FabTime Cycle Time Management Newsletter

Volume 10, No. 6 August 2009

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 this month include new Batch Lot List and Batch % Full charts, for tracking batch tool performance.

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Welcome

Welcome to Volume 10, Number 6 of the FabTime Cycle Time Management Newsletter! We've taken a bit of a break from the newsletter this summer (it's been 2 months since the last issue), and we're glad to be back. We have two announcements this issue, one about a book focused on improving factory performance, and the other about registration for the upcoming ISMI Manufacturing Week in Austin, TX. Our software user tip of the month is about using the new "export all data" capability in FabTime. We also have one subscriber discussion topic, about bringing a fab back up to full speed after a slowdown. We hope that this question will be relevant for many of you in the coming months.

In our main article, we discuss forecasting of lot completion dates. We believe that projecting shipment dates for individual lots is likely to become increasingly necessary for fabs. In this article, we offer a general method for predicting lot shipment dates using the sum of planned cycle times by step. We review several implementation details, particularly in regards to computing the step-level cycle times, and varying x-factors to account for changes in lot priority. We also briefly touch upon estimating earliness or lateness for in-progress lots, by comparing actual cycle time to expected cycle time to this point. We welcome your feedback.

Thanks for reading!—Jennifer

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Community News/Announcements

Book Announcement

James Ignizio is pleased to announce the publication of his book titled: *Optimizing Factory Performance: Cost-Effective ways to achieve significant and sustainable improvement* (McGraw-Hill Publishing, 2009). The book was released in July. A free preview may be found at: factoryanalyst.com/BookPreview.html.

Here's a brief summary from the author: "While the introduction of such methods as Lean Manufacturing, Six Sigma, and the Theory of Constraints have – when applied by the right people, with the right training, to the right problem, in the right manner – contributed to the improvement of factory performance, they have their limitations. This is particularly true when dealing with a reentrant production line, such as encountered in semiconductor fabs and solar cell production. *Optimizing Factory Performance* addresses both traditional and reentrant systems and provides a means to overcome the three primary obstacles to performance improvement; i.e., unnecessary complexity, excessive variability, and the politics and culture of the organization."

Registration Open for ISMI Manufacturing Week

The ISMI's Manufacturing Week, consisting of the Symposium on Manufacturing Effectiveness and a series of short courses and workshops, will be held October 19-22 in Austin, TX. Here is some information from a recent ISMI announcement.

ISMI Symposium on Manufacturing Effectiveness: October 21 & 22: Two days of parallel technical sessions focused on sharing information and methodologies for increasing productivity and reducing manufacturing expenses through advances in equipment, processes, resources, fab design, and manufacturing methods.

Sessions include:

- Green Manufacturing
- Fab Productivity
- Statistical Methods
- Equipment Productivity
- ESH Solutions
- E-manufacturing
- Yield Metrology
- Concepts in Manufacturing

Short Courses and Workshops: October 19 & 20: ISMI Manufacturing Week kicks off with two full days of optional workshops and short courses centered around some of the industry's hottest topics, including:

- Productivity software solutions
- Data visualization
- Fab risk management
- Alternate parts and services
- Second source parts
- Predictive and preventive maintenance
- Factory simulation
- 450 mm equipment test methodology
- Equipment energy reduction
- Emerging ESH regulations on manufacturing
- Metrology
- "Wait time waste" metrics

For complete details of the week's events, see ismi.sematech.org/ismisymposium

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

Export all Chart Data to Excel (Even Hidden Rows and Columns)

FabTime has long had the capability to export the visible rows and columns of any data table to Excel (using the Excel button and Excel link located above the data table). FabTime does not, by default, display all data table rows in your browser, because many charts might have accompanying data tables with thousands of rows. To speed performance, we default to show the first 25 rows (though you can always change the data table to display additional rows, using the "Rows:" control). Similarly, FabTime has the capability to hide individual columns of the data table, so that you only view the columns that you are most interested in. The current Excel button opens an instance of Excel (separate from the browser), with a file containing any data currently displayed in the data table; the current Excel link opens Excel inside the browser. You have always been able to export all of the data by increasing the number of rows displayed, and "unhiding" any columns. However, we're heard from customers a wish to export all of the data without going through this extra step.

What we've done in the most recent FabTime patch (#97, currently being installed at customer sites) is add "export all data capability". Clicking the Excel button or the "Excel (as shown)" link continues to give you the data table as displayed in the browser. Clicking "Excel (all data)" exports all available rows and columns (including hidden columns and columns used only to build the chart). In both cases, you have the option of saving the file to your computer, and then opening Excel, or opening Excel from directly within your browser. The links work with both Firefox and Internet Explorer (while the button only works with IE, because it uses an ActiveX control). We hope that you find this added Excel export capability useful.

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

Ramping Back Up After a Slowdown

Lou Cerra from Freescale sent us an interesting question recently. He wrote: "Is there any information on the maximum ramp rate of a mature fab after it has been running at a much lower utilization rate? I have some rules of thumb and empirical data based on hiring labor, un-idling and re-qualifying equipment, engaging suppliers, etc. The analogy I use is, you may have been a marathon runner capable of 6 minute miles six months ago, but if you have only been running a few miles per week since then, you are not in shape to immediately run a marathon. You must build back up to that capability."

FabTime Response: We agree 100% with Lou's intuition about this, and like his analogy, but we haven't seen anything published on this. Surprising, really, given the number of slow-downs and ramp-ups that we've weathered as an industry. But it's not something that we've run across. We are including the question in the newsletter, in case any other subscribers would like to share results or suggestions. Thanks!

FabTime welcomes the opportunity to publish subscriber discussion questions and responses. Send your questions or comments to newsletter@FabTime.com.

Forecasting Lot Completion Dates

Introduction

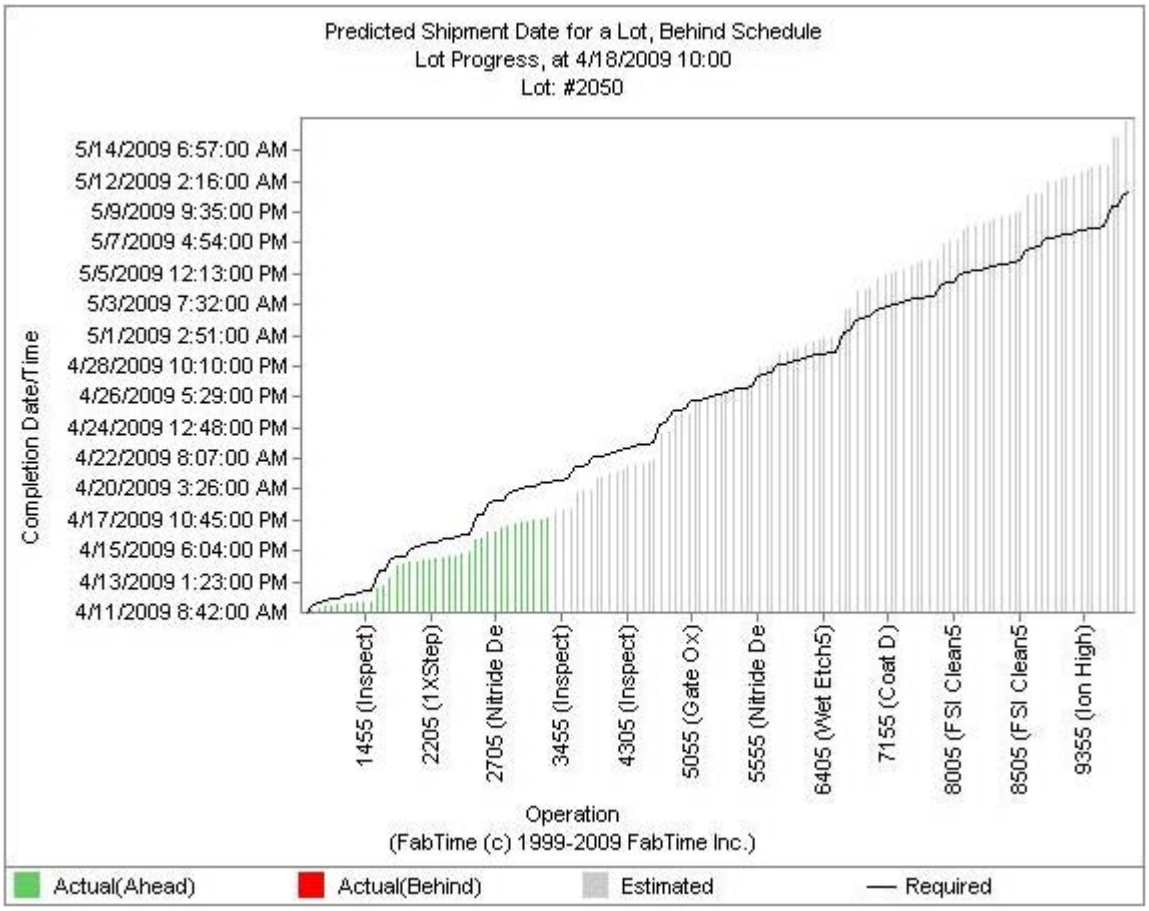
For people who run wafer fabs, a common piece of necessary information is projected lot completion dates. The production planning group wants to know when particular lots will be shipped, and what their due date performance will be. The production manager wants to know which lots are behind schedule, and what changes might be necessary to improve overall due date performance by the fab. In an increasingly customer-empowered era, it's not unheard of for fabs to have customers logging in directly in some fashion to check on the progress of their lots. These requests require fabs to be able to compare a lot's current cycle time performance with the plan, and predict lot completion dates.

This discussion is most relevant for fabs where individual customers (internal or external) own individual lots. For large-scale production where individual lots of a device are interchangeable, the projected completion date of a particular lot is less important than the knowledge that X wafers of device Y will be completed by a particular date, to satisfy demand for this device. Even in these situations, however, there will always be engineering lots, first-run qualification lots, and so on, where the projected lot completion date is of interest.

Forecasting a Lot's Shipment Date

There are two general ways of predicting a lot's future performance in a fab. One method involves the use of discrete event simulation. A simulation model can incorporate tool downtimes, operator constraints, current WIP levels, etc. Simulation models require very detailed data to be accurate, however, particularly in regards to tool downtimes. The second, much simpler, method involves using static projections based on planned cycle time data for each step. In this article, we will focus on the static projection method.

Predicting an expected shipment date for a lot, using planned cycle time data, is fairly straightforward. However, there are some subtleties to consider. In the simplest sense, static lot shipment projection is a matter of storing a planned cycle time number for each route-step combination, for all routes in the fab. At any point in time, we can add up those planned cycle times for all future steps for a given lot, add that total time to the current time, and get an estimate of when we think that this lot will complete. An example is shown above. To do this, however, we need to



have access to the planned cycle time data for each step. We also need a mechanism for adjusting the planned cycle times to reflect changes in lot priority. And we need a method for dealing with holds and fab shutdowns. Each of these is discussed below.

Planned Cycle Times by Step:

There are several ways that fabs estimate step-level planned cycle times. The most common way that we've seen is to take planned theoretical process time data for each step and then multiply by a general x-factor. This x-factor represents the expected average multiple of theoretical cycle time that will be observed in practice. A common target step-level x-factor in fabs is 3.0, representing two hours of other time (queue time, travel time, etc.) for each hour of process time. So, if we know that the target process time for a particular step is 1.5 hours, and the target x-factor is 3, we'll use 4.5 hours for the planned cycle time value for the step. These general x-factors are, ideally, selected to match target due dates for the fab.

Sometimes, however, detailed theoretical process time data may not be available. Or a fab many wish to use different x-factors for different steps. We've worked with fabs that use historical data to estimate an average cycle time per step. This typically requires some statistical analysis of the historical data, to remove outliers. [For example, where moves are tracked manually, it's not unheard of to see a move-in and move-out logged within a very short time interval (a few seconds). This is more a reflection of logging issues than actual cycle times, and must be removed from the data.] Obviously, the more data that is available (e.g. for more mature products), the more accurate the historical data will be.

What we do in FabTime is store the theoretical cycle time for each step, but

also store a planned step-level cycle time value. The planned values can, of course, be calculated by using a general multiple of theoretical. However, other values can, if available, be imported from the MES, or estimated using historical data. This allows a fab to use a different x-factor for bottleneck tools, or single path tools, than for other steps, and is, in general, flexible.

Variation in Lot Priorities

The planned step-level cycle times are subject to variation as a lot's priority changes over time. We handle that in FabTime by using a hierarchical approach. Each lot can have a lot-specific x-factor (though this isn't required). And each chart that is used to project lot shipment dates can also have a user specified target x-factor (for what-if analysis). We then use this algorithm:

- If the chart-level x-factor input is specified, forecast cycle times are computed using the planned theoretical times for each step, multiplied by this x-factor.
- If the chart-level x-factor input is not specified, and a lot has a non-zero planned lot-level x-factor, forecast cycle times for this lot are computed using planned theoretical times for each step, multiplied by the lot's planned x-factor.
- If the chart-level x-actor input is not specified, and a lot has a zero planned x-factor (i.e., not specified), forecast cycle times for this lot are simply the sum of the planned cycle times for each step across the flow.
- For each lot, FabTime sums the forecast cycle times in the flow for all steps (inclusive) between the lot's current step and the targeted shipment step. This sum is the remaining cycle time for the lot. Adding remaining cycle time to the as-of time gives the forecast out time for the lot.

Holds

If a lot is on hold at the time that its shipment date is being projected, what we do is use a site-defined assumption for remaining hold time. This is added to the estimated shipment date for the lot. Of course if any future hold steps are stored as part of the process flow, they will be included directly.

Shutdowns

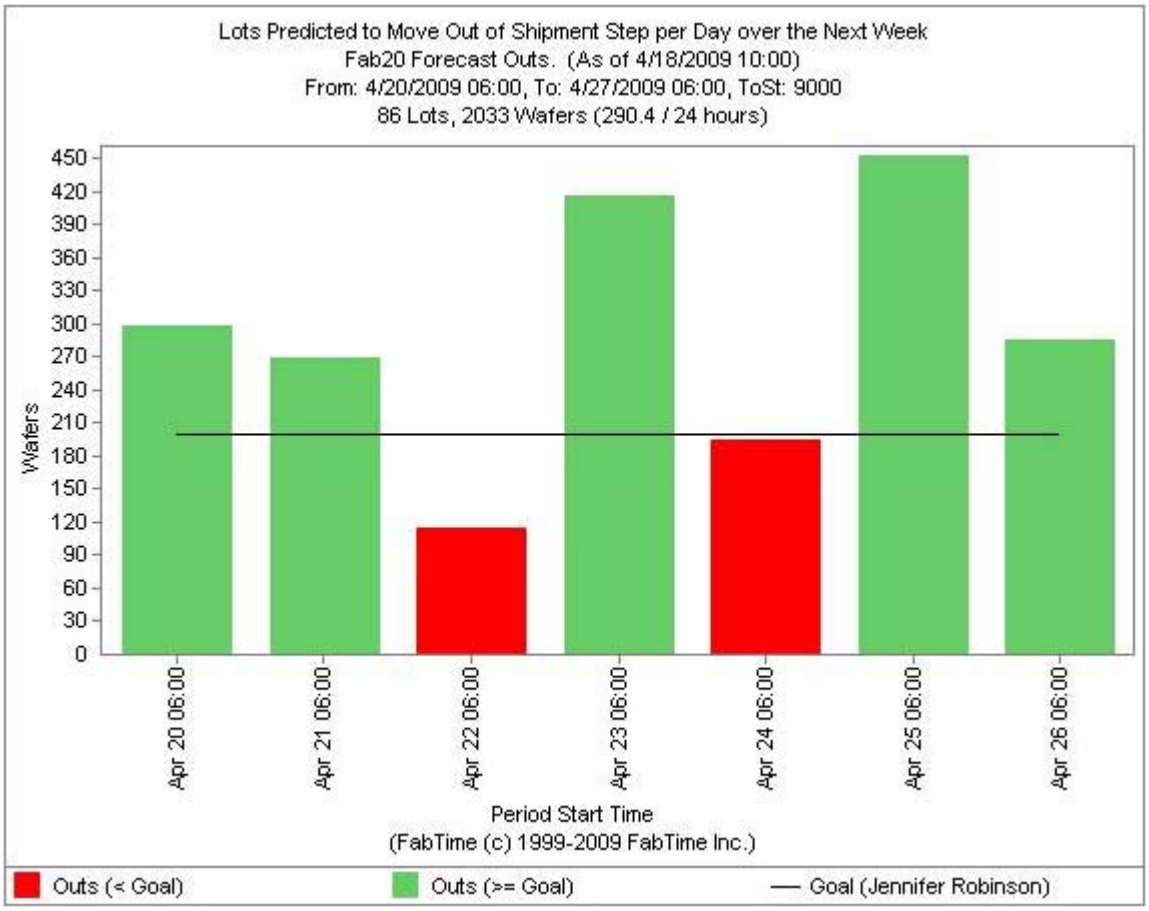
It's also necessary to include any scheduled fab shutdowns in the estimated completion time for a lot. What we do is check to see if the remaining cycle time for the lot overlaps any factory non-scheduled (i.e. shutdowns). If there is any overlap, we shift the estimated ship date forward by the amount of the overlap. Then we repeat this process to see if the new estimated ship date overlaps any additional factory non-scheduled time. We exit the loop when no additional factory non-scheduled overlap is found.

Projected Shipment Dates

Once all of the above factors are taken into account, the result is a projected shipment date for each lot. We can then aggregate across lots, to get a predicted total number of shipments within some future time interval. And, in fact, this basic methodology can be used, in addition to looking at shipments from the fab, to predict the number of lots that will move out of any operation within some future time interval, as in the sample chart at the top of the next page. In that case, we simply add up only the steps between each lot's current step and the target step. The details remain otherwise the same.

One More Comment on Static vs. Simulation-Based Projection Methods

As people who work in fabs know, nothing is simple when dealing with fab data. Fabs are highly variable environments, and dynamic predictions are subject to forecasting difficulties. For example, even if we know that a particular tool is down, we still don't know when the tool is going to be back up. If we're to run a simulation, we need to make some assumption about the expected length of the downtime. There's no particular reason to expect this assumption to be perfect, in any given



specific case. FabTime's feeling is that using planned cycle time data for forecasting provides a reasonable degree of accuracy (depending on the quality of the data), without the necessity of building and maintaining full-scale simulation models. We have heard of fabs that use short-term simulation for lot projection, but we have not, thus far, chosen to go in that direction. We would, however, love to hear from any of you who have.

Evaluating a Lot's Current Performance to Plan

The above method of predicting a lot's shipment date can, by comparing to the lot's due date, be used to estimated the expected overall earliness or lateness of the lot. However, after some in-depth discussion on this subject with one of our customers, we've come to the conclusion that there's a simpler way to think about whether an in-process lot is, right now, early or late. All we need to do is compare the lot's actual cycle time so far to what we expected the lot's cycle time to be so far. For the latter, this is a matter of taking the planned cycle time data by step (as described above), and adding it up across all of the steps that the lot has completed. If we do this and find, for example, that an in-progress lot's current cycle time is 3 days longer than what we planned for by this step, then we can say that this lot is currently 3 days late.

If we meet our planned cycle times for all of the future steps, then the lot will end up being exactly 3 days late. [Well, it will end up being 3 days late if the due date reflects the sum of our planned cycle times, which is certainly the most consistent thing when planning.] But the real point is that if we already know that the lot is 3 days late, we have a choice about whether to a) change the lot's priority (to speed it up); b) change the lot's due date; c) swap the lot in some way with another lot that's further along;

or d) do nothing and hope for the best. Our response to this question will, of course, depend on how far along the lot is in its process flow, and how important it is. In practice, many fabs use dispatch rules that in some fashion take into account each lot's earliness or lateness (e.g. the critical ratio rule), so that on-the-fly changes in lot priority are only necessary in extreme cases (the dispatch rule implicitly raises the lot's priority, without any overt change being required). We'll be discussing dispatch rules more in future issues.

Conclusions

Forecasting shipment dates for individual lots is likely to become increasingly necessary for wafer fabs. Customers will continue to expect more data visibility, and will require ever-improved on-time delivery performance. In this article, we're discussed a general method for predicting lot shipment dates using planned cycle times by step. We've covered specific details about the methodology, particularly in regards to computing the step-level cycle times, and varying x-factors by step and by lot. We've also briefly touched upon estimating earliness or lateness for in-progress lots, by comparing actual cycle time to expected cycle time to this point. Thus far, we have found the described methods to offer a reasonable compromise between accuracy and ease of computation / data availability. We welcome your feedback.

Closing Questions for Newsletter Subscribers

How do you estimate completion dates for individual lots? Do you use static or dynamic methods? If using planned cycle times by step, do you use a global x-factor, different x-factors for different lots, or different x-factors for different tools? When you consider whether or not an in-process lot is on time, do you look at projected due dates? Or do you just compare the lot's cycle time to date with the plan to date? We welcome your feedback on any of these due date/projection/cycle time performance questions. If there is sufficient feedback, we'll do a follow-up issue to discuss these topics in further detail.

Further Reading

Here are a few articles on shipment forecasting and due-date performance that you might find worth a look.

- P. C. Chang and J. C. Hsieh, "A Neural Networks Approach for Due-Date Assignment in a Wafer Fabrication Factory," *International Journal of Industrial Engineering - Theory, Applications and Practice*, Vol. 10, No. 1, 55-61, 2003.

- C. C. Chiu, P. C. Chang, and N. H. Chiu, "A Case-Based Expert Support System For Due-Date Assignment In A Wafer Fabrication Factory," *Journal of Intelligent Manufacturing*, Vol. 14, No. 3-4, 287-296, 2003.

- M. Hillis and J. Robinson, "Extremely Hot Lots: Super-Expediting in a 0.18 Micron Wafer Fab," *Proceedings of the International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM 2002)*, Editors G. T. Mackulak, J. W. Fowler, and A. Schoemig, Tempe, AZ, April 10-12, 2002. 106-111. (This paper is available for free download from www.fabtime.com/abs_MASM02.shtml.)

- C. Ling-Ho and S. Muralitharan, "Method to Enable Visibility and Forecast in Fab Cycletime Performance," *Proceedings of the 2002 International Symposium on Semiconductor Manufacturing (ISSM2002)*, Tokyo, Japan, 2002.

- S. J. Mason and J. W. Fowler, "Maximizing Delivery Performance in Semiconductor Wafer Fabrication Facilities," *Proceedings of the 2000 Winter Simulation Conference*, 2000. (All Winter Simulation Conference papers since 1997 are available for free download from www.informs-cs.org/wscpapers.html, including the ones below).

■ O. Rose, "Some Issues of the Critical Dispatch Rule in Semiconductor Manufacturing," *Proceedings of the 2002 Winter Simulation Conference*, 2002.

■ Oliver Rose (University of Würzburg), "Accelerating Products under Due-Date Oriented Dispatching Rules in Semiconductor Manufacturing," *Proceedings of the 2003 Winter Simulation Conference*, S. Chick, P. J. Sánchez, D. Ferrin, and D. J. Morrice, eds., 2003.

■ C. Y. Yu and H. P. Huang, "On-Line Learning Delivery Decision Support System for Highly Product Mixed Semiconductor Foundry," *IEEE Transactions on Semiconductor Manufacturing*, Vol. 15, No. 2, 274-278, 2002.

Subscriber List

Total number of subscribers: 2780, from 470 companies and universities.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (201)
- Intel Corporation (149)
- Chartered Semiconductor Mfg (87)
- Micron Technology, Inc. (82)
- Western Digital Corporation (76)
- X-FAB Inc. (72)
- Texas Instruments (64)
- ON Semiconductor (59)
- Freescale Semiconductor (57)
- Analog Devices (56)
- TECH Semiconductor Singapore (56)
- International Rectifier (56)
- NEC Electronics (53)
- IBM (49)
- STMicroelectronics (46)
- Infineon Technologies (44)
- NXP Semiconductors (38)
- Cypress Semiconductor (38)
- Seagate Technology (37)
- ATMEL (34)

Top 3 subscribing universities:

- Virginia Tech (11)
- Ben Gurion Univ. of the Negev (8)
- Nanyang Technological University (8)

New companies and universities:

- Bulheller Consulting
- Carl Zeiss Vision
- Korea Information Society
- Development Institute
- Norwich Pharmaceuticals
- SystatS Consulting
- VS Technology

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 dispatching and planning modules together for a single, fixed monthly fee (on top of your regular FabTime subscription). This includes:

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- Automation of the process of importing the additional data into FabTime.
- Validation against client data.

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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).