Where Your Bottleneck Spends Time

Continuing our plan of providing step-by-step instructions for performing practical tasks, we're going to talk today about how to identify the downtime substates (the states that are actually logged into the MES) in which your key tools spend the most time.

1. From the Charts page, under Tool Hours Charts, press "Go" next to Tool Hours Pareto.

2. Change the "From:" date to look back at least one week.

3. Enter the name of a bottleneck tool in the "Tool:" filter (or enter a ToolGroup, as appropriate).

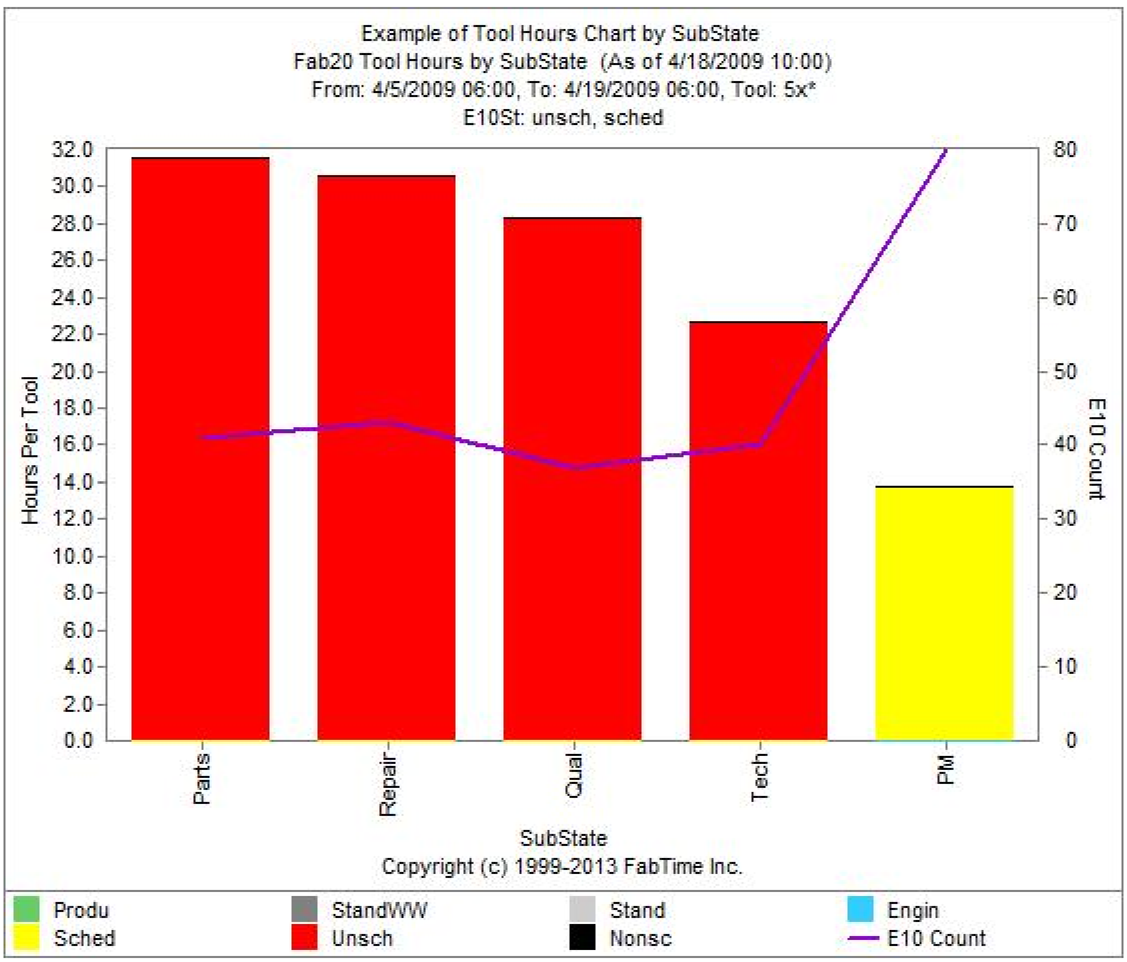
4. Enter “Unsch”, or “Unsch, Sched” in the “E10St:” field (depending on whether you wish to see only unscheduled downtime transactions, or both scheduled and unscheduled downtime transactions. Of course, you could also enter just “Sched” to see only scheduled downtime transactions.

5. Select “SubState” from the “Slice:” drop-down, and then press the “Go” button immediately below “Slice;”

The resulting chart will show hours logged during the week (or specified time period) in each SubState. If the chart is sorted in descending order by “HoursPerTool” (the default), then the SubState in which the tool spent the most time will be shown to the far left of the chart. For example, as shown below, you might see that in a key bottleneck tool group, tools spend more of their unavailable time waiting for parts than in any other SubState. This would suggest that keeping spare parts for this tool group on hand could improve fab performance.

In response to a suggestion from a long-time customer, in the future, we will be rotating tips between WIP-based and tool-based data. We’ll also occasionally feature general functionality, such as the use of our new JavaScript charting engine (coming very soon!). If you have any questions about how to do something in FabTime, or suggestions for a concrete task that you think other FabTime users might find useful, please send them to Jennifer.Robinson@FabTime.com.

Subscribe to the separate Tip of the Month email list (with additional discussion for customers only). Thanks!



Subscriber Discussion Forum

Issue 15.01: Dispatching and Line Balance

Mike Hillis, with whom we've had many discussions on WIP management, and who contributed some ideas for the simulation experiments described in the last issue, shared this feedback: "I am glad to see that the results of Mike Krist's simulations echo my stand on the pitfalls of using Critical Ratio (CR) as the sole method of lot prioritization. Work I have previously done showed exactly the same results (except this was in a real life fab!).

I hope your work continues with regard to line balancing methods. I think the idea that CR is the best method for getting on time delivery is incorrect. My experience and belief is that there must be some kind of proportioned approach that incorporates CR and a drum. This leads to a solid line balance situation which, once accomplished, virtually guarantees on time delivery across the board."

Staffing Models for Indirect Labor (Maintenance)

An anonymous subscriber asked: "Do you have some recommendation or reference on the following topic: "Staffing model for indirect people, mainly maintenance"?

We are opening up this question to our subscribers. Does anyone have papers, or experiences, that you would like to share on the topic of maintenance staffing models?

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

Impacts of Changing a Fab's Lot Size

Introduction

Back in 2000 we wrote about whether reducing lot size in a fab would lead to reduced cycle time. This question still comes up occasionally, as does (less often) the issue of lot size increase. So we thought that it would be a good idea to revisit some of the things that are affected by a lot size change. There are cycle time reduction opportunities, particularly from lot size reduction, but there are pitfalls, too.

In a wafer fab, there are four primary categories of tools, where the categories relate to how wafers are processed.

1. **Per-Wafer Tools**: The wafers in a lot are processed one at a time through a single operation, and then the lot is sent on to the next operation. Examples of per-wafer tools include steppers and implanters.

2. **Per-Lot Tools**: The entire lot can be processed at one time. Examples of per-lot

tools include sinks and inspection tools such as CD-SEMs.

3. **Per-Batch Tools:** The number of wafers that can be processed at one time is different from the number of wafers in a lot (usually larger, up to 200 wafers, though some 12-wafer batch tools exist). Examples of batch tools include furnaces and vapor prime ovens.

4. **Cluster Tools**: A single wafer is processed through several operations in sequence inside a clean environment, and multiple wafers can be processed at the same time, in different chambers of the tool. Examples of cluster tools include certain PVD and etch tools.

Per-Wafer Tools and Lot Size

The justification of lot size reduction for cycle time reduction comes into play primarily due to the per-wafer tools, which often include bottlenecks. Suppose that you have a lot size of 50 wafers, and a per-wafer process time of one minute. Then, if everything runs smoothly, to process a single lot through the operation takes 50 minutes (plus any applicable setup and load times). Each individual wafer spends 49 out of those 50 minutes waiting for the other wafers in the lot. This is true even if there are other tools free that could process the wafers in the lot (for operational and process reasons, a lot is not usually split across multiple tools, though this does happen in some cases).

If you cut the lot size in half to 25 wafers, then each wafer only spends 24 minutes waiting for the other wafers in the lot, rather than 49 minutes. Over the course of passing through many single-wafer tools, this can lead to a reduction in overall cycle time. If you can get all the way down to single wafer processing, you can rack up some significant cycle time reductions through those per-wafer tools. Conversely, of course, if you increase your lot size, then you can expect additional waiting time at per-wafer tools.

Per-Lot Tools and Lot Size

Lot size reduction can lead to capacity issues at per-lot tools. In some cases, it takes just as long to process a 25-wafer lot as it does to process a 50-wafer lot. Since cutting the lot size in half doubles the number of lots that must be processed, this can lead to capacity problems. You'll need to do some research to understand the process and capacity effect of the change on per-lot tools. This is an area in which having a good capacity model could be quite helpful. It's important that the capacity model not treat all of the tools as per wafer tools (a common feature of spreadsheet capacity models), because this will mask the effect of any lot size change.

On the other hand, if you increase lot sizes, you may be able to save some time at per-lot tools (if the larger size lot can fit into the tool all at once).

Per-Batch Tools and Lot Size

One of the biggest impediments to lot size reduction lies in the area of per-batch tools. First of all, you lose some of the benefits of the smaller lot sizes, because you have to keep grouping the lots back together at the batch tools (increasing cycle time and variability). If you have batch tools with many distinct batch ids, and small lot sizes, you might have trouble forming large enough batches, and end up with capacity issues.

In general (for all types of tools), the problem of deciding which lots to process next is more complex if there are more lots to choose from. If a fab runs very high volumes, it may make sense to use larger lot sizes simply because it's hard for the dispatch system to manage the sheer high number of lots in the fab with small lot sizes. This problem will be most noticeable at the per-batch tools.

Cluster Tools and Lot Size

To a point, smaller lots may lead to improved cycle time at cluster tools. As at per-wafer tools, wafers in each lot will spend less time waiting for others to finish making their way through the chambers. However, if you get down to very small lots (single or dual wafer), you may end up with ineffective usage of the cluster tools, due to some chambers being empty. Multiple lots will need to be in the cluster tool at the same time, which could cause issues with the dispatching or MES systems.

Other Positives and Negatives

In addition to providing direct cycle time benefits at per-wafer tools, smaller lot sizes also make a fab more flexible, more adaptive in the event of problems, and reduce variability. However, smaller lot sizes can also lead to issues with the MES and material handling systems. These aspects are each discussed below.

Yield:

Smaller lot sizes can help mitigate yield problems. If an entire lot must be scrapped, it's clearly better to have that be a 25-wafer lot than a 50-wafer lot. Also, because smaller lots are completed more quickly through certain inspection tools, they can sometimes identify a yield problem more quickly, before other lots start a process sequence. This reduces scrap and rework, and generally reduces variability in the fab.

If you get all the way down to single wafer lots, then you never have the issue of a rework parent waiting for a child lot. This simplifies processing and reporting.

Smooth Flow:

In addition to reducing waiting times at individual per-wafer tools, smaller lot sizes smooth the flow through sequences of tools, and reduce variability in arrivals to other tools. In a variability sense, it's better to have a 25-wafer lot arrive every 15 minutes than to have a 50-wafer lot arrive every 30 minutes. It's even better, for variability, to have all single wafer lots, though grouping things back together at batch tools mitigates this benefit somewhat.

Hot Lots:

If you have a policy that says, finish whatever lot you're currently processing, but then move any hot lots to the front of the queue, you'll see shorter hot lot cycle times if the regular lots have smaller lot sizes. This is because lots are finished more frequently (at least on per-wafer tools), and thus, the hot lots can be started more quickly.

Material Handling:

On the plus side, smaller lot sizes are lighter, and thus easier for operators to transport without ergonomic issues in non-automated fabs. However, this leads to an increased load on transport operators (more trips, with fewer wafers carried in each trip). This might translate into a need for additional operators. You'll also have more loads and unloads with smaller lot sizes, which may impact the required number of operators. You may need new lot boxes, or at least more of them, which will have a cost impact.

In some cases, transport between bays is achieved using transfer batches that are larger than one lot to begin with. In this case, much of the benefit of switching to smaller lot sizes would be lost, as the wafers would still end up waiting to form transfer batches.

For fabs with automated material handling, the system may be configured for the larger lot sizes, and could be costly or disruptive to change. Just grouping two smaller lots into the space previously taken up by a single lot could lead to mis-processing errors (since you wouldn't necessarily know what wafers were in each lot from the outside). Yet, if the system is just run using lots half as large, the load on the transport system will be doubled, which could cause capacity problems.

MES:

Cutting the lot size in half effectively doubles the number of lot move transactions reported in the fab. It's possible that this will put a strain on the fab manufacturing execution system, or that a larger database will be required for storage of historic data. You may even need more CPU for your reporting system.

Three-Sentence Summary

Reducing lot sizes may reduce fab cycle times by smoothing the flow of lots through the fab, and reducing the time that individual wafers spend waiting for the rest of their lot. Increasing lot sizes may improve fab cycle time through improvements at per-lot tools, and simplification of dispatching decisions. In general, there are a number of issues that should be carefully considered before the lot size is changed.

Summary of Cycle Time and Lot Size Interaction Factors

If you reduce your fab's lot size, the interactions shown in the table below may influence overall fab cycle times (where the converse may be true for a lot size increase).

Conclusions

Lot size is a hidden assumption in many areas of a fab - in the MES, the transport system, the dispatching policies, the capacity model, perhaps even the reporting system. Breaking this assumption can have unanticipated consequences. For example, the reporting system might take the number of lots started and multiply by 50 to get wafer starts per week. This doesn't mean that you shouldn't change the lot size, but that you need to think through the potential consequences of the change carefully.

We have no black-and-white recommendation to make concerning lot sizes and cycle time. Smaller lot sizes may reduce cycle time, and make a fab more flexible. However, reducing the lot size can cause problems with material handling, capacity, MES performance, and fab complexity, particularly during the transition period. We suggest then, that you consider lot size changes to reduce cycle times, but that you consider them very carefully.

Factor	Cycle Time Impact
Smoother flow to downstream tools	↓
Less waiting at per-wafer tools	↓
Yield potentially improved	↓
Hot lot cycle times improved	↓
Increased transport system loading	↑
Increased loading at per-lot tools	↑
Increased complexity for dispatch	↑

Further Reading

■ T. Adachi, J. J. Talavage, and C. L. Moodie, "A Rule-Based Control Method for a Multi-Loop Production System," *Artificial Intelligence in Engineering*, Vol. 4, No. 3, 115-125, 1989. The authors found that for production systems with reentrant flow, the most influential factors on system performance were dispatch rule, lot size, and start rate (using simulation to evaluate this).

■ O. Bonnin, D. Mercier, D. Levy, M. Henry, I. Pouilloux, and E. Mastromatteo, "Single-Wafer/Mini-Batch Approach for Fast Cycle Time in Advanced 300- mm Fab," *IEEE Transactions on Semiconductor Manufacturing*, Vol. 16, No. 2, 111-120, 2003. "This paper reviews the front-end steps within a semiconductor manufacturing flow where batching requirements may be replaced by single-wafer or mini-batch alternatives for improved cycle time. Encouraging process results for front-end applications for potential single-wafer replacements are presented."

■ S. Ikeda, K. Nemoto, M. Funabashi, T. Uchino, H. Yamamoto, N. Yabuoshi, Y. Sasaki, K. Komori, N. Suzuki, S. Nishihara, S. Sasabe, and A. Koike, "Process Integration of Single-Wafer Technology in a 300-Mm Fab, Realizing Drastic Cycle Time Reduction with High Yield and Excellent Reliability," *IEEE Transactions on Semiconductor Manufacturing*, Vol. 16, No. 2, 102-110, 2003.

■ Jesus Jimenez, Michael Bell, Charitha Adikaram and Victoria Davila (Texas State University) and Robert Wright and Alexander Grosser (International SEMATECH Manufacturing Initiative), "AMHS Factors Enabling Small Wafer Lot Manufacturing In Semiconductor Wafer FABS," *Proceedings of the 2010 Winter Simulation Conference*, Modeling and Analysis of Statistical Methods (MASM) Track, 2010. "In this paper, AMHS productivity detractors affecting small lot manufacturing are studied, including the track layout, number of vehicles, empty vehicle management rules, number of stockers, stocker capacity, among others."

■ J. Potoradi, G. Winz, and L. W. Kam, "Determining Optimal Lot-Size For A Semiconductor Back-End Factory," *Proceedings of the 1999 Winter Simulation Conference*, 1999.

■ Kilian Schmidt (AMD Saxony LLC & Co. KG) and Oliver Rose (Dresden University of Technology), "Simulation Analysis of Semiconductor Manufacturing with Small Lot Size and Batch Tool Replacements", *Proceedings of the 2008 Winter Simulation Conference*, Miami, FL, December 7-10, 2008.

■ R. Singh, M. Fakhruddin, and K. F. Poole, "The Impact of Single-Wafer Processing on Semiconductor Manufacturing," *IEEE Transactions on Semiconductor Manufacturing*, Vol. 16, No. 2, 96-101, 2003.

■ A. M. Spence and D. J. Welter, "Capacity Planning of a Photolithography Work Cell in a Wafer Manufacturing Line," *Proceedings of the IEEE International Conference on Robotics and Automation*, Raleigh, NC, 702-708, 1987. In this study, Performance was improved by adding operators and equipment, by reducing setup times, rework, and repairman wait times, and by changing lot sizes.

Note: All Winter Simulation Conference papers (including recent MASM papers) are available for free download from http://www.wintersim.org.

Subscriber List

Total number of subscribers: 2800, from 444 companies and universities.

Top 20 subscribing companies:

- Intel Corporation (151)
- Micron Technology, Inc. (140)
- Maxim Integrated Products, Inc. (130)
- International Rectifier (121)
- Fairchild Semiconductor (102)
- GLOBALFOUNDRIES (85)
- Carsem M Sdn Bhd (72)
- Texas Instruments (72)
- ON Semiconductor (71)
- X-FAB Inc. (63)
- STMicroelectronics (54)
- Western Digital Corporation (54)
- Freescale Semiconductor (53)
- Analog Devices (51)
- Infineon Technologies (51)
- Skyworks Solutions, Inc. (50)
- IBM (49)
- Seagate Technology (43)
- Cypress Semiconductor (33)
- ATMEL (31)

Top 4 subscribing universities:

- Ecole des Mines de Saint-Etienne (EMSE) (12)
- Arizona State University (8)
- Nanyang Technological University (7)
- Virginia Tech (7)

New companies and universities this month:

- Dresden Univ. of Applied Sciences
- I-VI Incorporated
- Kaori Heat Treatment Co. Ltd.
- Thin Film Electronics Inc.

Sampler Set of Other Subscribing Companies and Universities:

- Applied Materials Corporation (15)
- Axcelis Technologies (1)
- DMEA (14)
- Door King (1)
- Fujitsu (1)
- Gemalto (1)
- ICG / Semiconductor FabTech (1)
- JDS Uniphase (3)
- Linear Technology (3)
- Onix Microsystems (1)
- Politecnico di Milano (1)
- PRTM (1)
- Qualcomm MEMS Technologies (11)
- Records RSA (1)
- SAE Magnetics (2)
- Sensor Analytics (1)
- ST Assembly Test Services (1)
- Toppoly Optoelectronics (1)
- University of Hagen – Germany (1)
- ZettaCore (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.

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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.

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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. The course is only available for delivery at sites within the United States, unless it is delivered in conjunction with software training for FabTime customers.

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.

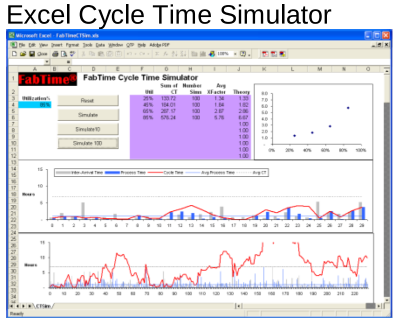
Skills Gained

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