FabTime Cycle Time Management Newsletter

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Information

Mission: To discuss issues relating to proactive wafer fab cycle time management.

Publisher: FabTime Inc.

Editor: Jennifer Robinson

Contributors: Scott Mason (University of Arkansas), Athena Fong, and Hermann Gold (Infineon Technologies)

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Welcome

Welcome to Volume 2, Number 9 of the FabTime Cycle Time Management Newsletter. In the interest of making the newsletter increasingly valuable to our subscribers, we have decided to start distributing a PDF attachment version upon request. The PDF version is in color, and is formatted using columns. You may find it easier to print out and read than the text email version. Because many people are cautious about receiving attachments, we will continue sending the text email version by default. If you would like to receive the PDF version, instead of or in addition to the text version, simply email me at Jennifer.Robinson@FabTime.com (or you can use the newsletter subscription form at www.FabTime.com/newsletter.htm to indicate your new preference).

This month's discussion is about implicitly accounting for cycle time in the capacity planning process. This might appear to be a singularly bad time to be thinking about capacity planning and cycle time (Chartered, for example, was at 22% utilization in Q3, and they no doubt have great cycle times). But the planning, budgeting, and procurement cycle for capital purchases can be lengthy, and technology cycles continue to evolve, so the need for capacity planning never goes away. In this article, we talk about how companies already include cycle time implicitly in the process. Next month we will discuss methods for drawing a more explicit relationship between cycle time and capacity decisions.

Thanks for reading! -- Jennifer

FabTime

325M Sharon Park Dr. #219
Menlo Park CA 94025
Tel: 408 549 9932
Fax: 408 549 9941
www.FabTime.com

Community News/Announcements

The Winter Simulation Conference

The 2001 Winter Simulation Conference will be held December 9-12 at the Crystal Gateway Marriott in Arlington, Virginia. As in the past two years, this year's conference will include a special track dedicated to semiconductor manufacturing. Session topics include bottleneck equipment management, cycle time versus throughput analysis, scheduling and dispatching, and modeling methodology. Early registration for the conference ends November 9th. You can find more information online at http://www.wintersim.org.

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

Responses to Previous Newsletter Topics

Lot Size for 300mm

Scott Mason (University of Arkansas) asked "Do you know how many wafers per lot are being run in 300mm factories? I remember a while back that the standards discussions were centered around 13 or 25."

FabTime Response:

We don't actually know the answer to this question. We have heard examples that use 25 wafers, particularly in the context of discussing how heavy lots will be for 300mm fabs. But we know that some companies are using this significant change to 300mm as a time to re-think such basic assumptions. If anyone has any non-confidential information to share on this topic, we, and Scott, would be interested in hearing it.

Cost Savings: Cycle Time Reduction

Another reader asked "I'm in the process of improving the Cycle Time in our manufacturing process, I'm including the process time, move time & NVA time (wait, delays, etc...). How can we estimate a cost saving or avoidance - if we reduce the actual time by 25%, which elements should be consider in this computation?"

FabTime Response:

In answer to your question, I know of no standard model by which you can directly translate a 25% cycle time reduction into an X% cost reduction. However, there are certainly things that you can look at. We are working on a spreadsheet tool for a future newsletter that will tackle this question. In the meantime, I can suggest a couple of ways of estimating cost benefits from cycle time reduction.

- One way is to look at the question of inventory write-off during a downturn. We have a spreadsheet tool and discussion of this topic available at www.fabtime.com/ctbenefit.htm (description attached, in newsletter issue 2.6).

- Another thing that you can do is look at the capacity buffer that you typically plan for your equipment. In wafer fabrication, capacity planners usually allow for about a 15% buffer on all tools (so, the tools are planned to be busy no more than 85% of the time). The reason for this buffer is to keep cycle times acceptable (the smaller the buffer, the higher the cycle times - this is a known relationship given any variability in the factory). If you can do something that reduces cycle times, then you can perhaps shrink this buffer, thus getting more throughput out of the same toolset. We will talk about this more in the next newsletter issue.

■ A third thing to look at is reduced time to market for new products. If your cycle times are lower, you can get new products to market quicker, and capture more market share over the lifetime of the product, relative to your competitors. Similarly, if you have lower, more predictable cycle times, you may be able to charge a higher sales price for your products.

I realize that none of these gives a simple relationship between cycle time and cost, but I'm afraid that it's a complex situation. We will be dealing with various aspects to this question in future newsletter issues.

Productivity Report Indices

Athena Fong asked: "I would like to know if your newsletter to date compiled any collections of websites/papers on how useful Productivity Improvement Reports or Indices. In a company which just starts to use scheduling tool like RTD (Real-Time Dispatch) I believe the company will be moving away from the basic reports like Current WIP / Move Reports. Having these reports allow user to gauge the incoming WIP based on planned cycle time however it's more of reporting what has happen in the shift or previous day..... It does not trigger immediate actions, (that is personal opinion). Thus am wondering if you have some suggestions on useful production reports."

FabTime Response:

I have actually seen very little in the way of websites or papers that discuss productivity improvement reports/indices. We did have a newsletter issue last year that focused on wafer fab performance measures, and which ones we thought we most useful (attached). We've also had extensive discussions in subsequent issues on the subject of OEE (Overall Equipment Effectiveness), which seems to be a very popular performance measure.
In our experience, most people in wafer fabs seem to be doing as you mentioned - focusing on basic WIP and moves related reports, and their deviation from goal. Some of the more advanced fabs also focus quite a bit on WIP turns (operation moves/starting WIP), because WIP turns are more of an indicator of future cycle times (instead of past cycle times). I would guess that people using RTD do have some more specialized reporting, but I haven't seen any papers in which the types of reports are made public.

We have also recently added a chart to our FabTime software that one of our customers request: the Summed Operation Cycle Time chart. This metric involves calculating the average operation cycle times over some recent time period (day or shift, for example), and then summing those recent averages across all operations in a process flow. This results in an estimate of what overall cycle times would be, if the current performance was continued through the process flow. This is a better predictive measure than simply looking at historic cycle times, since cycle times can be very long. The summed operation cycle time calculations can be a bit difficult, however, since some estimate is required for operations that were not run during the time period in question.

Something else that we have done to address the issue that you raised (about how looking at reports does not necessarily trigger any action), is to include user-defined alerts in our software. A user can set up FabTime to page him or her when a lot waits at any operation for more than some specified period of time. Or when a tool goes into some defined state and stays in that state for more than some defined period of time. Or when the WIP at a particular toolgroup exceeds some threshold. In this way, manufacturing personnel can learn about problems right away, and try to do something about them.

I certainly agree with you that reporting past performance alone is not sufficient to make real improvements. We have some other charts that project forward based on the current state of the fab, and recent past performance. We are currently collaborating with university researchers on a new generation of algorithms that perform more in-depth analyses, and alert fab management of potential cycle time problems that are building within the fab. But this research is at a fairly early stage. We think that having some automated means of adjusting short-term goals will be important (as we discussed in the last newsletter issue) as part of this process.

I hope that these comments are useful to you. What I would like to do next is pose this question to my newsletter readers, and see if any of them have other suggestions to contribute.

New Product Introductions

Another reader asked: "Do you, by any chance, have references and/or literature regarding new product introductions? Anything and everything will be interesting to me.... Thanks."

FabTime Response:

We have a couple of references related to new product introductions, though not a lot of information. We've included the references below. Note that these papers are mostly not specific to the semiconductor industry. Our guess is that people in the semiconductor industry may not publish much on this topic because a) things change so quickly that it's hard to study and b) information related to new products is often proprietary. Sorry we don't have more. We hope that these references help.

- C. Terwiesch and R. E. Bohn, "Learning and Process Improvement During Production Ramp-Up," *International Journal of Production Economics*, Vol. 70, No. 1, 1-19, 2001.

- J. Mapes, C. New, and M. Szwejczewski, "Performance Trade-Offs In Manufacturing Plants," *International Journal of Operations & Production Management*, Vol. 17, No. 9-10, 1020-1033, 1997.

- J. K. McCreery and L. J. Krajewski, "Improving Performance Using Workforce Flexibility In An Assembly Environment With Learning and Forgetting Effects," *International Journal of Production Research*, Vol. 37, No. 9, 2031-2058, 1999.

- S. Manivannan and C-F Hong, "A New Heuristic Algorithm for Capacity Planning in a Manufacturing Facility Under Learning," *International Journal of Production Research*, No. 29, 1437-1452, 1991.

Best Case X-Factor (response to goals article)

Hermann Gold (Infineon Technologies) wrote: "With respect to the last FabTime Letter my hypotheses on operator impact implies that the expectation of the best X-Factor is (1+alpha/2) X, where alpha is the variability of the Fab (c_a^2+c_e^2)/2. It does not contradict that 1X is the absolute best theoretical, but it might be an interesting notion in this context."

FabTime Response:

Hermann's observations look reasonable to us. He has spent a lot of time thinking about man machine interference in wafer fabs, and has an interesting paper on the subject, to be published in Operations Research Proceedings 2001 (OR 2001), Duisburg, Germany, September 2001. If you're interested in receiving a copy of the paper, write to Jennifer.Robinson@FabTime.com, and I can put you in touch with Hermann.

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Implicitly Including Cycle Time Capacity Planning

Introduction

Cycle time is always considered in the capacity planning process for wafer fabs. In most cases, however, cycle time is considered implicitly, rather than explicitly. If your capacity planning team was not considering cycle time, they would plan for the minimum toolset to meet throughput requirements, with perhaps some additional tools to account for potential product mix changes. Instead, they include planned idle time for essentially all tool groups. They also try to avoid one-of-a-kind tools, frequently recommending duplicates of even very lightly loaded tools. In this article, we will talk about these traditional methods of implicitly accounting for cycle time in the capacity planning process. Next month we will looks at ways to be more explicit, and shoot for specific cycle time targets.

The Traditional Capacity Planning Process

The traditional method of capacity planning is to use a spreadsheet model. I believe that this method is still in use in the majority of wafer fabs today. Certainly it was the dominant method in 1994, when I participated in the Measurement and Improvement of Manufacturing Capacity Project (MIMAC). MIMAC was a joint project between SEMATECH and JESSI (its European counterpart), for the purpose of identifying capacity loss factors in wafer fabs. Part of the research for MIMAC involved doing written surveys and detailed face-to-face interviews on how wafer fabs plan capacity. The material in this section is drawn from that work, as well as from my subsequent experience as a performance improvement consultant working with companies like Seagate Technology, IBM (recording head wafer division), Siemens (now Infineon), and Digital Equipment Corporation (Intel).

There are also commercially available analytic and/or database models for planning capacity. WWK's Factory Explorer (developed by FabTime's Frank Chance) is the product with which I am most familiar. Other products are available from Abbie Gregg, Inc (AGI), TEFEN, and Brooks' AutoSimulations division. These follow a similar logic to that described here for calculating the required number of tools, but may be more sophisticated in accounting for complexities like nested rework. We will refer to spreadsheet models here for simplicity.

In a spreadsheet capacity model, we start with a set of process flows, including estimates for process time by operation. We also need, at a minimum, estimates of product mix (start rates by product) and line yield. We use this information to sum the total required processing time by tool group (where a tool group is a set of identical tools). The required process time is then divided by the available time per tool, to obtain the required number of tools in each tool group. A detailed example illustrating this process follows.

Estimating the Required Time Per Tool

Suppose that we have two tool groups, A and B, and two process flows, as follows, where process times are given as per-lot times.

Product 1

- OP 10 - 15 minutes on tool group A
- OP 20 - 30 minutes on tool group B
- OP 30 - 30 minutes on tool group A

Product 2

- OP 10 - 15 minutes on tool group A
- OP 20 - 40 minutes on tool group B
- OP 30 - 15 minutes on tool group A

Suppose, for simplicity, that line yield is

100%. (Since we're using per-lot process times, individual wafer scrap does not affect the capacity calculations - use of per wafer times, and step yields, is probably more common, but the general process is the same). Each lot of Product 1 thus takes 45 minutes (15 + 30) on tool group A, and 30 minutes on tool group B, while each lot of Product 2 takes 30 minutes (15 + 15) on tool group A and 30 minutes on tool group B. Suppose also that we expect to start 100 lots per day of Product 1, and 200 lots per day of Product 2. Then we need the following minutes of processing time on the two tool groups.

Required process time per tool group per day = (Required time to produce one lot of Product 1) * (Lots/day of Product 1) + (Required time to product one lot of Product 2) * (Lots/day of Product 2).

- Tool Group A: (45 min/lot x 100 lots/day) + (30 min/lot x 200 lots/day) = 4500 + 6000 = 10500 min/day
- Tool Group B: (30 min/lot x 100 lots/day) + (30 min/lot x 200 lots/day) = 3000 + 6000 = 9000 min/day

And so we have the total estimated time required on each tool group to produce the expected product mix.

Estimating the Available Time Per Tool

The next part of the capacity model involves estimating how many minutes per day each tool group can spend processing. Since most fabs run 24 by 7, we have 60 minutes per hour times 24 hours is 1440 minutes per day per tool. However, this amount must be decreased to account for time not spent processing. For example, suppose that tool group A spends 20% of the day down for preventive maintenance, and another 5%, on average, on unscheduled downtime and tool group B spends 10% of the time down for preventive maintenance, and 10% down for unscheduled downtime. Then we have:

- Tool Group A: Available time = 1440 - 0.2*1440 - 0.05*1440 = 1440 - 288 - 72 = 1080 min/day/tool.
- Tool Group B: Available time = 1440 - 0.1*1440 - 0.1*1440 = 1440 - 144 - 144 = 1152 min/day/tool.

If we calculate the minimum required tools from the information so far, we get the following:

Minimum Required Tools per Group = (Required process time per tool group per day) / (Available time per tool per day)

- Tool Group A: (10500 min/day) / (1080 min/day/tool) = 9.72 tools
- Tool Group B: (9000 min/day) / (1152 min/day/tool) = 7.81 tools

These results are then rounded up to the next integer, to give the minimum required number of tools. In this example we need 10 tools in tool group A and 8 tools in tool group B simply to manage the required throughput.

Including a Cycle Time Factor when Estimating Available Time Per Tool

In practice the available time per tool is adjusted further to account for cycle time and variability. The subtracted time may be divided into one or more buckets, and given various names, such as "Operator Unavailability Factory", "Catch-Up Capacity", "Slack Capacity", and "Cycle Time Factor".

The reason that capacity planners include these loss factors is because they know that in the presence of variability, if a tool does not have sufficient planned idle time, the tool will have unacceptably high cycle times. This happens because the variability

will occasionally cause the tool to starve (sit idle due to no work being at the tool). If the tool has no planned idle time, there will be no way for it to catch up for the lost time (hence the term "catch up capacity"), and cycle time will become large. Planned idle time amounts vary by company, and sometimes by type of tool, but typically are in the area of 10 to 15 percent of either the total time or the available time (after downtime is subtracted out). The reason for the choice of 15% is that typically cycle time increases more steeply with loading above 85% loading for tools. (See www.fabtime.com/ctcapac.htm for illustrations.)

Returning to our example, suppose that we use a cycle time factor equal to 15% of total time. This means that each tool loses an additional 15%, or 216 minutes, of available time per day. This leaves:

- Tool Group A: 1080 min - 216 min = 864 min.
- Tool Group B: 1152 min - 216 min = 936 min.

If we calculate the minimum required tools now, we get the following:

- Tool Group A: (10500 min/day) / (864 min/day/tool) = 12.15 tools -> 13 tool minimum.
- Tool Group B: (9000 min/day) / (936 min/day/tool) = 9.62 tools -> 10 tool minimum.

So, we have to purchase 3 extra tools for tool group A, and 2 extra tools for tool group B, to provide a buffer of 15% idle capacity for each tool group.

Side Note 1: Extensions to the Traditional Capacity Planning Method

We have neglected rework in the above calculations. One way of handling rework is to modify the process time calculations to account for some estimated rework path. For example, if we believe that 10% of the time, all lots through tool group B have to be reworked at that tool group, then we would increase the required process time on tool group B by 10%. Alternatively, we could subtract the estimated time spent on rework per day from the available time at tool group B. The latter is less accurate, but easier to include in a spreadsheet, and so is sometimes used in practice.

Other complexities that are sometimes included in spreadsheet capacity models include per-unit and per-batch process times, in addition to per lot process times, load and unload times, setup times (typically included as another capacity loss factor on the appropriate tools), engineering time, and step yield percentages. These make the models more complex, and usually more accurate, but do not change the basic methodology.

Side Note 2: One-of-a-Kind Tools

If the above method is followed and results in a single tool being required for a particular tool group, many companies will routinely round up to two, instead of one. This is because one-of-a-kind tools can have a large impact on cycle time. When a one-of-a-kind tool goes down, everything gets stopped at that tool, causing a WIP bubble, and future cycle time problems. Therefore, many companies will always purchase a second tool, even if both tools will be lightly loaded. (We discussed single-path tools in Issue 1.8 of the newsletter.)

Summary

The capacity planning method described here is very simple:

1. Figure out the required processing time for each type of tool.

2. Figure out the available minutes of processing time on each tool (adjusted for downtime).

3. Adjust the available minutes per tool by some cycle time (or catch up capacity) factor.

4. Calculate the required number of tools in each tool group by dividing (1) by (3).

5. (Optional) Round up to eliminate one-of-a-kind tools.

This method implicitly accounts for cycle time in step (3). If we didn't care about cycle time at all, we wouldn't need to include planned idle time on the tools, and we could skip over that step altogether. This would, of course, save quite a bit of money. In the example included above, the 15% cycle time factor drives the need for five extra tools. In a real wafer fab, these factors drive tens of millions of dollars of capital spending. In the next issue, we'll talk about some ways to be more explicit in relating cycle time to equipment capacity (rather than applying a single global factor), to hopefully save money and improve cycle times.

Further Reading

For more on the SEMATECH MIMAC project, see: J. W. Fowler and J. K. Robinson, "Measurement and Improvement of Manufacturing Capacity (MIMAC) Project Final Report," SEMATECH Technology Transfer #95062861A-TR, 1995.

For a more in-depth discussion of the capacity planning process for wafer fabs, see: J. K. Robinson, J. W. Fowler, and E. Neacy, "Capacity Loss Factors in Semiconductor Manufacturing." Working paper.

Both of the above papers can be requested from www.fabtime.com/bibliogr.htm. References to a number of other articles related to wafer fab capacity planning can be found at www.jkrconsult.com/CAPBIB.htm (see especially Section 7: Capacity Modeling).

FabTime Recommendations

CyberFab Portal

This site is a useful and visually pleasing portal for those interested in semiconductor manufacturing. It includes updated industry news (with links to the original sources), technical articles by industry experts (including presentations and links to relevant articles), and industry stock market quotes. There is also a link to a new Cyberfab service that sends industry news headlines to wireless devices like WAP cell phone and (soon) PDAs (www.semiconductornews.net/html/). Other useful site features include an industry-specific dissertation abstracts repository (more on the process side than the manufacturing methods side) and a unit-conversion applet. See www.cyberfab.net.

IIE Transactions Issue on Semiconductor Manufacturing

A special issue of IIE Transactions dedicated to semiconductor manufacturing will be released in Feb 02, and will include articles like:

- Cycle time estimation for a wafer fab with engineering lots.
- Shift scheduling for steppers in the semiconductor wafer fabrication process.
- Using in-line equipment condition and yield information for maintenance scheduling and dispatching in semiconductor

wafer fabs. You can browse the table of contents for this issue, and view abstracts, at www.wkap.nl/journalhome.htm/0740-817X. Full articles are available online if you subscribe electronically to the journal.

FabTime Book Review

The FabTime website has a new book review available at www.fabtime.com/man-month.htm. The book is "The Mythical Man-Month" by Frederick Brooks, Jr. This review was written by Frank Chance, and describes one of his favorite books on one of his favorite topics (organizing and managing large-scale programming projects).

Semiconductor FabTech

This industry magazine frequently has interesting articles related to factory performance improvement. Many of the articles from recent past issues are available online (as downloadable PDF files). You can access these past issues from http://www.fabtech.org/journals/index.shtml. Note that to read the current issue you will have to subscribe to the journal.

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