FabTime Cycle Time Management Newsletter

Volume 4, No. 7 July 2003

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. We are currently installing Version 5.5 of FabTime. New features in this version include A20/A80 availability charts and shift-level production planning capability.

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Welcome

Welcome to Volume 4, Number 7 of the FabTime Cycle Time Management Newsletter. Subscriber discussion topics for this month include a response to last month's main article about operators and cycle time, several responses to last month's question about how companies calculate On Time Delivery percentage, a new question about the productivity of engineering staff, and a new question about wet bench capacity. We very much appreciate the people who have taken the time to write in with their questions, and particularly those who have taken time to respond to other people's questions. You are helping to make this newsletter an increasingly valuable community resource.

This month's main article is about identifying real-time cycle time problems in a wafer fab. We wrote this article in response to an informal cycle time problems survey that we have been conducting. The fourth-most common response to date has been real-time identification of cycle time problems (e.g. problem tools or operations). This is a nuts-and-bolts kind of topic that we've addressed only indirectly in this newsletter so far. In this issue, we propose metrics and methods for identifying cycle time problems in the fab on a short-term basis, so that they can be addressed and improved. Metrics discussed include operation-level cycle time, summed operation cycle time, inventory age, arrival coefficient of variation, and availability variability.

Thanks for reading!—Jennifer

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Community News/Announcements

Past Newsletter Issue Sets Now Available from Amazon

Earlier this year, we made individual past issues of the FabTime cycle time management newsletter available from our zShop at Amazon.com (www.amazon.com/shops/fabtime). All 35 issues published to date are available for purchase for $9.95/issue. We have recently added discounted multiple issue sets, making it both more convenient and less expensive for people who wish to obtain multiple past issues. You can purchase all of the issues from Volume 1, Volume 2, or Volume 3, or you can purchase the complete set of issues published to date. We accept Amazon payments, which means that you can pay Amazon by credit card, and Amazon pays us.

ASMC Proceedings Availability

We noticed while searching for something on Amazon recently that you can now purchase past proceedings of the Advanced Semiconductor Manufacturing Conference from Amazon. Most of them are available only by special order, but the 2000 and 2002 issues are available by regular purchase, for less than $200. We think that this is good news, because it makes past conference papers easier to come by.

FabTime welcomes the opportunity to publish community news and announcements. Simply send them to Jennifer.-Robinson@FabTime.com.

Subscriber Discussion Forum

Response to Last Month's In-Depth Guide to Operators and Cycle Time

Jimmy Giles (STMicroelectronics) wrote: "Regarding the 'Wafer Moves Per Operator' discussed in this month's newsletter, we measure productivity through an index called Direct People Productivity (DPP) which is calculated by determining the Number Of Good Wafers Processed [divided by] the Attended Paid Hours. From there we take it one step further, and measure Weighted Direct People Productivity (WDPP), which takes the use of overtime into account. Each module is given a WDPP target and the module headcount is established using the WDPP target and the planned capacity utilization.

One aspect that doesn't seem to be taken into account when discussing Direct Labor Staffing is that staffing models should be contingent on the critical site goals at that time. The site goals should dictate your staffing calculation. For example: if cost reduction is the priority, obviously high Moves Per Operator (WDPP) goals would need to be established and staffing would be stretched thin; however, if capacity maximization is the critical goal, staffing should be established to accommodate optimization of the bottlenecks and the overall production line."

Responses to Last Month's Question about Calculating OTD and Number of Moves

Issue 4.07 - A. An anonymous subscriber wrote:

"Regarding the question on On Time Delivery, allow me to share some methods of calculation currently in use. Two indices are used to measure OTD. The first index calculates the cumulative wafers shipped by the last day of the sales order against the total wafer qty of the particular sales order. The second index goes more in-depth and calculates the timeliness of the deliveries with respect to intermediate delivery dates (and not just the last day of sales order). The following example is given:

- Sales order quantity = 1000 pcs
- Committed delivery dates = 20 June (first 300), 25 June (next 300), 30 June (remaining 400)
- Actual delivery dates (cumulative) = 250 (by 20 June), 525 (by 25 June), 1000 (by 30 June)

OTD1 = Wafers shipped by last day of sales order / Sales order quantity
= 1000 / 1000 = 100%

OTD2 = Weighted average of OTD on 20, 25 and 30 June.

OTD(by 20 June) = 250/300 = 83.33%
OTD(by 25 June) = 525/600 = 87.5%
OTD(by 30 June) = 1000/1000 = 100%

=> **OTD2** = 300/1000 x 83.33% + 300/1000 x 87.5% + 400/1000 x 100% = 91.25% To calculate the month's OTD performance, a weighted average (depending on size of order) of the OTDs for all sales orders to be delivered in that month is evaluated.

I realize that this may not be industry standard. Are there any other references? Any comments on this method of calculation? Thanks."

FabTime Response: This method looks reasonable to us. Obviously customers care about intermediate delivery dates, not just final delivery dates, so we can see the need for a metric like OTD2 in addition to the simpler OTD1. Perhaps some other subscribers will care to comment / compare their own methods with this one.

Issue 4.07 - B. Matthew Nadeau (NEC Electronics) wrote:

"Here at NEC, we have utilized individual step completion as the definition of a wafer move in our facility. This method provides the most meaningful information regarding queue time, inventory trends, run time vs. inventory relationships, etc. The downside to this method is that it can give misleading data regarding the quality of wafer moves: a move through a stepper would be equivalent to a move through a transportation step. We have found that the benefits of this level of granularity have out-weighed the downsides.

For OTD, we measure the achievement of our commitment date to our customer. Our planning department will take an order from our customer and utilize standard lead times to determine the due date (or else the customer will dictate a due date). Our OTD measurement is simply the percentage of the orders that achieved the agreed upon due date (we measure by PO quantity and also by order quantity, so we look at two different OTD measurements). The key to having a meaningful OTD measurement lies within the lead time that is used. We could obviously pad the lead times and always achieve 100% OTD, but we would quickly lose a lot of business. Our lead times are standardized throughout NEC (6 - 8 fabs depending on the product) and where we have a competitive advantage (i.e. North American customer or better cycle times) we will quote a faster lead time. Typically, our OTD performance is between 90 - 98%."

Issue 4.07 - C. Cameron Creech (Bookham Technology) wrote:

"It is unusual to find one performance indicator that satisfies all business needs. Guiding principles of a meaningful delivery performance measure should include; a customer/shareholder perspective of performance, positive contribution to continuous improvement behavior, and an accurate reflection of your business performance. Experienced in both the semiconductor & computer industries, I have a number of different techniques that vary due to your business model. Here are a few:

Semiconductor - Build To Stock

Part Index:

(Count of product families whose actual wafer/chip deliveries >= Demand) / (count of product families whose demand > 0). Demand = Monthly Forecast + approved in-month increases. Deliveries = OTD Shipments.

Example:

Product	Deliveries	Demand	Hit/Miss
Lasers	127	125	Hit
Detectors	40	50	Miss
Modulators	33	25	Hit
Transmitters	40	40	Hit
Misc.	10	0	N/A

Performance = 75% (3 hits / 4 products with demand).

Volume Index:

(Count of wafer/chip deliveries whose demand > 0, not exceeding demand qty) / demand in wafers.

Example:

Product	Deliv	Counted Deliv	Demand
Lasers	127	125	125
Detectors	40	40	50
Modulators	33	25	25
Transmitter	40	40	40
Misc.	10	0	0
Subtotal:		230	240

Performance = 95.8% (230 Counted Deliveries / 240 wafers with demand)

Unconstrained Volume Index:

Count of wafer deliveries / demand in wafers.

Example:

Product	Deliveries	Demand
Lasers	127	125
Detectors	40	50
Modulators	33	25
Transmitter	40	40
Misc.	10	0
Subtotal:	250	240

Performance = 104% (250 deliveries / 240 wafers with demand)

Computer Industry - Build to Order

Shipment to Schedule (Orders):

(Count of "On-time Orders" delivered within a period) / (count of orders delivered during that period). "On-time Orders" = delivered "prior to" or "on" Scheduled Date. The Scheduled Date could equal; Customer Request Date, Factory Scheduled Date, Lead-time calculated date, Factory Commit Date.

Example:

Product	On-Time Ord Deliv	Orders Deliv
Lasers	127	127
Detectors	40	50
Modulators	33	33
Transmitters	40	40
Misc.	10	10
Subtotal:	250	260

Performance = 96% (250 orders on-time / 260 orders delivered).

This metric would need to be supplemented with an "Aged Past-due Backlog report" as it would not factor orders scheduled during the period that were NOT shipped/delivered."

Productivity of Engineering Staff

Terry Behrens (Intel) wrote: "Have you ever had a news letter discussion or topic on measuring engineering productivity and optimal engineering staff size? I remember in a previous job coming across a model that had a staffing algorithm in it, but I don't think it was very sophisticated. Do you know where I might find some information on how to measure and model engineering productivity and model staff size? We would like to know about Best Known Methods for labor measurement in the engineering organization, including the calculation method and variables used..."

FabTime Response: I don't believe that we've had any discussion in the newsletter about engineering staffing/productivity. My impression is that a model would be fairly company-specific, depending on what type of products you have, how often you change them, etc... In any case, I am raising this question in the newsletter, to see if other subscribers have any thoughts on engineering staffing models.

Wet Bench Capacity

An anonymous subscriber wrote: "We would like to understand how the industry configures Wet bench:

1. How much "excess" capacity is required for Wet bench machines in order to achieve smooth operation?
- Is it set to be 20% of the overall loading or any other "well-known" number?
- It's known that Photo is the planned bottleneck tool for most fabs, since it's the highest cost per floor area & COO. But if Wet capacity is equal/equivalent to Photo capacity, then it will be a problem of meeting the CT targets, right?

2. Is there a discount factor to wet bench capacity to cater for time constraints?
- e.g. We have Wet bench that need to feed to furnace within time window of 1 ~ 2 hrs, and the processing time of furnace is 5 ~ 7 hrs. Thus if we need to continuously feed furnace (which happen to be a bottleneck tool) then we need to have more hoods available. Is there any written formula to work around the time constraint problem between Wet bench & furnace?

FabTime Response: We don't know specifically how the industry configures wet bench capacity. We have not heard of a standard value for excess capacity on wet bench tools, although we do agree that if the capacity of the wet bench tools is the same as the photo capacity, you might have cycle time problems as a result. This is particularly true because of the second part of your question, regarding the time constraints for feeding the furnace. This (time constraints) is actually a very complex question. It's addressed in a general sense in the paper "Capacity Planning for Semiconductor Wafer Fabrication with Time Constraints between Operations", available for download from http://www.fabtime.com/abs_TBS99.shtml. We think that it should be possible to use simulation and/or queueing models to develop guidelines for specific cases, but we have not spent time looking into this. If any other subscribers have feedback on wet bench capacity and/or planning capacity in light of time constraints between wet bench and furnace, please let us know.

Identifying Real-Time Cycle Time Problems

Introduction

For about a year now, FabTime has been surveying people about the biggest cycle time problems in their fabs. The top response to date has been "equipment downtime." We discussed this in detail in Volume 4, Number 4 earlier this year. The next most frequent responses have been bottleneck utilization and one-of-a-kind (single path) tools. These have also been discussed extensively in past newsletter issues. We've stated that utilization is the biggest driver of cycle time, and that cross-qualifying a recipe so that it can be done on two tools instead of only one can decrease cycle time by about 50%.

In this issue, we would like to talk about the fourth-most common response: identifying real-time cycle time problems (tools, operations, etc.). This is a nuts-and-bolts kind of topic that we've addressed only indirectly in this newsletter so far. In this issue, we propose metrics and methods for identifying cycle time problems in the fab on a short-term basis, so that they can be addressed and improved.

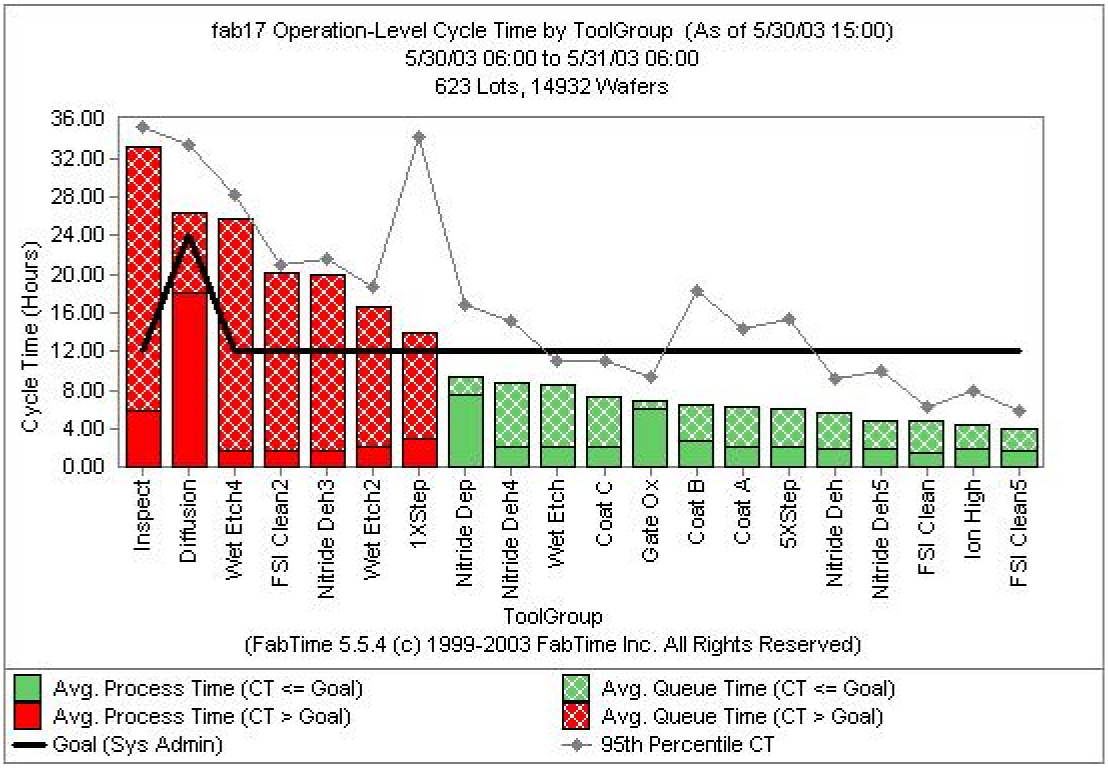
In Volume 3, Number 6, we introduced three cycle time management styles (the Traffic Cop, the Shepherd, and the Relay Coach). Not too long after that, we realized that we had missed a fourth style - the person who identifies gaps between planned and actual cycle time, and makes operational changes to fix cycle time problems. We've since dubbed this person the Mechanic. The Mechanic focuses on nuts-and-bolts types of problems, and is a primary candidate for metrics and methods discussed in this article (though of course many people in the fab work on short-term problems, including shift managers and module managers and all sorts of engineers).

Metrics

The question is, which metrics should you use if you want to identify short-term cycle time problems? The traditional cycle time metric is shipped lot cycle time, possibly displayed as a pareto of time spent in each area, or each tool group. However, shipped lot cycle time is a purely historic measure. It tells you where the lots that shipped this week spent their time over the past several weeks. It doesn't tell you where the cycle time problems are now, today. In this section, we review several metrics that are appropriate for real-time cycle time management.

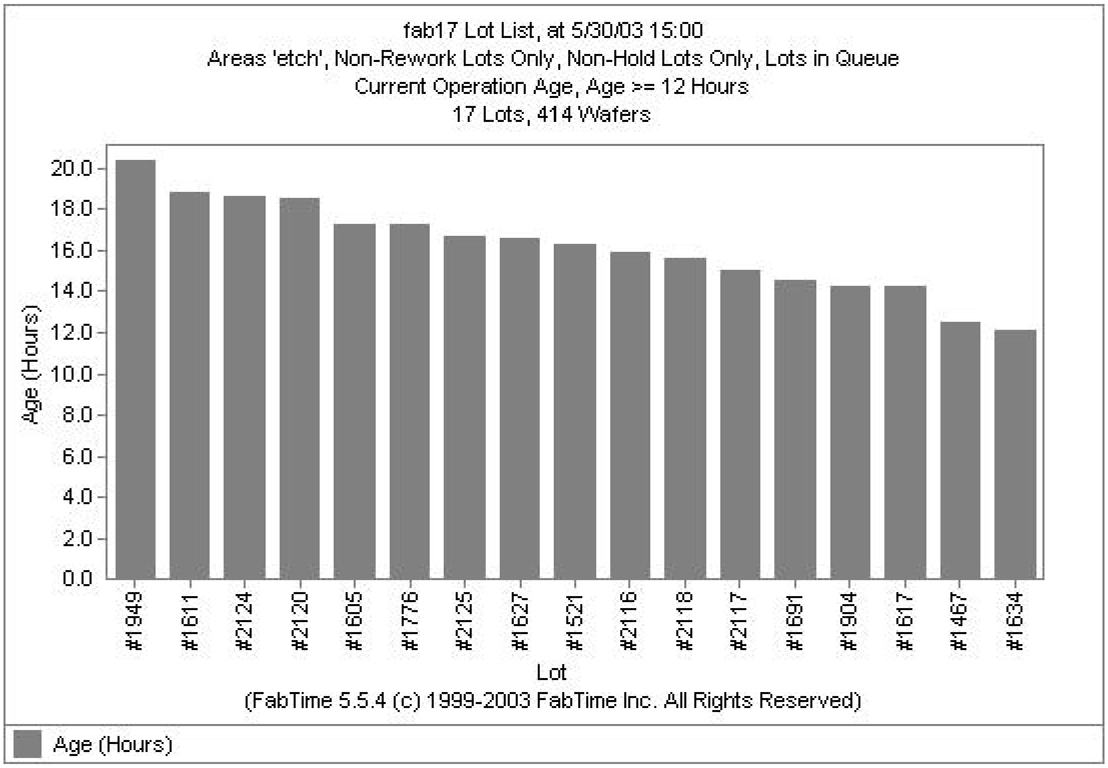
Instead of focusing on shipped lots, FabTime recommends that you look at operation-level cycle times for the current day or shift, and pareto them by tool group or operation. To calculate this, you take all of the lot move-outs for a given operation (or tool group) and measure both the queue time and the process time for each individual move-out. Then you average these observations by day or by shift, and then sort the results for all operations in descending order of queue time. This tells you which operations (or tool groups) are incurring the most queue time right now. An example is shown at the top of the next page. Note that you'll only be able to break out queue time vs. process time if you log "start process" transactions in your fab. Otherwise, you may only be able to report overall operation-level cycle times. These are still useful, but will probably be more useful if you divide them by planned cycle times. In any case, once you have an idea of where actual cycle times are high relative to process times (or planned cycle times), you will have a first-pass list of where to focus improvement efforts.

Another way to identify short-tem cycle time problem tools or operations is to look

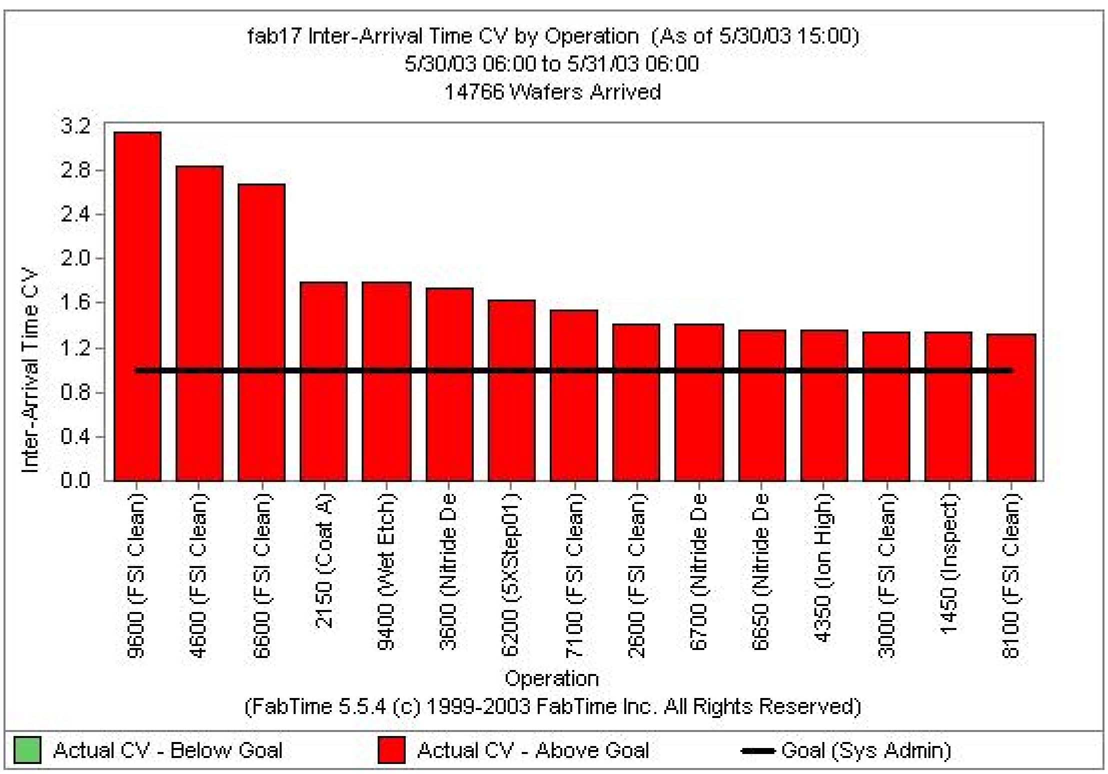


at the summed operation cycle time pareto. The summed operation cycle time indicates cycle time conditions based on current operation-level cycle times and, for operations that have not been recently completed, planned cycle times. Operation-level cycle times are estimated and then summed to provide an overall cycle time estimate, which you can pareto by area, operation, tool-group, segment, etc. This is a slightly higher-level, and more forward-looking approach than simply looking at actual operation-level cycle times. It says, based on your current performance and your planned performance, here's what you can expect your future cycle time to be, if the current situation continues. If this total cycle time is not satisfactory, you can use the pareto to pinpoint problem areas.

As an alternative, instead of focusing on tools or operations, you can focus on the inventory age of the individual lots. Here inventory age is defined as the time from when the lot arrived at its current operation to now. Lots are flagged as being inactive, or static, if their inventory age exceeds some threshold, like 12 hours. Inactive lots are usually reported by area (module) at the start of every shift. An example of an inactive list for a Photo area is shown on the next page. We've seen fabs reduce cycle time just by focusing on inactive lots, and pushing those through as quickly as possible. A focus on inactives tends to drive a fab towards first-in-first-out processing (since the oldest lots are worked on first), which tends to lower variability. Focusing on inactives is also helpful for fabs that run a large number of engineering lots, because it doesn't allow the more difficult engineering lots to be hidden in the corner. They quickly show up as inactive, and become a priority for movement. The exact threshold to use for defining lots as inactive will vary depending on the amount of WIP in the fab. As a fab decreases cycle time (and correspondingly WIP) management will need to reduce the inactive threshold accordingly. We know of one fab where lots are defined as inactive if they sit for more than four hours.



A third approach, instead of focusing on operation-level cycle times or on inventory age, is to look at variability metrics. Where variability is high, you can expect that cycle times will be higher than they should be. We recommend recording arrival coefficient of variation by tool or operation, and sorting the results in descending order by CV for the current day or shift, as shown below. This will pinpoint operations where high arrival variability is likely to start driving up cycle time. Coefficent of variation was described in Volume 4, Number 1. It is calculated by taking the



standard deviation of a set of values (e.g. interarrival times) and dividing by the average of the values.

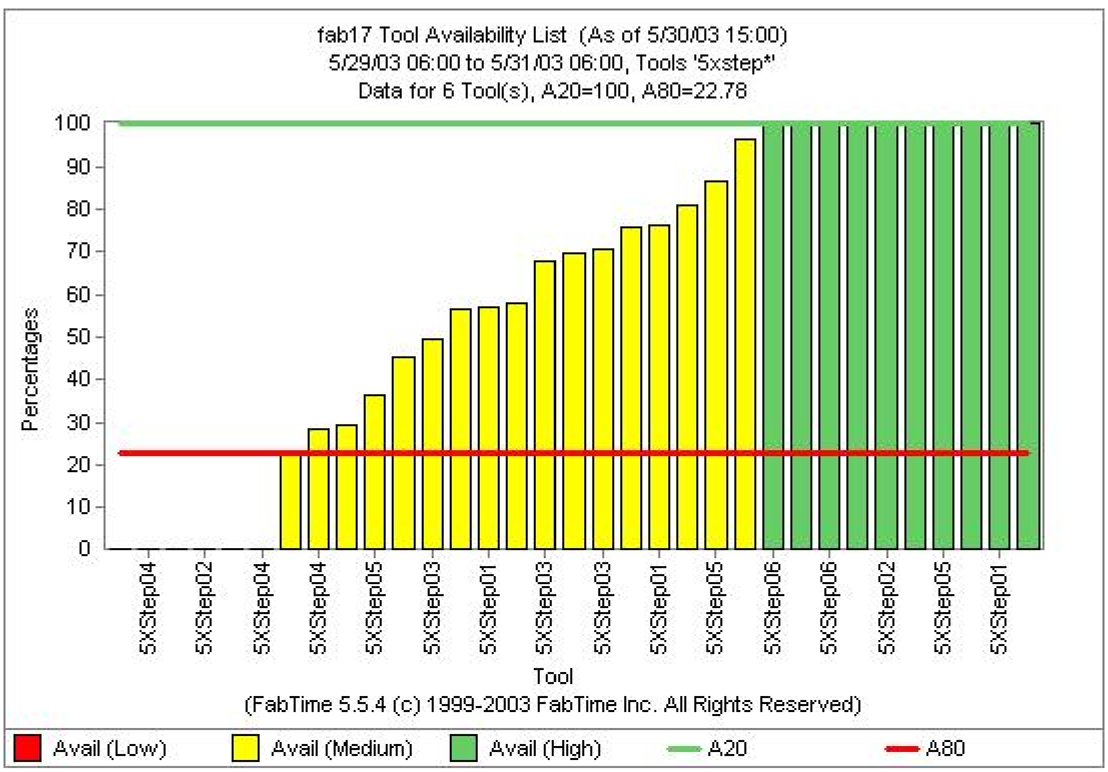
We also recommend measuring A20/A80 availability variability, as described in Volume 4, Number 2 of the newsletter. A80 is the best availability reached within 80% of the periods in a set of periods (shifts, days, weeks, etc.). So, for example, if the availability is at least 75% for four out of five days, and then is some lower value on the fifth day, A80 for this set of days will be 75%. A20 is the best availability reached (or exceeded) in at least 20% of the periods in a set. The difference between A20 and A80 is a measure of how variable the availability is between periods (shifts, days, weeks, etc. - the calculations would be performed the same way). An example is shown below.

There are certainly other metrics that are, and should be, used in the fab. Moves, turns, scrap, on-time-delivery, etc. The metrics described here are some that are particularly applicable to identifying short-term cycle time problems, by tool, operation, or lot. The benefit of identifying short-term problems, of course, is that if they are identified quickly enough, then it may be possible to actually do something proactive to cause improvement, as described below.

Methods

The Mechanic focuses on short-term, nuts and bolts cycle time problems, and recommends operational changes to drive cycle time improvement. Some places where you might suggest that the Mechanic focus are:

Tool Dedication - Generate reports showing the number of tools that are really used to perform each recipe/operation. Look for operations that are only being done on a single tool, regardless of qualification matrices. Sometimes operator preferences, in addition to tool qualifications, can lead to single path operations. Eliminating single path operations will almost certainly improve cycle time. See Volume 1, Number 8 and Volume 3, Number 3 for details.



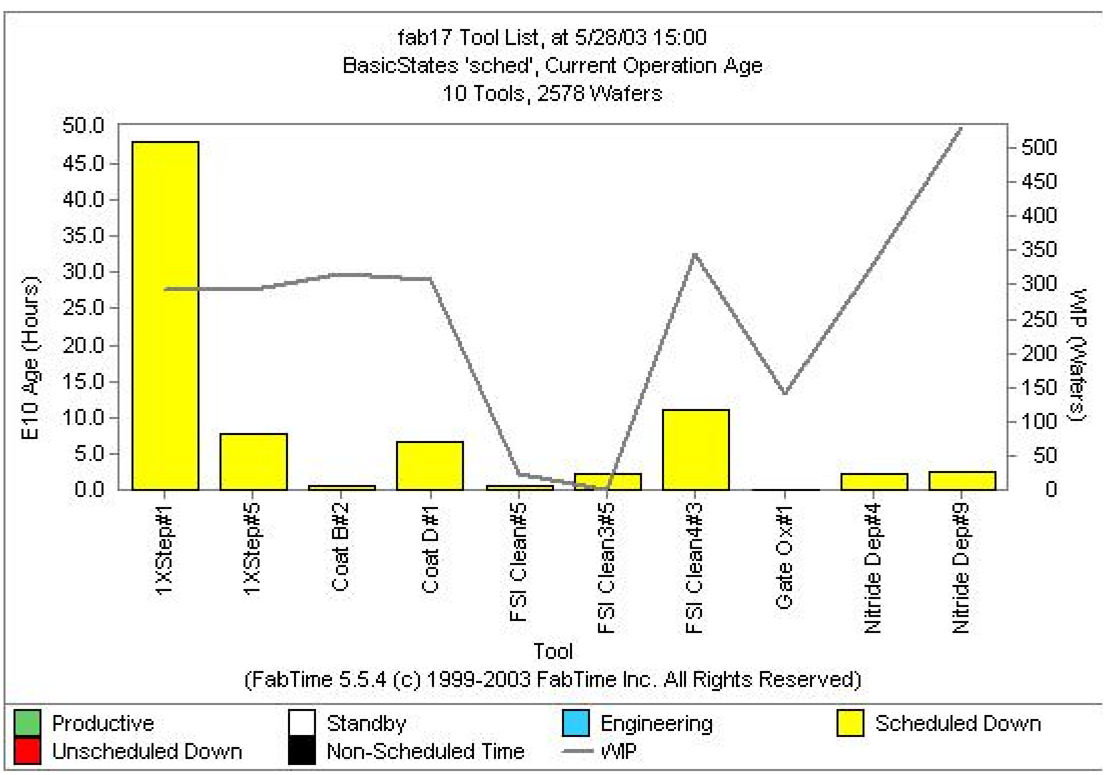
Staffing Decisions - For cycle time bottleneck tools (as identified above) measure the percent of time that those tools spend waiting for operators. Whenever operators are shared across multiple tools, there will be times when tools have WIP, but are idle due to waiting for an operator. Reassigning staff to eliminate this forced idle time can move tools away from the steep part of the operating curve, and significantly reduce cycle time. See Volume 3, Number 9 and Volume 4, Number 6 for details.

Batch Loading Rules - Look at operation-level cycle times by product for large batch tools such as furnaces. See if low volume products are experiencing long queue times. This can be an indication that batch loading policies need to modified. When the batch loading policy is to wait for a full, or nearly full, batch, long queue times can result, especially for low volume products. See Volume 2, Number 1 and Volume 3, Number 8 for details.

PM Scheduling - Generate reports showing, for each tool, the length of time that the tool has been in its current state. Filter to only show tools that are down for scheduled maintenance. An example is shown below. Find the tools that have had the longest continuous scheduled maintenance time (1XStep#1 in the example), and review maintenance schedules to see if this could in the future be broken down into shorter, more frequent maintenance events. See Volume 4, Number 4 for details. For unscheduled downtime, follow a similar procedure, but then pareto the downtime events by reason code, or by shift, or by employee, to see if there are patterns leading to the long downtimes that might be corrected.

A Note on Data Collection

The above-described metrics are most useful if calculated in something approaching real time (every five or ten minutes). While you can certainly get to them using custom queries against your MES, we recommend that you do something more standardized. Everything described in this issue (both the metrics and methods sections) is available from standard charts



in FabTime's cycle time management software. This standardization means that Mechanics working on different shifts, or even in different fabs, have access to the same data, in the same format. This makes the Mechanic's information more bullet-proof when he or she proposes changes to others in the fab.

We have also found that if a metric is difficult for people to calculate or generate, they won't use it. It has to be calculated automatically, and updated frequently, or it will never be widely used. People in fabs are too busy to spend lots of time manipulating data. In our software, all of these metrics come up as standard charts, which the user can then filter to look at particular subsets of data. This means that the Mechanic can spend time solving problems, instead of spending time writing lots of custom reports just to find the problems. Whatever system you use, we recommend that at a minimum you automate the generation of operation-level cycle times, inactive lists, and variability metrics, and that your system update them in real time.

Summary

In this issue, we have described several metrics that we recommend for identifying short-term cycle time problems in the fab. These metrics include operation-level cycle time, summed operation cycle time, inventory age/inactive lots, arrival coefficient of variation, and A20/A80 availability variability. We have also touched on some more detailed methods for using real-time data to understand problems and improve operational decisions. Specifically, we have focused on tool dedication, staffing decisions, batch loading policies, and maintenance schedules. These are just a few of the tools that your Mechanics (nuts-and-bolts problem fixers) can use to improve fab cycle times.

Closing Questions for FabTime Subscribers

Do you have other metrics or methods that you use to identify short-term cycle time problems? If you send us your input, we will include it in the subscriber discussion forum in the next issue.

Further Reading

Here are a few references to articles that describe real-world (not just simulated) cycle time improvement projects. Most of these papers are not available from FabTime, but should be publicly available from a paper distribution service such as Infotrieve (www.infotrieve.com).

- F. G. Boebel and O. Ruelle, "Cycle Time Reduction Program at ACL," *Proceedings of the 1996 IEEE/SEMI Advanced Semiconductor Manufacturing Conference*, Cambridge, MA, 165-168, 1996.

- J. Bonal, M. Fernadez, O. Maire-Richar, S. Aparicio, R. Oliva, S. Garcia, B. Gonzalez, L. Rodriguez, M. Rosendo, J.C. Villacieros, and J. Becerro, "A Statistical Approach To Cycle Time Management," *Proceedings of the 2001 Advanced Semiconductor Manufacturing Conference (ASMC 01)*, Munich, Germany, 2001.

- M. Hillis and J. K. Robinson, "Super-Expediting in a 0.18 Micron Wafer Fab," *Proceedings of the 2002 Modeling and Analysis for Semiconductor Manufacturing Conference (MASM 2002)*. Tempe, AZ, April 10-12, 2002. This paper is available for download from http://www.fabtime.com/abs_MASM02.shtml.

- S. Johnishi, K. Ozawa and N. Satoh, "Dynamic X-Factor Application for Optimizing Lot Control for Agile Manufacturing," *Proceedings of the 2002 International Symposium on Semiconductor Manufacturing (ISSM2002)*, Tokyo, Japan, 2002.

■ R. C. Leachman, J. Kang, V. Lin, "SLIM: Short Cycle Time and Low Inventory in Manufacturing at Samsung Electronics," *Interfaces*, Vol. 32, No 1, 2002.

■ K. Potti and M. Whitaker, "CT Reduction at a Major Texas Instruments Wafer Fab," *Proceedings of the 14th Annual IEEE/SEMI Advanced Semiconductor Manufacturing Conference and Workshop*, Munich, Germany, 2003.

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