FabTime Cycle Time Management Newsletter

Volume 7, No. 8 October 2006

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 a new alert for queue time of lots of a particular priority class and the ability to include ancestor lot cycle time as part of the total cycle time for a lot.

Editor: Jennifer Robinson

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Welcome

Welcome to Volume 7, Number 8 of the FabTime Cycle Time Management Newsletter! We've been keeping very busy at FabTime with software development, training, and customer support (we're just starting work with our eleventh software site), and we hope that business is holding up well for all of you. We've also added more than 100 new subscribers since the last newsletter issue. Welcome! In this issue we have two announcements related to industry conferences. Our FabTime software user tip of the month is about how to look at shipped lot cycle times for individual lots in more detail. We have no subscriber discussion in this issue, but we do welcome your questions or comments for future newsletters.

In our main article this month we discuss several ways that operating practices in fabs contribute to arrival variability, and hence to cycle times. These include releasing lots into the fab in large batches, forcing full batches on lightly utilized batch tools, and using carts for manual transportation of lots between steps. Each of these practices directly increases fab cycle time. We recommend relatively low-cost changes that, if implemented, can help to smooth the flow of WIP through the fab, and make cycle times lower and more predictable.

Thanks for reading!—Jennifer

FabTime

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

Community News/Announcements

ISMI Manufacturing Effectiveness Symposium: October 9-11, Austin, TX

FabTime's Jennifer Robinson will be attending the upcoming Third Annual ISMI Symposium on Manufacturing Effectiveness. The conference will share information and methodologies for reducing manufacturing expenses in both existing and next-generation fabs through advances in equipment, process, resources, fab design, and manufacturing methods. Challenges will be addressed in several parallel sessions dealing with fab and equipment productivity, ESH, fab design, defect inspection, statistical methods, modeling and simulation, and e-manufacturing. The Symposium will offer papers from selected ISMI projects and leading device and equipment manufacturers. Also planned is a discussion by industry experts on the status of 300 mm Prime and 450 mm wafer transition. More details can be found at ismi.sematech.org/ismisymposium/.

If you will be attending the symposium, and would like to meet, and/or see a demo of FabTime's software, please email Jennifer.Robinson@FabTime.com.

ASMC Abstracts Due October 19th

SEMI® and IEEE are soliciting abstracts for the 18th Annual IEEE/SEMI Advanced Semiconductor Manufacturing Conference (ASMC), which will be held on 11–12 June 2007 at a new venue—Stresa, Italy, not far from Milan. The deadline for submitting abstracts is 19 October 2006. Featuring presentations and participants from leading device manufacturers, their suppliers, and academia, ASMC provides practical manufacturing solutions direct from the fab. ASMC 2007 is being co-chaired by Thomas Beeg of Qimonda and Dave Gross of Advanced Micro Devices. For the complete call for papers and guidelines, visit the ASMC homepage at www.semi.org/asmc.

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

FabTime User Tip of the Month

Look at Shipped Lot Cycle Times for Individual Lots

We had a user question recently about how to look at shipped lot cycle times for individual lots of a particular owner category (e.g. engineering lots). We thought that other FabTime users might find this useful, and are sharing the response here:

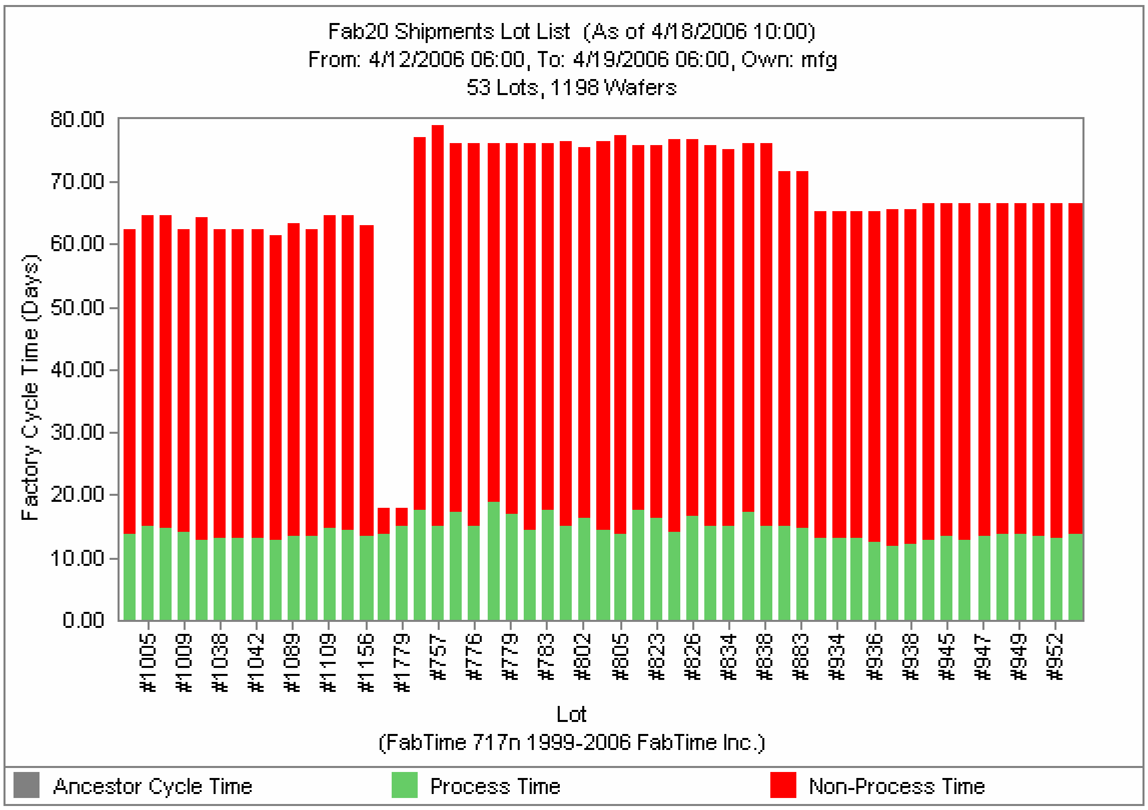
- Display the Charts page.
- Press "Show" next to Shipments charts on the Charts page.
- Press "Go" to generate the Shipments Lot List chart.
- Edit the date range to your time period of interest.

■ Enter the owner name of interest in the “Own:” filter, and any other filter values that you need.

■ Press “Go”, or hit enter, to make sure that FabTime has accepted your date and owner filter changes.

■ If necessary, look to the left of the chart, below the big set of filters, to find the sort controls. Selecting “Lot” in the first sort drop-down and pressing the go button underneath will sort the picture by lot ID. Note that you probably won’t see all of the lot ids listed on the chart axis, because there isn’t room, but there will be a column for each lot. And all of the lots will be included in the data table (depending on how many rows you have displayed).

The above will give you the individual cycle time for each lot. An example is shown below. If you have questions about this, or any other software-related issues, just use the Feedback form in the software.



Subscriber Discussion Forum

FabTime welcomes the opportunity to include subscriber-suggested topics for discussion. Send them to newsletter-@FabTime.com. There are no subscriber discussion topics in the current issue.

Perhaps one of our new subscribers will introduce some topic of interest for next month.

Ways that Fabs Create Arrival Variability and CT

Introduction

As we have discussed many times in this newsletter, one of the primary drivers of fab cycle time is variability, both in how lots arrive to tools and in how lots are processed. In this article, we discuss the ways that some fabs create arrival variability through their operating practices. These include releasing lots into the fab in large batches, forcing full batches on lightly utilized batch tools, and using carts for manual transportation of lots between steps. Each of these practices directly increases fab cycle time.

Lot Release

One place where arrival variability is controllable is where lots are released into the fab. Starting large groups of lots at one time, instead of spreading the starts out over the day or over the week, will tend to increase variability at early operations, and hence drive up cycle time. Smoother releases usually help to reduce variability, and thus to improve cycle time. This is particularly a problem for post-fab manufacturing areas, which are subject to irregular deliveries from the fab.

Simulation Example:

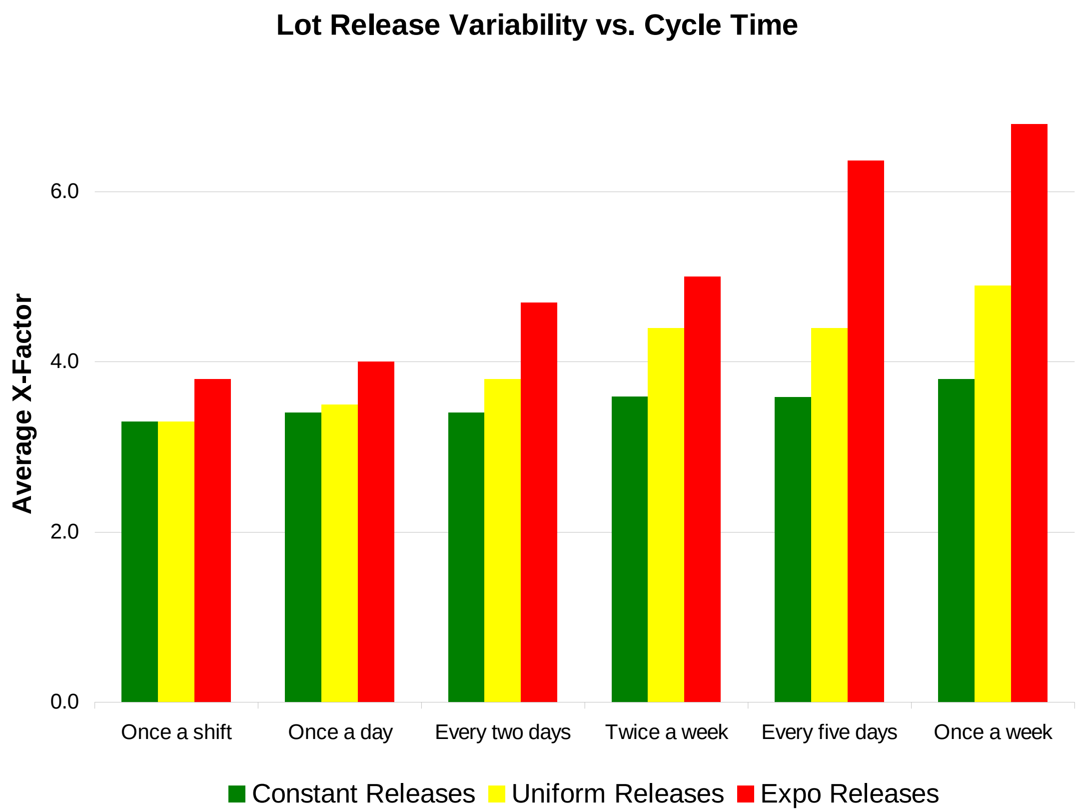
We constructed a full-fab simulation experiment in which we varied two parameters that capture lot release variability. First, for the same total number of lots started per week, we varied how frequently, on average, lots were released into the fab. We did this by varying the number of lots included in each release, and letting the simulation model calculate the exact time between releases (keeping the overall number of lots released per week constant). There were five products in the model. The lot release schedules used are shown below. The number of lots included in each release was held constant in each of the above cases. That is, for the once a week case, exactly 22 lots of each product type were released each week.

# of Lots Released	Approx. Time between Releases
1 lot per product	Every 8 hours
3 lots per product	Once per day
6 lots per product	Once every two days
11 lots per product	Twice a week
16 lots per product	Once every five days
22 lots per product	Once a week

However, we also varied the time between lot releases, looking at three different levels of variability:

- Constant time between releases (e.g. lots released exactly once a week, at the same time each week)
- Uniformly distributed time between releases (e.g. lots released on average once a week, but the exact time of the release was uniformly distributed throughout the week)
- Exponential time between releases (e.g. lots released on average once a week, but the time from each release to the next was exponentially distributed). This was the highest variability case studied.

We simulated each of the above cases (18 combinations of release frequency and inter-release time distribution). We simulated each case for two years, and cleared statistics after one year, recording the average cycle time for the second year only. This was so that any initialization effects would not be included. We did five replications (independent simulation runs with different random numbers) for each case, and recorded the weighted average cycle time x-factor across the five replications. All simulations were run using the Factory Explorer capacity analysis and simulation tool, distributed by Wright Williams and Kelly (www.wwk.com). The results are at the top of the next page in tabular and graphical format.



Release Frequency	Constant Releases	Uniform Releases	Expo Releases
Once a shift	3.3	3.3	3.8
Once a day	3.4	3.5	4.0
Every two days	3.4	3.8	4.7
Twice a week	3.6	4.4	5.0
Every five days	3.6	4.4	6.4
Once a week	3.8	4.9	6.8

What these results show is that, for the simulated factory, if the time between lot releases is held constant, cycle time increases by about 15% as we move from releasing lots every eight hours to releasing lots once a week. For the case with uniformly distributed lot releases, cycle time increases by nearly 50% as we move from eight hours between lot releases to weekly lot releases. For the exponentially distributed time between lot releases (the highest variability case examined), cycle time increases by nearly 80% from the most frequent to least frequent time between releases. Also, regardless of the average frequency of the lot releases, the more variability there is in the time between releases, the higher the cycle time x-factor.

These results, though taken from a single fab model example, support the idea that smaller, more frequent lot releases, as well as more predictable lot releases, will result in lower fab cycle time. There are, of course, exceptions:

- It may make sense to release lots in batches that correspond to the size of an early furnace operation, if the furnace is highly loaded, because lots will end up grouped in large batches after the furnace anyway.
- In some fabs, releasing lots smoothly across the 24-hour day is impossible, because Production Control staff members work only during day shift.
- Some fabs release lots in groups by route, so that they will arrive at problem tools roughly together, to minimize setups, or facilitate batching.
- Sometimes development/engineering lots have to be started as soon as possible,

regardless of the variability that this introduces.

Overall, however, we believe that smaller, more frequent lot releases, and consistent, predictable times between lot releases, will tend to result in lower cycle times. Irregular lot releases are one of the most common sources of cycle time problems cited by probe and assembly and test areas.

If your total volume of lot releases is constant, you may also wish to check that the volume of starts by device type is roughly constant as well. For example, suppose you start 1000 wafers per day this week of a device that requires stepper type A, and 1000 wafers per day next week of a device that requires stepper type B. Overall, your total release volume stays constant at 1000 wafers per day. But when this work arrives to litho you will first be overloading stepper type A and starving type B, then overloading stepper type B and starving type A. If litho is a bottleneck or near bottleneck this situation can lead to capacity losses.

Batch Processing

Another way that fabs sometimes introduce arrival variability at individual toolgroups is via batch processing at upstream tools. A certain amount of arrival variability due to batch processing is inevitable in most fabs, because the process flow dictates that some operations are conducted on single wafer or single lot tools, while others are conducted on large batch tools such as diffusion furnaces. Batching in the furnace area leads to irregular arrival patterns at operations downstream, in which we have long periods of time with no arrivals at all, and then a series of lots arriving all at once. This is a significant source of variability (and hence of cycle time) in wafer fabs, and cannot be entirely eliminated without technology changes.

However, what we have observed is that many fabs exacerbate the variability due to batch tools by requiring that operators always run full batches on these tools. This makes sense for tools that are relatively highly utilized (once average batch size is taken into account). However, forcing full batches on tools that have a lower utilization can significantly, and artificially, increase cycle times in the fab. What happens at lower utilizations is that the first lots to arrive at the batch tool have to wait a long time in order for there to be enough lots to form a full batch. Then, when the full batch finishes processing and is sent downstream, the downstream tool experiences a high level of variability in the time between arrivals. Thus, forcing full batches contributes twice to long cycle times (queue times at the batch step and arrival variability at the downstream step).

We recommend that for batch tools that are less heavily utilized, fabs adopt a "greedy" batching policy, by which the tool is run whenever there are any lots waiting. A greedy policy is actually quite robust to changes in utilization, meaning that it can safely be applied at busier tools also. What happens is that if a greedy policy is applied to a relatively busy batch tool, there may occasionally be a less than full batch processed. However, because the tool is fairly busy, by the time that less full batch finishes processing, there will most likely be a full batch waiting for the next run.

There are cases where a greedy policy is not practical, because of high per-run costs on the batch tool, or because of an extremely large number of low volume products that can't be batched together. However, in most cases, a greedy policy will improve overall fab cycle time. What many fabs do is operate a modified greedy policy by which the operator first checks the queue for any full, or nearly full, batches. Only if there are no full batches will the operator run a smaller batch. However, the operator will not wait for a full batch, and will run the smaller batch if there are lots there and waiting to be processed.

We discussed batch size decisions in more detail in issues 2.1 and 3.8. If any subscribers would like copies of those issues, you may request them from newsletter@fabtime.com between now and when the next issue is published.

Carts

A third way that fabs introduce arrival variability is by using carts to transfer lots between operations. The problem here is not so much one of policy as one of human nature. If an operator has a cart that can hold twelve lots, the natural thing for that operator to do, to maximize his or her own efficiency, is to wait until the cart is full before moving it to the next step. However, as with forcing full batches at batch tools, this behavior directly adds to fab cycle time. The first lots to be placed on the cart will wait until the remainder of the cart load is ready to go. Then, when the full cart is taken downstream, the downstream tool will experience a high level of arrival variability. The arrival pattern looks like this: no lots for a long time, then suddenly twelve lots arrive at once. If the downstream tool is a per-wafer or a per-lot tool, some of the lots on the cart will wait quite a long time to be processed.

There are several ways to counteract this problem. Some fabs that we have worked with have chosen to implement smaller carts, to mitigate the effect of batching for transport. Others have no carts at all. Some fabs have dedicated runners, who move the lots between operations. It should also be possible to adjust operator metrics, to reward more prompt deliveries of lots to downstream steps. Naturally, this is less of a problem for fabs that have automated material handling systems (though there may be other variability issues specific to the AMHS). However, for fabs that do have manual transportation of lots via carts, an examination of arrival variability due to the carts may suggest an opportunity for improvement.

Conclusions

Cycle times in the fab are strongly influenced by variability at individual operations. Many sources of variability in fabs, such as tool downtime events, the presence of batch steps, and high levels of product mix, are difficult for manufacturing to control. However, there are several operating practices by which fabs introduce arrival variability to individual operations, and hence drive up cycle times. The first is through irregular scheduling of lot releases into the fab. Lot releases that are smaller and more frequent, and more consistent in terms of time between releases, will tend to improve overall fab cycle times. Also, many fabs implement a policy of always running full batches at batch tools. When implemented at relatively lightly utilized tools, this policy can have a significant impact on cycle time. A greedy policy, by which the tool will be run if there are any lots there and waiting to be processed, will tend to reduce arrival variability and improve cycle time. Finally, the presence of carts for moving lots between operations can contribute to arrival variability. If there is sufficient operator availability, the use of smaller carts, or the elimination of the carts altogether, is likely to reduce overall cycle time. These are all relatively low-cost changes that, if implemented, can help to smooth the flow of WIP through the fab, and make cycle times lower and more predictable.

Closing Questions for FabTime Subscribers

How often do you release lots into your fab? Do you release lots so that they'll arrive in groups to early batch operations? If you work in a back-end facility, do you struggle with non-linear arrivals into your facility from the fab?

Further Reading

■ E. Akçali and R. Uzsoy (Purdue University) and D. G. Hiscock, A. L. Moser, and T. J. Teyner (Intersil), "Alternative Loading and Dispatching Policies for Furnace Operations in Semiconductor Manufacturing: A Comparison by Simulation," *Proceedings of the 2000 Winter Simulation Conference*, 2000.

■ N. Bahaji, "Simulation Study of the Effect of Dispatching Rules and Lot Release Strategies in Semiconductor Fabrication Facilities," Master's Thesis, Louisiana State University and Agricultural and Mechanical College, Department of Industrial and Manufacturing Systems Engineering, December 2000.

■ J. W. Fowler, S. Brown, H. Gold, and A. Schoemig, "Measurable Improvements in Cycle-Time-Constrained Capacity," *Proceedings of the 6th IEEE/UCS/SEMI International Symposium on Semiconductor Manufacturing (ISSM)*, October 6-8, 1997, San Francisco, A21-A24.

■ J. Kim, R. C. Leachman, and B. Suh, "Dynamic Release Control Policy for the Semiconductor Wafer Fabrication Lines," *Journal of the Operations Research Society*, Vol. 47, No. 12, 1516-1525, 1996.

■ Y. D. Kim, D. H. Lee, J. U. Kim, and H. K. Roh, "A Simulation Study On Lot Release Control, Mask Scheduling, And Batch Scheduling In Semiconductor Wafer Fabrication Facilities," *Journal of Manufacturing Systems*, Vol. 17, No. 2, 107-117, 1998.

■ J. Robinson and F. Chance, "Arrival Variability and Cycle Time," *FabTime Newsletter*, Vol. 4, No. 5, 2003.

■ J. Robinson and F. Chance, "Impact of Batch Size Decision Rules on Cycle Time," *FabTime Newsletter*, Vol. 2, No. 1, 2001.

■ J. Robinson and F. Chance, "A Simple Rule of Thumb for Batching Decisions," *FabTime Newsletter*, Vol. 3, No. 8, 2002.

■ J. Robinson, J. W. Fowler, and J. F. Bard, "The Use of Upstream and Downstream Information in Scheduling Semiconductor Batch Operations," *International Journal of Production Research*, Vol. 33, No. 7, 1849-1870, 1995.

■ L. M. Roderick, D. T. Phillips, and G. L. Hogg, "Comparison of Order Release Strategies in Production Control Systems," *International Journal of Production Research*, Vol. 30, No. 3, 611-626, 1992.

■ A. I. Sivakumar, N. F. Choong and C. S. Chong, "Modeling Causes and Effects of Semiconductor Backend Cycle Time," *Solid State Technology*, Vol. 44, No. 12,51-53, 2001. ("Smooth lot release scheduling of demanded capacity gave shorter queue times and a narrower cycle-time distribution.")

■ A. I. Sivakumar, "Simulation Based Cause and Effect Analysis of Cycle Time Distribution in Semiconductor Backend," *Proceedings of the 2000 Winter Simulation Conference*, 2000. (All WSC papers since 1997 are available for free download from www.informs-cs.org/wscpapers.html).

■ L. Solomon, J. W. Fowler, M. Pfund, and P. H. Jensen, "The Inclusion of Future Arrivals and Downstream Setups into Water Fabrication Batch Processing Decisions," *Journal of Electronics Manufacturing*, Vol. 11, No. 2, 149-159, 2002.

■ L. M. Wein, "Scheduling Semiconductor Wafer Fabrication," *IEEE Transactions on Semiconductor Manufacturing*, Vol. 1, No. 3, 115-126, 1988.

Subscriber List

Total number of subscribers: 2279, from 458 companies and universities. 23 consultants.

Top 10 subscribing companies:

- Intel Corporation (137)
- Analog Devices (75)
- ATMEL Corporation (75)
- Micron Technology (70)
- Infineon Technologies (63)
- Cypress Semiconductor (59)
- Freescale Semiconductor (58)
- STMicroelectronics (58)
- Texas Instruments (54)
- Philips (52)

Top 3 subscribing universities:

- Virginia Tech (11)
- Arizona State University (7)
- Ben Gurion Univ. of the Negev (7)

New companies and universities this month:

- COM DEV Space
- CUBIC Electronics
- IM Flash Technologies
- Lydall Industrial Thermal Solns
- Novellus
- Test Advantage
- Universität Klagenfurt

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

Installation

For a fixed price, FabTime will:

- Identify the source of any additional data needed for the planning module.
- Automate the process of importing the additional data into FabTime.
- Validate against client data.

Interested?

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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).