FabTime Cycle Time Management Newsletter

Volume 10, No. 2 February/March 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 the software this month include the ability for sites to import longer MES comments, and the ability for system administrators to create custom charts.

Editor: Jennifer Robinson

Contributors: David Jimenez (WWK); Matt Grimshaw (Mazik Media/Fab Engineering & Operations Magazine); Beth Chance (Cal Poly – San Luis Obispo)

Table of Contents

Welcome

Welcome to Volume 10, Number 2 of the FabTime Cycle Time Management Newsletter! March marks the 10 year anniversary of the founding of FabTime, and we remain happy to be here. In this issue, we have two community announcements (one about an industry survey and another about an industry-specific networking site). Our FabTime software tip of the month is about identifying current top cycle time contributors in a fab. We have no subscriber-submitted discussion, but we have introduced a new topic (dispatch compliance reporting).

In our main article this month, we discuss potential charts to explore data correlation in wafer fabs. We begin with a general discussion on correlation vs. causation, and then propose several potential data pairing that we think would be useful in increasing our understanding of fab behavior. These range from the obvious example of looking at tool group cycle time vs. utilization to less obvious examples, such as overall fab cycle time vs. number of current single path operations. We hope that this article will stimulate discussion among our subscribers on data relationship in the fab. We welcome your feedback.

Thanks for reading!—Jennifer

FabTime

Tel: (408) 549-9932
Fax: (408) 549-9941
www.FabTime.com
Sales@FabTime.com

Community News/Announcements

WWK's 3rd Annual Semiconductor Manufacturing Technology Survey

David Jimenez from WWK sent us a slightly longer version of this announcement:

Wright Williams & Kelly, Inc. (WWK), a cost & productivity management software and consulting services company, announced today the start of its 2009 survey on equipment and process timing in the semiconductor industry. The survey results will be consolidated and provided to all participants free of charge. Participation in the survey is the only way to receive a full set of results. The survey form can be downloaded from the WWK web site at: http://www.wwk.com-/2009survey.pdf.

Last year's survey showed that respondents expect to see the following manufacturing technologies in production by 2010:

- Double patterning
- Equipment suppliers using remote diagnostic capability
- Manufacturing capacity, utilization and cycle time simulation
- Implementation of 300mm prime advances

By 2012, respondents expect to see:

- 193 high index immersion lithography
- Imprint lithography
- Wafer-level reliability testing
- 300mm whole wafer testing

Daren Dance, WWK's Vice President of Technology, commented, "We were not surprised in 2007 that the most frequent response to the question about 450mm wafer timing was 2013 or beyond but we were surprised that in 2008 56% of respondents indicated that 450mm wafers would never happen in production manufacturing. This year's survey will look to see if those opinions, and others, have changed."

New Industry-Specific Social Networking Site

Matt Grimshaw (Mazik Media) told us about a brand new social networking site, developed by Future Fab International, aimed at people from the semiconductor industry: Future Fab Connect, http://www.futurefabconnect.com/. There are currently more than 250 members, including FabTime's Jennifer Robinson. As with other social networking sites, you can "friend" people, upload photos and videos, form groups, send notes to people, and add and view events. For example, two events currently listed are the SEMATECH Surface Preparation and Cleaning Conference, March 23-25, 2009 in Austin and the IMEC Technology Forum 2009, June 2-4, 2009 in Brussels.

We think that if more people join, it has the potential to be a nice "water cooler" for industry professional (something especially important in this economy). If we accumulate enough members there who are newsletter subscribers, perhaps we can set up a FabTime newsletter group within the site. Would any of you be interested in something like that?

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

FabTime User Tip of the Month

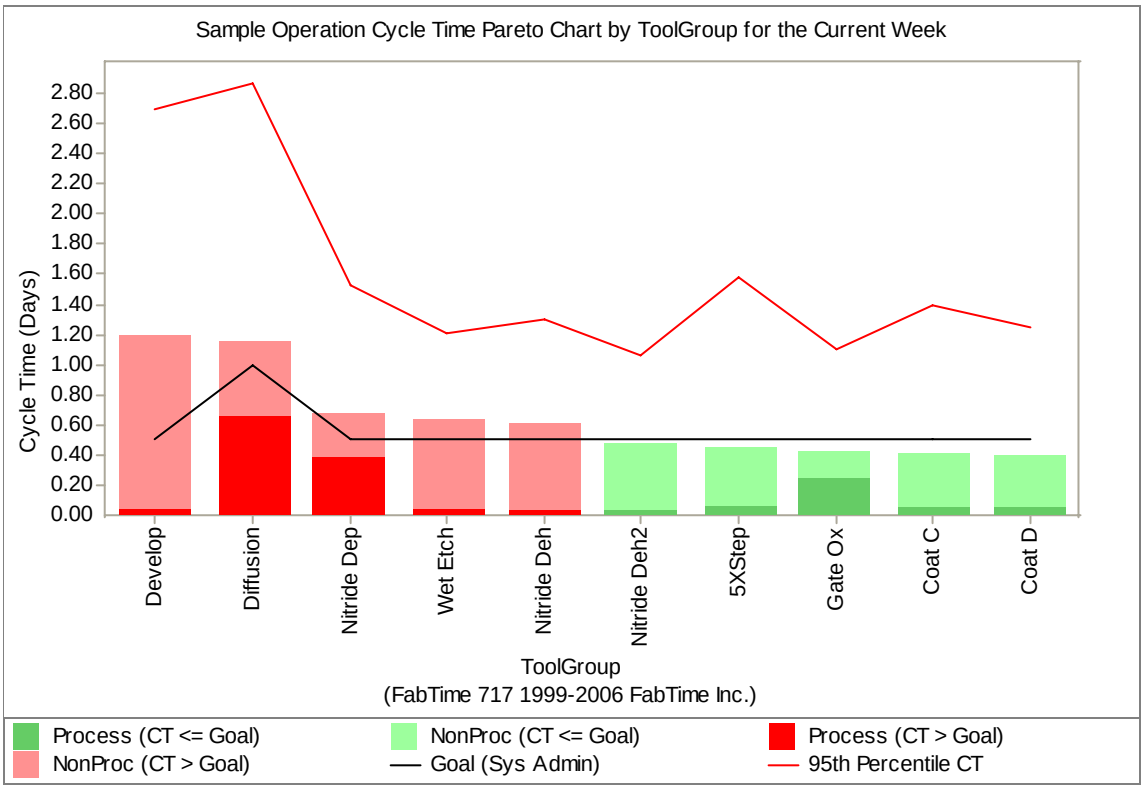
Identify Current Top Cycle Time Contributors

A useful thing to know when striving for cycle time improvement is: where have lots been spending the most time recently? There are two types of charts in FabTime that can help you to look at this. The first is the Operation Cycle Time Pareto Chart (available in the Operation Cycle Time Charts section). To identify the toolgroups that have been contributing the most to cycle time in your fab over the past week:

- Generate the Operation Cycle Time Pareto Chart.
- Slice by ToolGroup.
- Change the date range to cover the past week (or other time period of interest).
- Filter as needed for manufacturing and engineering lots, a major process flow, etc.

The chart will, by default, show you the top 10 toolgroups, in terms of actual average cycle time per visit. That is, each bar shows, for all of the lots that moved out of that toolgroup during the past week, the average cycle time spent during that visit. The solid color shows process time, while the lighter color shows queue time (both displayed as red or green, depending on whether or not the average behavior met the goal for that toolgroup). An example is shown below.

If the bars to do not appear in descending order of cycle time, change the sort control for the chart to show ActualAvgCycleTime first, with the box checked for descending order. If you need to see more than 10 toolgroups, change the Points entry in the formatting section (in the lower left-hand corner of the page). Use the data table for the chart to check the number of lots included in the average for each bar (to avoid outliers). Toolgroups that show a high cycle time per visit, particularly a high



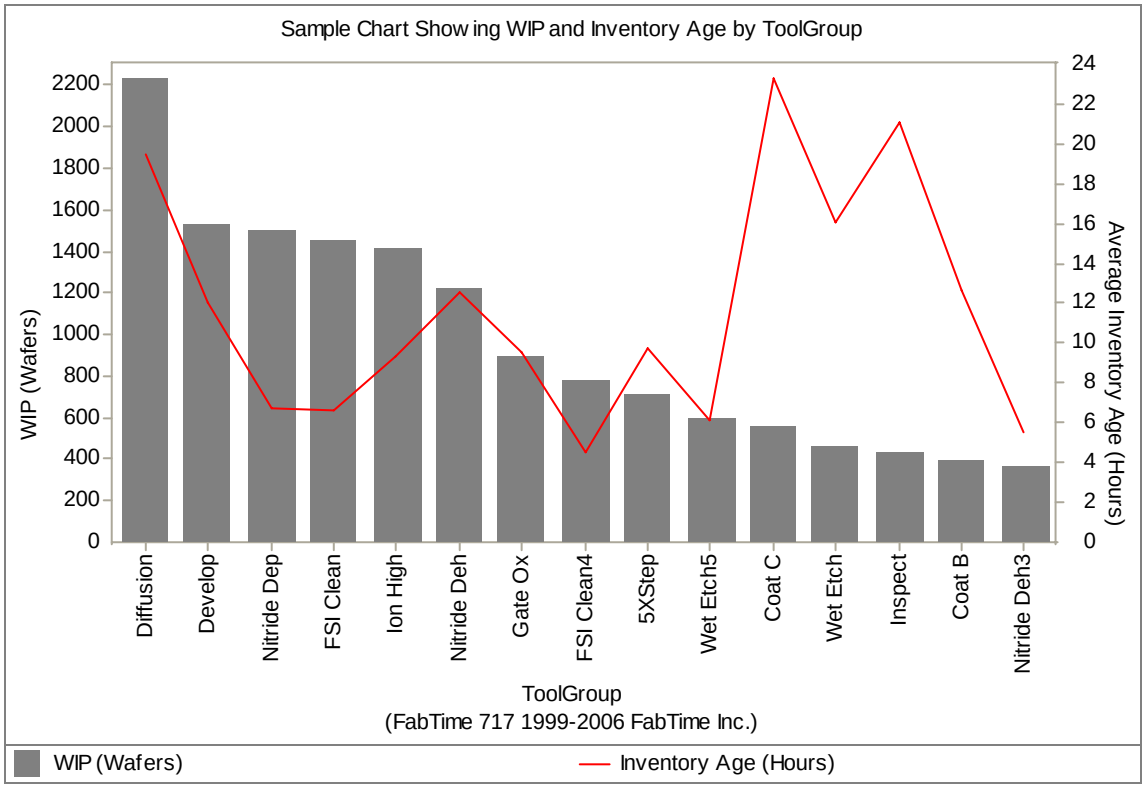
queue time per visit, and have a relatively large number of lots moved out are good candidates for short-term cycle time improvement projects.

Another chart that shows you where lots are spending their time is the WIP Pareto chart, sliced by ToolGroup (and again filtered for the lots of interest). What you're looking for here are toolgroups that have a high value for average (or total) inventory age (the red line). Inventory age in FabTime is simply how long each lot has been at the current operation. For example, in the chart below, lots at the Coat C ToolGroup have been there, on average for nearly 24 hours. Although the total amount of WIP at Coat C isn't as high as at some other tools, it's probably worth investigating why the inventory age is so high.

For such toolgroups, you can drill down (using the "list" links on the data table) to the WIP Lot List chart for the toolgroup. This shows, for all of the lots currently at that toolgroup (either in queue or in process), how long each lot has been there. In general, you're looking for toolgroups that have a relatively large number of lots that have been there for a long time.

The difference between these charts is that the Operation Cycle Time Charts show you the cycle time after lots move out of a toolgroup, while the WIP charts show you lots that are still at their current operation. Thus the WIP charts can highlight problems a bit sooner. However, the Operation Cycle Time Trend chart can be easier to understand, with the inclusion of queue time and cycle time, already averaged across all of the lots. Both of these charts, in any case, can help you to highlight current, short-term cycle time problems.

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

Dispatch Compliance Measurement

We have no subscriber-contributed discussion this month, so we've decided to include a question of our own. Something we're asked fairly often is "what are good performance measures for dispatch compliance?" What we do in FabTime right now is report, for each tool, the average location on the dispatch list of all of the lots that were processed. For example, a result of 3 for a tool means that, on average (over the time period displayed on the chart), the operators ran the third lot from the dispatch list (instead of the top lot from the dispatch list). This data can be aggregated across toolgroups and areas, and can also be displayed for individual employees.

We believe that, at least for nonautomated fabs, using compliance reporting is more realistic than forcing the operator to only be able to process the first lot. Unless a fab has a detailed tracking system, not all of the lots that show up on the dispatch list are always available at the tool. Lots might be in transit somewhere, sitting on a cart waiting to be moved. It's usually better to keep a tool running, even if it means running the second or third lot from the list, than to hold the tool idle for a lot that isn't there yet. A low dispatch compliance score can thus be an indicator of problems with lot delivery.

What do you all think? Do you report dispatch list compliance? Do you use something like the average dispatch order described above, or do you have some other method for tracking this? We welcome your feedback (which we'll include in the next issue, either in attributed or anonymous fashion, as you prefer).

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

Correlation in Wafer Fab Data

Introduction

In this newsletter and in our cycle time course we often discuss factors that we know affect cycle time (utilization, variability, number of qualified tools, etc.). We have studied the factory dynamics that drive these relationships, and we have come up with queueing and simulation models that demonstrate this behavior. What we'd like to do now is make it easier for people to observe and verify these relationships using actual fab data. Thus we're looking at adding a series of X-Y plots to FabTime that our customers will be able to use to explore correlations between fab variables. We think that this type of data could be useful to anyone (whether you look at it in FabTime or in some other reporting system), both in increasing understanding about fab performance and in highlighting opportunities for improvement. Therefore,

in this article, we will discuss correlation between variables in general, and then propose a series of correlation charts that we think would be useful for fabs. We would love to have your input on what you think would be the most informative charts to use in this manner.

Correlation vs. Causation

The Merriam-Webster Dictionary defines correlation as: "a relation existing between phenomena or things or between mathematical or statistical variables which tend to vary, be associated, or occur together in a way not expected on the basis of chance alone." That is, correlated variables can be observed to move together, when we look at an X-Y plot of data. Statistical textbooks are quick to warn us that correlation in data does not imply causation. (See, for example, this explanation by the George Mason University STATS department: http://stats.org/in_depth/faq/causation_correlation.htm, or this discussion, with references, on Wikipedia: http://en.wikipedia.org/wiki/Correlation_does_not_imply_causation.)

Sometimes data is spuriously correlated. That is, you can create a graph in which the X and Y variables do move together, but an actual cause and effect relationship is unlikely. For example, there was a newswire story in late January (http://tinyurl.com/b3zsgg) that reported: "A review of the annual returns of the S&P 500 indicate that, on average, the market performs significantly better in years of a Steelers' Super Bowl victory." According to Nancy L. Skeans, CPA, CFP(R), "In the years of the previous five Steelers Super Bowl victories, the S&P 500 had an average return of + 25.5%. This is compared to an average return rate of approximately 9% in the years that a team other than the Steelers won the Super Bowl." We're pretty sure that this year's Superbowl win by the Steelers is not, alas, going to help the market to recover.

Other times, someone might think that a correlation is working one way, when it's really working the other way. An example here, from the book Freakonomics, is the folktale of a czar "who learned that the most disease-ridden province in his empire was also the province with the most doctors. His solution? He promptly ordered all the doctors shot dead".

Still other times, two pieces of data are not causally dependent on one another, but are each correlated with a third variable. For example, sales of snow shovels might well be correlated with car accident rates, but the snow shovels are unlikely to be the cause of very many of the car accidents. Instead, both statistics could be related to snowfall amounts. We found a whole set of links to article titles that North Central College psychology professor Jonathan Mueller says "suggest causal relationships when, upon closer reading of the article itself, one finds that the research was correlational in nature, and the headline is not justified." (http://tinyurl.com/zjgfy)

And yet, even when we can't say for sure that two pieces of data are causally related, correlation can give us a clue that some sort of interesting dynamic is occurring. Both of FabTime's founders took a class from Edward R. Tufte (who the New York Times called "The Leonardo da Vinci of data") on the visual display of quantitative information. Tufte observed that "Correlation is not causation but it sure is a hint." In the previous example, if we did have data about an uptick in snow shovel sales and a correlated uptick in car accidents, we could probably hypothesize that something must be going on with the weather, and we'd know where to look for further information. In a fab, we have lots of data, about cycle times and utilization rates and variability and other factors. Observed correlations in this data could give us hints about operational practices that aren't working, or areas to focus on for improvements.

Potentially Correlated Data in Wafer Fabs

Here's a list of a few pieces of fab data that we suspect, either from fab behavior theory or from our own observations, may be correlated. In each case, the presumed output variable (the Y-variable on the chart) is shown first.

- Cycle time and fab utilization
- Delivery performance and fab utilization
- Toolgroup-level cycle time and arrival variability
- Toolgroup-level cycle time and downtime variability
- Line yield and cycle time
- Cycle time and rework
- Cycle time and percentage of hot lots (or number of hand-carry lots)
- Cycle time and number of single path operations
- Cycle time and number of holds

In looking at this list, we see that there are several potential Y-variables:

- Cycle time (by toolgroup or for the fab as a whole)
- Delivery performance for the fab
- Line yield for the fab

Potential X-variables (inputs) vary according to whether we're considering the fab as a whole, or considering an individual toolgroup.

Fab-Level X-Variables:

- Fab utilization (measured as utilization of the bottleneck, or just percent of maximum throughput for the fab, under the currently active toolset)
- Percent of hot lots
- Number of hand-carry lots
- Number of holds (that is, the number of instances in which any lot was placed on hold)
- Number of single path operations (that is, at a given point in time, the number of operations in the fab, with WIP, that have only one qualified tool)
- Cycle time (note that cycle time could be a causal variable when looking at line yield, but could also be an output variable when looking at utilization or variability)

Toolgroup-Level X-Variables:

- Tool utilization
- Arrival variability to the tool group
- Downtime variability at the tool group
- Process time variability

Some questions: What are we missing? Which of these do you think would show the strongest correlations? Which do you think would be the most useful, in either verifying a causal relationship, or in identifying opportunities for improvement?

In some of the above cases, even if we agree that the relationship is worth studying, further decisions will need to be made on how to best capture and plot the data. For example, what is a valid point estimate for line yield (something that we can plot over time)? Should we use some sort of rolling line yield number, as discussed in Issue 9.06, or should we instead look at number of wafers scrapped per time period? What does percentage of hot lots actually mean in a fab with multiple tiers of lot priorities? How should we measure downtime variability? Is it enough to look at coefficient of variation of the downtime (and maintenance) events, or are there better downtime variability metrics?

Even looking at tool utilization vs. cycle time isn't necessarily straightforward. The standard definition of utilization, productive time / (productive time + standby time) could include standby time caused by operator delays. The utilization that truly drives cycle time is productive time / (productive time + standby no WIP time) (as discussed in Issue 5.05). Time that the tool is in a standby state (up, but not running) but has WIP waiting is really a capacity loss, one that should be accounted for in looking for correlations. For that matter, looking at the correlation

between cycle time and standby WIP waiting time could tell us about a third variable, the presence (or absence) of sufficient operators.

Conclusions

Fabs are complex environments. One tool for understanding them better is data, and that includes data on correlations between variables. Correlation tells us when two pieces of data move together (whether in the same direction or in oppose directions). Although correlation doesn't necessarily imply causation (that one of the pieces of data is driving the other), correlation often does give us a strong hint as to what's going on. This is especially true when all of the data in question comes from the same fab. We can use X-Y plots to verify our intuitions about certain relationships (like the relationship between cycle time and utilization), or to give us indicators of where a third variable might be influencing behavior. In this article, we've discussed correlation vs. causation, and proposed a number of potentially useful X-Y plots based on fab data. Some of these charts will require further decisions, such as clarifying the definitions for the variables. We often find that the mere process of thinking about the best way to quantify something is also helpful in increasing understanding.

Questions for FabTime Newsletter Subscribers

What do you think would be useful X-Y plots to use to look at potential correlations in fab data? Do you look at this type of data for your fab? Which of the charts that we've outlined above do you think would be the most useful?

Acknowledgement

We thank Professor Beth Chance for helpful discussions about correlation.

Further Reading

- George E.P. Box, William G. Hunter, and J. Stuart Hunter (1978), *Statistics for Experiments: An Introduction to Design, Data Analysis, and Model Building*. Wiley Interscience. ISBN 0-471-09315-7.
- S. P. Cunningham and J. G. Shanthikumar (1996), "Empirical Results on the Relationship Between Die Yield and Cycle Time in Semiconductor Wafer Fabrication," *IEEE Transactions on Semiconductor Manufacturing*, Vol. 9, No. 2, 73-277.
- Wei Jie Lee (2002), "Optimize WIP Scale through Simulation Approach with WIP, Turn-Over Rate and Cycle Time Regression Analysis in Semiconductor Fabrication," *Proceedings of the 2002 Semiconductor Manufacturing Technology Conference*, 299-301.
- Steven D. Levitt and Stephen J. Dubner (2005). *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything*. William Morrow. ISBN 0-06-073132-X.
- J. Robinson and F. Chance (2004), "WIP Utilization Percentage", *FabTime Newsletter*, Volume 5, No. 5.
- J. Robinson and F. Chance (2008), "Definitions for Short-Term Line Yield Metrics", *FabTime Newsletter,* Volume 9, No. 6.
- K. Srinivasan, R. Sandell, and S. Brown (1995), "Correlation Between Yield And Waiting Time: A Quantitative Study," *Proceedings of the Seventeenth IEEE/CPMT International Electronics Manufacturing Technology Symposium: Manufacturing Technologies - Present and Future*, Austin, TX, 65-69.
- Edward R. Tufte (2006). *The Cognitive Style of PowerPoint: Pitching Out Corrupts Within*. Cheshire, Connecticut: Graphics Press. ISBN 0-9613921-5-0. http://www.edwardtufte.com/tufte/powerpoint.
- Edward R. Tufte (1997). *Visual Explanations*. Graphics Press.

Subscriber List

Total number of subscribers: 2852, from 475 companies and universities.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (223)
- Intel Corporation (152)
- Micron Technology, Inc. (83)
- Chartered Semiconductor Mfg. (82)
- X-FAB Inc. (72)
- Western Digital Corporation (68)
- Texas Instruments (65)
- Analog Devices (60)
- Infineon Technologies (60)
- Freescale Semiconductor (58)
- ON Semiconductor (56)
- TECH Semiconductor Singapore (56)
- International Rectifier (55)
- NEC Electronics (53)
- STMicroelectronics (49)
- IBM (45)
- NXP Semiconductors (45)
- Cypress Semiconductor (43)
- Seagate Technology (36)
- ATMEL (31)

Top 3 subscribing universities:

- Virginia Tech (11)
- Arizona State University (8)
- Ben Gurion Univ. of the Negev (8)

New companies and universities this month:

- Littlefuse
- NorSun
- Sensor Analytics
- STATSChipPAC
- SunPower Corporation
- Visa Inc.

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.

To subscribe to the newsletter, send email to newsletter@FabTime.com, or use the form at www.FabTime.com/newsletter.htm. To unsubscribe, send email to newsletter@FabTime.com with "Unsubscribe" in the subject. FabTime will not, under any circumstances, give your email address or other contact information to anyone outside of FabTime without your permission.

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:

- 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).