FabTime Cycle Time Management Newsletter

Volume 13, No. 1 February 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 site-specific control over standard WIP turns scaling and increased support for maximum number of site-specific WIP attributes.

Editor: Jennifer Robinson

Contributors: Andy Naylor (International Rectifier); Michael Hassoun (Ariel University Center); John Matthews (Anadigics); James Ignizio (The Institute for Resource Management); Gregg Damminga (Cypress)

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Welcome

Welcome to Volume 13, Number 1 of the FabTime Cycle Time Management Newsletter! It's hard to believe that we're headed into our 13th year of publication, and still coming up with things to talk about. In this issue we have a link to a news story from the Wall Street Journal that references Little's Law (one of the fundamental drivers of fab behavior), a call for papers for the MASM 2012 conference (to be held in Berlin in December), and an announcement about recent and upcoming Fab Owners Association meetings. Our FabTime user tip of the month is about using new stacked WIP and Moves charts. We have an extensive amount of subscriber discussion in this issue. Apparently, December's topic of metrics for fab variability was of particular interest.

In our main article this month, we share six potential variability-related metrics, inspired by subscriber and customer suggestions. These range from tracking first pass success rate for preventive maintenance events to aggregating lot slack times across tools or areas in the fab. It is clear from the broad response to this topic that many of us are working on finding new metrics to reduce variability in the fab. It is our hope that, together, through discussions like the ones shared below, we can work to find better solutions. We are grateful to all of the people who took time to share their thoughts on this topic, and welcome additional feedback.

FabTime would also like to express condolences to our subscribers from Micron on the sudden and tragic death of their CEO, Steve Appleton. Our thoughts are with you at this difficult time.

Thanks for reading – Jennifer

Community News/Announcements

Little's Law in the WSJ: The Science of Checkout Lines

In our cycle time class, we always introduce Little's Law, a fundamental principle that defines the relationship between WIP, cycle time, and throughput in a factory. We rarely run across Little's Law in the popular press. However, back in December, Frank was reading the Wall Street Journal, and found a mention of Little's Law in an article by Ray A. Smith about the work that retailers are doing to improve the checkout line experience for customers. The main article is here.

The reference to Little's Law is actually in an interactive figure that illustrates the science of checkout lines, located here (or just click on the figure that has "View Interactive" in small text).

Call for Papers: Modeling and Analysis of Semiconductor Manufacturing (MASM 2012)

8th International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM) 2012 and INTERNATIONAL SEMATECH MANUFACTURING INITIATIVE (ISMI) MMC/IE Council Meeting

Berlin, Germany

December 9th-12th 2012

The 2012 International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM) aims to again be a forum for the exchange of ideas and best practices between researchers and practitioners from around the world involved in modeling and analysis of high-tech manufacturing systems. The MASM 2012 conference will be fully contained within the Winter Simulation Conference 2012 (WSC 2012), the leading conference in discrete event simulation. WSC 2012 features a comprehensive program ranging from introductory tutorials to state-of-the-art research and practice. WSC 2012 will take place in Berlin, Germany. All attendees of the MASM conference will register for WSC 2012 at the same cost. All participants of WSC 2012 can attend MASM 2012 sessions.

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 decisions 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.

More details are available at http://www.WinterSim.org.

Fab Owners Association (FOA) Quarterly Meetings

The first quarterly meeting of the Fab Owners Association (http://www.waferfabs.org) was held at the **Telefunken** wafer fab in Roseville, California last week. 18 representatives from independent device manufacturers were present, along with 79 representatives from associate member companies (including FabTime). The FOA started a new tradition at this meeting by making a charitable donation to the Roseville Police Volunteers in Telefunken's name.

The next FOA meeting will be held at the **Fairchild** wafer fab in Salt Lake City on May 9th and 10th. The FOA is an

international, nonprofit, trade association of semiconductor & MEMS fab owners and industry suppliers who meet regularly to discuss and act on common manufacturing issues, combining strengths and resources to become more globally competitive.

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

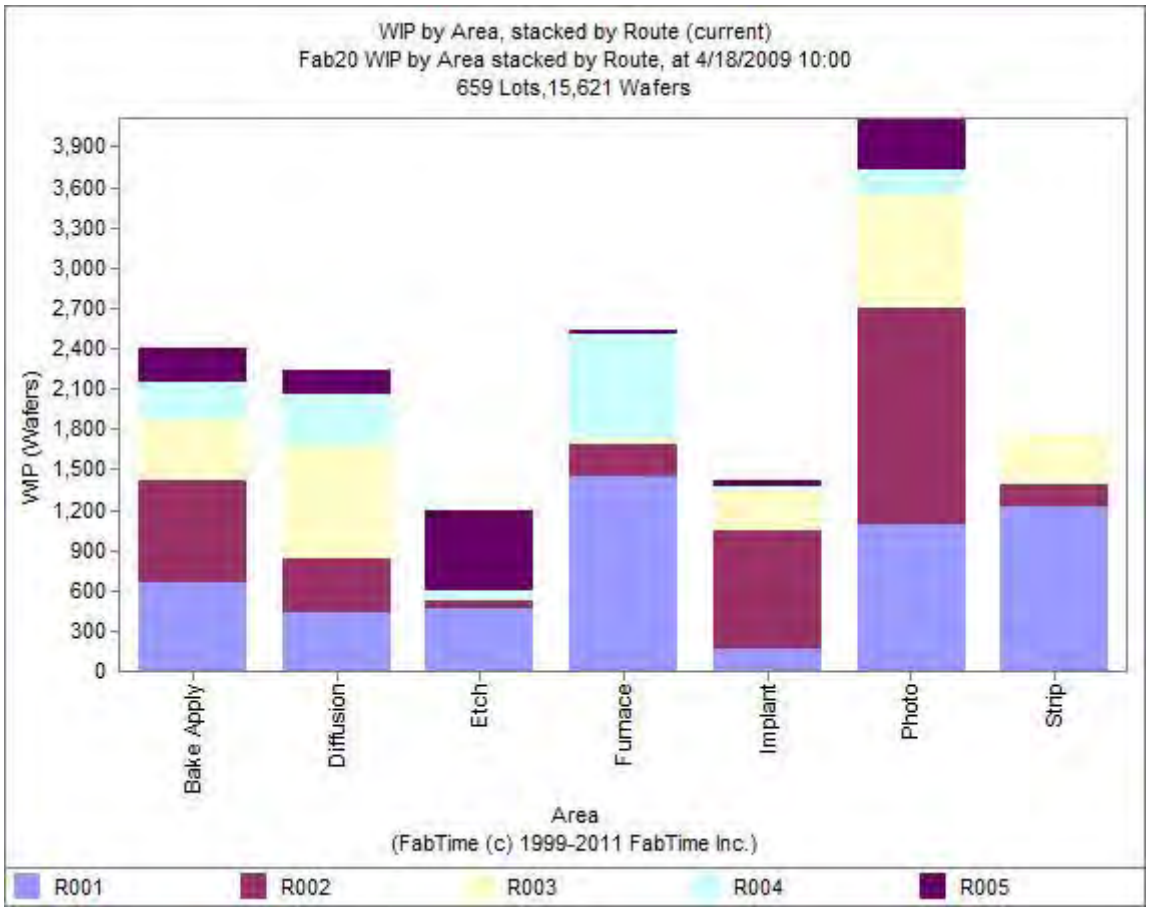
Use the New Stacked WIP and Moves Charts

After receiving a number of requests to see Moves or WIP stacked by one variable or another (owner code, product family, etc.), FabTime has implemented a general solution that allows you to view Moves or WIP stacked by any one of up to 25 user-selected variables (priority class, tool group, layer, etc). To use this functionality, simply select the Moves Stacked Trend, Moves Stacked Pareto, WIP Stacked Trend, or WIP Stacked Pareto chart from the chart list (at the bottom of, respectively, the Moves Charts and WIP Charts sections). For any of these charts, you'll now see a new "Cross:" drop-down at the bottom of the main set of filters to the left of the chart (just above the "Go" button). Select your stack-by variable from the "Cross:" drop-down, and then press the "Go" button. FabTime will stack each bar of the chart according to the selected variable. A separate row will appear in the data table for each segment of each stacked bar. An example is shown on the next page.

Note that for Pareto charts, the "Slice:" drop-down is still available. Slice tells FabTime which variable to slice up the chart by - that is, what will appear on the x-axis of the chart. As before, you'll see a separate column on the Pareto charts for each Slice item (e.g. for each Area). The "Cross:" drop-down, on the other hand, applies to how the variables are stacked within each bar. By default, each chart will show up with the first variable selected for both Slice and Cross, typically Area. However, you can select any combination of Slice and Cross that you like, and then save that chart configuration by adding it to one of your home page tabs.

There are a couple of caveats for practical use of the stacking functionality. If you Cross by a variable that isn't defined on your FabTime server (e.g. tool Model or Vendor), the stacking will just show up as "Undefined" with a single color. Conversely, if you Cross by a variable with a very large number of values, such as Lot, the chart will become unreadable, because the legend will be so large. However, used judiciously, we think that the Stack/Cross functionality will give you access to very useful set of charts.

If you have any questions about this feature, or any questions about the software, just use the Feedback form inside FabTime. Subscribe to the separate Tip of the Month email list (with additional discussion for customers only) here. Thanks!



Subscriber Discussion Forum

Note: We received a number of responses to our recent article on metrics for fab variability. We are including those responses here, but will respond to several of them in more detail as part of this issue's main article.

Issue 12.05: PM Effectiveness

Gregg Damminga from Cypress Semiconductor wrote in response to Mike Hillis' question from issue 12.05, about PM Effectiveness. Gregg wrote:

"We monitor first pass success very closely on our top 8-10 loaded toolsets. We calculate it pretty easily:

- When the PM is done, change the tool state to "mfg qual" in our MES system.
- If the tool goes from state "mfg qual" directly to state "production", then first pass success was achieved.
- If the tool goes from state "mfg qual" to anything else (e.g., eng, down, spc fail, etc.), then first pass success was not achieved.

We actually measure the loss ratio of misses/total PMs, with the desire to drive to zero. Most of our critical toolsets run at less than 10%, meaning that more than 90% of the time, first pass post PM was achieved."

Fab Variability Metrics

Michael Hassoun of Ariel University Center, Israel commented: "About the question on the roots of variability, I think the number of tools in a toolset is an important player. At the same load level, a

large number of tools can mitigate the adverse effects of setups, downtimes, batch processing etc. and help smoothening the downstream flow."

FabTime Response: We certainly agree that the number of tools in a toolset is an important feature in driving cycle times. We wrote about this in Issue 6.05, and alluded to it again in 9.01. Perhaps it's time to address that topic again in the newsletter. We think that having more tools helps to mitigate all of the effects of variability. This also makes tool dedication policies very important in driving cycle time (and more immediately controllable than the number of tools). We would like to see more fabs reporting their number of single path operations – we think that would go a long way towards improving cycle time.

John Matthews from Anadigics wrote: "Great newsletter this week. I really liked the discussion on variability and I agree with you that its reduction is a big lever for improving global metrics for the Fab. We are finding a lot of success, from the perspective of driving understanding, by trending the WIP variation by bucket. As you discuss, we also use the CV for our metric on this. We would love to see canned charts in FabTime that trend that metric for us." (John also shared some examples with us; examples that he has shared with the Industrial Engineering working group associated with the Fab Owners Association.)

FabTime Response: This is exactly the sort of thing that we were looking for when we introduced the original article – what are new metrics for variability that are useful in driving operational decisions? We will address this one further in the main article.

James Ignizio, founder of The Institute for Resource Management, wrote "The main topic of your December 2011 Newsletter (i.e., Variability Metrics for Fabs) is one to which I have devoted much of my career - particularly the past two decades. In that discussion you note that you (i.e., FabTime) do not compute the CV (coefficient of variation) of process times - and that the calculation of Effective Process Time (CV_{ept}) is "computationally challenging."

I wholeheartedly agree that the collection of data (particularly, credible data) for the development of CV_{ept} is indeed a challenge. As just one example, in the semiconductor firms I have either worked for, or consulted for, the logging of tool downtime is particularly problematic. And yet it is the variability about this downtime (either scheduled or unscheduled) that plays a major role in the magnitude of CV_{ept}.

I believe, however, that fab management could be motivated to allocate the resources necessary to develop reasonably accurate CV_{ept} values if they were made aware of the substantial impact that this type of variability has on the performance of their multi-billion dollar fabs. It is, I believe, a matter of educating management (as well as factory engineers) in this topic.

To accomplish this I have placed on the Internet several small (but representative) factory models that may be used to provide an education in variability as well as a means to compare various alternative means (e.g., Theory of Constraints, "Educated Guesses," and Variability Reduction) for the improvement of factory performance (e.g., improved cycle time, capacity, and WIP levels).

These factory models, available at no cost to the public, are housed at the McGraw-Hill Professional website. More specifically, they may be accessed at www.mhprofessional.com/ignizio.

At least two factory managers, at two different firms, recently found these models sufficient to allocate the resources necessary to collect and compute CV values for both Effective Process Times as well as Job (e.g., wafer) Inter-arrivals.

I invite anyone who might doubt the substantial impact of these two sources of variability to run these simulations - which require only the use of an Excel spreadsheet."

FabTime Response: We are certainly in favor of educating people about the impact of variability. We like that you've given people a way to connect variability improvement to bottom line dollar benefits.

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

Variability Metrics for Fabs: Part 2

Introduction

In the last issue of the newsletter we talked about our quest for new fab variability metrics. We asked our subscribers: "What do you think are the best metrics to use to monitor and improve fab variability (and hence improve cycle time)? If you were creating a fab variability snapshot report, what would be in it?" These are complex questions, and we didn't have anyone reply "These are the top 5 metrics for fab variability." We did, however, receive a number of subscriber responses to the topic. Within each of those responses, we found suggestions for potential new metrics for tracking fab variability. These potential new metrics are each outlined below.

First Pass Success for PMs

As outlined by Gregg Damminga above, a metric for tracking PM effectiveness is the loss ratio of misses to total number of PMs, where "misses" occur when, after a PM, the tool does not go directly from "mfg qual" back to "production". Although this metric was technically proposed in response to a subscriber discussion question (from Mike Hillis) about PM Effectiveness, we do think that this First Pass Success Ratio is a useful metric for monitoring (and hence reducing) variability. A significant portion of the impact that downtime (whether scheduled or unscheduled) has on cycle time stems from the way that downtime increases the variability of availability. A metric like this, which drives people to get the tool up and running more quickly, will tend to improve availability variability, and thus improve cycle time.

Number of Single Path Operations (and/or % of Single Path Operations)

Michael Hassoun's comments above about how the number of tools per toolset impacts variability suggested a new metric to us. We know that single path operations are a major contributor to cycle time in fabs, whether these stem from one-of-a-

kind tools or from process restrictions. The number of one-of-a-kind tools in a fab is not a particularly useful metric, since it changes so rarely in most cases (and is generally outside of the immediate control of the people operating the fab). However, it seems to us that the number of single path operations, across all active routes, could be a useful thing to track. In comparing across fabs, one could use the percent of single path operations (relative to the total number of operations). However, within the fab, we like the idea of looking at the absolute number of operations, and working every day to reduce it.

As an implementation matter, it may not always be immediately clear which operations are "active", since product mix changes rapidly. One thing that we do in FabTime is report, for all of the operations that currently have WIP waiting, the number of tools that are qualified to run that operation. We don't currently add up this number across operations, though it would be a simple matter to do so. Of course this is a lower bound on the number of single path operations, since some operations might not have WIP in front of them when the list is generated. It might be better to roll this up, at sub-intervals, across a week, or look across all routes that have any WIP anywhere along the line. However, it's been our experience that single path operations that are causing cycle time problems will usually have WIP in front of them most of the time anyway. So, even a simple number reported each morning that says: "today we have XYZ number of single path operations with WIP waiting", would be a good place to start.

Coefficient of Variation of WIP, by Bucket

This metric was proposed above by John Matthews. The idea is to divide each process flow into buckets, or segments, of roughly equal length (in terms of expected cycle time), and measure the WIP in each bucket. Then, over time, track the coefficient of variation of the sequence of WIP-by-bucket values. The lower this coefficient of variation, the smoother the WIP is throughout the line. In a perfectly balanced line, the coefficient of variation of WIP by bucket would approach zero.

As an implementation matter, it might be possible to do this as an extension to the Stacked WIP Trend and Pareto Charts described above (in the Tip of the Month section). Each bar would consist of a series of WIP observations stacked by some value (bucket, or segment, in this case, though one could generalize to other choices). We would then add a line across this chart, against the second y-axis, that reports the coefficient of variation of the numbers that make up each stacked bar. One would need to make sure that enough granularity was included in the stacking variable to compute the CV with some degree of confidence. Then the goal would be to drive down the CV values as much as possible.

Coefficient of Variation of Effective Process Times

Although not a new metric (we've been aware of it for a number of years), James Ignizio encouraged us all to make an effort to measure and use Coefficient of Variation of Effective Process times at the tool level. The idea here is to measure, for each lot, the time from when it arrives to the front of the queue until it finishes processing. This is the lot's effective process time. In many cases, the effective process time is equal to the actual process time. However, if a lot arrives to the front of the queue for a tool that is down, or if a setup is required, that time is added to the effective process time for the lot. Intuitively, using the effective process time makes sense. Consider when you are at a store. If you get to the front of the checkout line, and the cashier needs to change the register tape before processing

your order, that setup time is effectively part of your checkout time.

The variability of this effective process time is a more accurate indicator of cycle time than the variability of the pure process time alone. However, what makes measuring the effective process times challenging is that what lot is at the front of the queue can change. Suppose Lot A arrives to Tool X, and is the only lot in queue. The clock starts ticking for Lot A's effective process time. If Tool X is down, then that downtime is recorded as part of the effective process time. However, suppose that before Tool X comes back up, Lot B arrives, and is a higher priority lot than Lot A. We have to stop the clock for calculating Lot A's effective process time (saving that time for later), and start the clock for Lot B. Because of the high mix in many fabs, and the chance of long downtimes, these calculations can become cumbersome quite quickly. However, we do agree that the CV of the effective process times is considerably more useful as an indicator of cycle time (and a value to use in queueing models) than the CV of standard process times.

Coefficient of Variation of Availability

We also mentioned in the last issue the idea of recording the coefficient of variation of availability. We had some discussions about that concept with one of our customers (Andy Naylor of International Rectifier in Newport, Wales), and wanted to share a few thoughts here. The question arose as to what would be a good value to target as a goal for the CV of Availability, and whether or not tracking CV of downtime, or A20/A80, would be more useful.

We proposed that in setting a target for CV of Availability, a good start would be to look at the spread of the CV of Availability values for the major toolsets in the fab, and then look at something like the top 20%, and set the cutoff for what constitutes "high variability" there (since there does not appear to be a lot of documentation for the use of this metric in practice). The tricky part is that the cutoff to use is going to depend upon what time period is used for looking at availability. If you look at availability by shift or by day, you'll see a much higher range in values (and hence a higher CV) than if you look at availability by week. There's more variation over shorter periods than longer ones. That's what makes this a slightly complex metric to use.

We believe that looking at CV of Availability and looking at the range in the A20/A80 chart is going to give similar results (since the two measures are based on the same underlying data). In both cases, the results will depend strongly on what value is used for the sub-period, and what overall time period is used for the calculation. CV of Availability is a bit more quantitative than A20/A80 (you end up with one number, instead of looking at a range), and you can compare it with other metrics for which you look at CV. So it's nice that way.

But we do think that the metric that most drives cycle time in this area is going to be CV of repair time. The results won't be as dependent on what you choose for period length (because they're based on number of downtime events, which is mostly independent of the period length (except for boundary conditions). The CV of the unscheduled downtimes is probably most closely tied to cycle time (vs. the CV of scheduled downtime), though both are likely to have an impact.

Aggregate Measures of Lot Slack Time

An anonymous subscriber wrote to suggest the inclusion of metrics that aggregate slack measures across lots. In FabTime right now we report two different slack-related metrics for in-process lot. The first looks ahead and projects an estimated completion date for each lot, and

compares that with the due date for the lot, reporting estimated days early or late. The second metric adds up the cycle time of the lot so far, and compares that with the target cycle time of the lot so far, and reports a target minus actual at this point in the line. There are some subtleties to these calculations, depending on whether operation-specific planned cycle time values are included for the lot, and whether or not those are overridden by a target x-factor applied to the chart. But clearly both metrics are an indicator of which lots are ahead of vs. behind schedule.

We're still not quite clear on how one would aggregate these metrics to compare lot slack time across tool groups or areas. Do you penalize for being early, or just for being late? Do you report a total slack time across all lots, or a weighted average by lot size? Or do you just focus on the outliers? The question is whether or not there is an effective way to use this data as a variability metric to drive behavior improvements, in addition to however the data is used by the dispatch system. We would welcome additional feedback if anyone has it.

Conclusions

In the December issue of the newsletter, we asked for subscriber feedback regarding useful new metrics for monitoring fab variability. Thanks to generous subscriber and customer responses, we have in this issue proposed six new types of variability metrics. These range from tracking first pass success rate for preventive maintenance events to aggregating lot slack times across tools or areas in the fab. Some of these metrics appear relatively cut and dried (CV of WIP by bucket, for example), while for others implementation questions and/or challenges still exist.

It is clear that many of us are struggling to find the right metrics to reduce variability in the fab. It is our hope that together, through discussions like the ones above, we can work to find better solutions. We are grateful to all of the people who took time to share their thoughts on this topic. We welcome any additional feedback.

Closing Questions for FabTime Subscribers

What do all of you think? Do any of these metrics sound promising? Which ones do you think we should implement in our software? Are there others that you would suggest instead?

Subscriber List

Total number of subscribers: 2708, from 441 companies and universities.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (151)
- Intel Corporation (145)
- Micron Technology, Inc. (110)
- Texas Instruments (87)
- Western Digital Corporation (69)
- ON Semiconductor (68)
- X-FAB Inc. (68)
- Carsem M Sdn Bhd (67)
- International Rectifier (63)
- TECH Semiconductor Singapore (61)
- STMicroelectronics (58)
- GLOBALFOUNDRIES (54)
- 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:

- Ariel University Center
- Sitronics
- nLight
- Alta Devices

Sampler Set of Other Subscribing Companies and Universities:

- AAI Corporation (1)
- Asia Management Group (1)
- Compugraphics International Ltd. (1)
- Cree, Inc. (12)
- Dongbu HiTek Co. (4)
- European Aeronautic Space and Defense Company (1)
- First Solar Inc. (1)
- Innovo Strategy (1)
- Linear Technology (2)
- Litel Instruments (1)
- Micralyne (2)
- National Microelectronics Institute (UK) (1)
- Powerex, Inc. (1)
- Semtech (1)
- STATSChipPAC (1)
- Soitec (9)
- SunPower Corp. (2)
- Tiger Venture Analysis (1)
- Veeco Instruments (1)
- Wichita State University (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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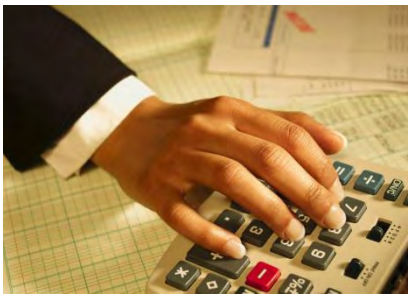
FabTime® Software Capacity Planning Module



CP Configuration

We offer our capacity planning module for an additional monthly fee (on top of your regular FabTime subscription). This includes:

- Identification of the source of any additional data needed for the planning module.
- Automation of the process of importing the additional data into FabTime.
- Validation against client data.

Interested?

Contact FabTime for more information, or 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 need to answer questions like:

- Given a target product mix, do we need any new tools?
- Given the tools that we have, and the products that we are running, how many wafers can we expect to produce?
- Given our existing set of products and tools, what happens if the product mix changes? Where can we expect bottlenecks?

Are you tired of maintaining a standalone capacity planning spreadsheet?

FabTime's capacity planning module leverages the data already stored in the FabTime digital dashboard software, to make it easier to build capacity planning scenarios. The only required manual inputs are:

- Weekly ships per product.
- Product line yield percentages.

FabTime uses route information from the fab MES and calculates UPH data (tool speed) based on actual performance. FabTime also uses tool uptime performance to estimate availability (though this can be overridden). These inputs are used to generate predicted utilization percentages for each capacity type. Detailed intermediate calculations (UPH, tool productive time, tool rework percentage, etc.) are also available (an example for one tool is shown below). All outputs can be easily exported to Excel.

Capacity Planning Module Benefits

- Eliminate the need to maintain offline capacity planning models.
- Automatically update capacity planning data to reflect new conditions (process flows, tool uptime characteristics).
- Quickly run scenarios to anticipate (and avoid) bottlenecks caused by product mix changes.

C Type	Output	Value	Notes
1XStep	Rework Moves/Week	21	2004-09-06 10:00:00 to 2004-11-15 10:00:00
1XStep	Total Moves/Week	12310	2004-09-06 10:00:00 to 2004-11-15 10:00:00
1XStep	Rework Ratio	0	Rework Ratio = Rework Moves / Total Moves.
1XStep	Productive%	61	2004-09-06 10:00:00 to 2004-11-15 10:00:00
1XStep	Availability%	76.26	Availability = Productive% + Standby%.
1XStep	Historic Utilization%	79.99	Utilization (Mfg efficiency) = Productive% / Availability%.
1XStep	Productive(Rework)%	0.1	Productive(Rework)=Productive% * ReworkRatio.
1XStep	Net Availability%	76.15	Net availability% = Availability% - Productive(Rework)%.
1XStep	Arrivals (Units/Hour)	79.36	Based on total plan WGR=2025
1XStep	Tool Quantity	8	1XStep#1 ... 1XStep#8
1XStep	UPH	15.02	UPH = (TotalMoves/ToolQty) / (Productive% * 168)
1XStep	Required Hours/Day	126.84	Required hours = 24 * HourlyArrivalRate / UPH
1XStep	Predicted Utilization%	86.75	Util = 100 * ReqdHours / (24 * NetAvail * ToolQty / 100)
1XStep	Max WGR	2334.22	MaxWGR = PlanWGR / PredictedUtilization
1XStep	Historic WGR	2457.8	(Non Rework Moves) / (OperationCount / ProductCount).