FabTime Cycle Time Management Newsletter

Volume 18, No. 3 June 2017

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 development right now include the ability to exclude individual charts from AutoSlide and a new interface for copying and renaming entire home page tabs.

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Contributors: Seth Phelabaum (Cree); Jay Maguire (Intersil - A Renesas Company); Kelvin Lim (Innovative Global Solutions and Services Pte Ltd.)

Keywords: Shutdown; Delivery

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Welcome

Welcome to Volume 18, Number 3 of the FabTime Cycle Time Management Newsletter! In this issue we have a brief announcement about our first webinar-based training session. Our FabTime user tip of the month is about a shortcut for opening multiple home page tabs quickly. In our subscriber discussion forum we have several responses to the last newsletter topic of fab shutdowns. We think you'll find them interesting.

In our main article this month we discuss using root cause analysis to better understand lots that miss their due dates. In addition to providing a structure for such analysis, we suggest some ways for using the outcome of the analysis to catch future lots earlier, before they become late. As always, we welcome your feedback.

Thanks for reading – Jennifer

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Community News/Announcements

FabTime's First Customer Training Webinar

FabTime recently hosted our first training webinar for customers. This webinar was about using features in the latest FabTime software release, Patch 108. We used the GoToWebinar service from GoToMeeting, which allowed participants to ask questions during the webinar via instant message, and allowed us to record the webinar (without the Q&A session, to preserve confidentiality) so that customers can view it in the future.

The webinar, hosted by FabTime's **Mike Krist**, was a success, with 15 real-time participants. For information about accessing the archived version, please contact support@FabTime.com (customers only). To be added to the announcement list for future webinars, please sign up for our Tips email list.

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

FabTime User Tip of the Month

Open Multiple Home Page Tabs Quickly

A member of our FabTime user group recently mentioned a wish to open several home pages at once, in different tabs of a web browser. **Seth Phelabaum from Cree** shared a helpful tip for this, though it only currently works in certain browsers.

1. Open the home page tabs of interest as separate tabs in your browser.

2. Bookmark each of these tabs, putting all of the bookmarks into a single bookmark folder. Depending on your browser, you may be able to bookmark all of the open tabs at once, using the "Bookmark all tabs" functionality. Otherwise, you will have to bookmark each home page tab manually (but you will only have to do this once). Bookmarking manually allows you to name the bookmark for each tab individually, which can also be helpful.

3. In Chrome, right-click on the folder that you created and select "Open all bookmarks". Chrome will then open each home page tab that you saved as a different tab in your current browser session. An example is shown at the top of the next page. You do need to be logged in to FabTime first for this to work.

This functionality also works in Firefox and Safari, with minor variations in naming of the bookmarking and opening functions. There does not appear to be an option to open all of the bookmarks in Internet Explorer or Edge, but it's worth checking back for that in the future. If you are someone who likes to have a bunch of tabs open at once, and you usually open the same set of tabs, this tip can be a real time-saver.

This tip is incidentally an excellent illustration of the value of our virtual FabTime user group. If you work at a FabTime customer site and would like more information about joining the user group, contact Jennifer.Robinson-@FabTime.com.

Subscribe to the separate Tip of the Month email list (with additional discussion for customers only). Thanks!

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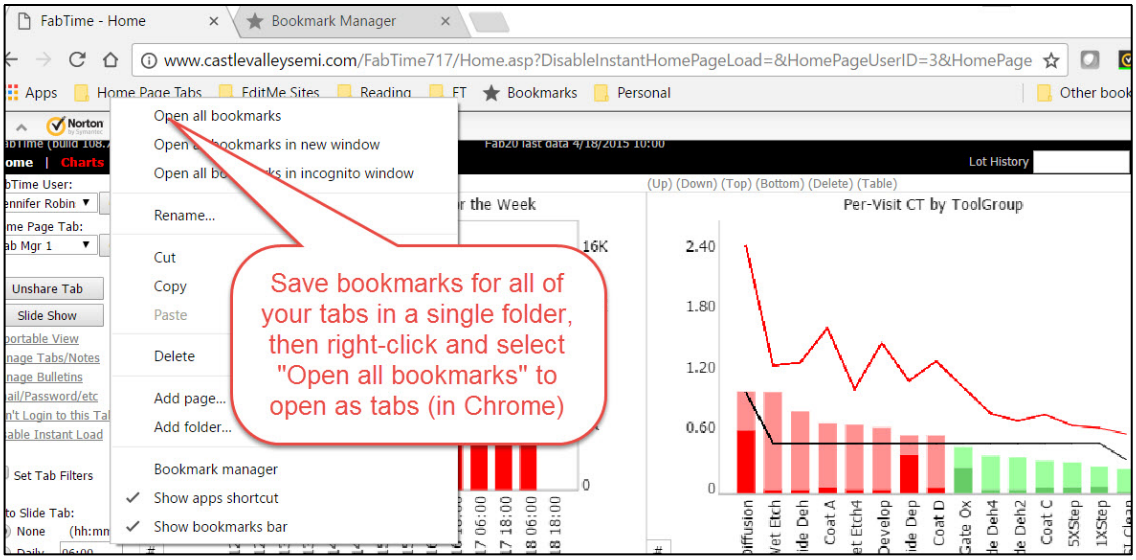

Figure 1. Example of "Open All Bookmarks" Functionality in Chrome

Subscriber Discussion Forum

Issue 18.02: Temporary Fab Shutdowns

As we hoped, the last newsletter article did inspire a few people to write in and share their experiences with temporary fab shutdowns. We hope that these comments will inspire even more discussion.

Jay Maguire from Intersil (A Renesas Company) pointed out an issue regarding non-linearity of safe points:

"Our safe points tend to overload WIP in the backend metallization loops and that's probably true for most fabs. If metal is etched it must be covered or 'passivated' prior to extended storage to avoid corrosion. That means that if you aren't sure you can etch, strip and deposit a covering oxide you stop it before it is etched. Also, if the shutdown is more than a few days long, you need to rework through photo any lot not etched so you would stop it at photo. For contacts and vias, if you aren't sure you can etch, strip and get through metal deposition before shutdown you stop the lot before it is etched or, more likely, before it's patterned. Meanwhile, the rest of the line, pre contact level, has fewer risks so those zones move faster leading up to shutdown.

We all have specific technology and equipment related issues associated with shutdowns (close couples, contamination risks, etc.) but I think we are going to find all fabs have similar backend of line issues and some may not realize it. If so, what do you do about it? To avoid heavier WIP in the backend would mean parking lots earlier and having less activity leading up to the shutdown. However, this might also result in a better, more linear, start-up? Maybe it's better to run full speed ahead up to shutdown while honoring safe points and focus the start-up on backend tools (and diffusion)? I would be interested to hear how other subscribers manage this specific issue."

An anonymous subscriber wrote about issues with commit dates:

"The issue of order commitments is very interesting and I would love to know how other fabs do it. We re-date in our MES

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lots in WIP that will not ship before shutdown. The question is: when should you do that? A quarter in advance? If you wait until the week of the shutdown, you might have customer issues. If you do it too early, you might have a lot of maintenance to do on due dates. Not all lots in WIP are directly pegged to customer orders. Some are to satisfy forecast or buffer build. When you re-date a pegged order the date promised to customer can be affected. So, you have to coordinate with planning and tactical marketing in some cases.

There is also the issue of dating new lot starts. Depending on the cycle time and time remaining to shutdown you might or might not add the shutdown duration to the cycle time."

Kelvin Lim from Innovative Global Solutions and Services Pte Ltd (IGSS) wrote:

"Interesting topic on Fab shutdown. I used to coordinate Fab shutdowns at my previous company during the 90's and created a manual for future reference. I'm not sure if it is still being used now.

Most of the time fab shutdown was scheduled as it was mandatory. This usually happened for us once every 2 to 3 years. It involved total power down of the fab for at least 12 hours to perform maintenance on the incoming transformers. We managed to fully recover the fab in <28hrs from the start point of total power down (which usually took >3 days). These results I credit to the pre-work done together with the shutdown task force.

While I cannot remember all the details, I know that pre-work during fab shutdown could take months (usually 2-3 months) and involved things like: identifying critical & non critical activities; identifying key engineering activities; doing a spending forecast review; engaging vendor standby support; preparing test wafers; communicating with customers including additional projected days for cycle times; consideration of WIP staging; ordering anti-static bags & silicon gels; renting dehumidifiers; identifying safety & startup crew roles and more. Activities picked up from weekly to daily meetings as the schedule moved closer.

Lots staging was done via manual holds by using the future hold function. Usually we would have 2 hold points identified in case lots moved faster than expected. Staging steps were reviewed with the integration team and usually were at masking (before coat) or diffusion (before pre-clean) or metal dep (before metal). The spending forecast was important in order to minimize the cost impact of the shutdown. Test wafer requirements and usage needed to be planned well to ensure smooth recovery of tools.

Then came the actual startup where tools were able to power up. Care had to be taken not to power up all the tools together as this might cause a power trip (unscheduled fab shutdown). We usually provided timing for modules to power up. Tool priorities were set based on the actual WIP staging. Metrology tool usage for setup was controlled by the manufacturing team.

In my experience, putting more details in place during pre-shutdown will ensure a faster and smoother fab recovery."

FabTime Response:

FabTime is grateful to these subscribers for contributing to the discussion on factory shutdowns. We would be happy to publish additional responses in the next issue, if anyone else has anything to add.

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

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Understanding Why Lots Miss Their Due Dates

Introduction

We talk quite often in this newsletter about overall cycle times, which usually imply average cycle times. Average cycle times are important, of course (particularly as a ratio of theoretical cycle time), because they tell you something about how your fab is performing overall. However, the thing that can really cause business problems for a factory is not so much the average but the outliers. The problem here is coping with the lots that ship significantly later than promised. These are the ones that make customers (and thus management) unhappy.

In the high variability environment of a fab, any time you make things to order there is some risk of late lots. This is because there is a distribution of cycle times across lots of a given product type. You can give commit dates based on, say, the 95th percentile of this cycle time distribution (if you have enough data to know that). But this still means that 5% of your lots are going to be late. And if you push to, say, the 99th percentile, you risk alienating customers because your commit dates are too far out, and your competitors promise something more aggressive.

So it is that for many fabs, some number of lots will end up shipping late. A question we've been thinking about recently is: how can we best perform retrospective data analysis to understand why particular lots miss their due dates? The goal here is to learn from this analysis to avoid similar problems in the future, and ultimately to deliver fewer late lots to customers.

In this article, we propose a method for performing retrospective data analysis for late lots to try to tease out common causes. We also discuss the possibility of using this data to identify earlier the lots that are at risk of being late, so they can possibly be accelerated.

Retrospective Data Analysis in General

One of the things we help our customers do with FabTime's software is retrospective data analysis. This involves:

- Looking at something that went wrong;
- Figuring out why it went wrong; and
- Making recommendations on how one might avoid that problem in the future.

Of course you can do retrospective data analysis with any reporting system that gives you sufficient access to historical data. This type of analysis is an excellent use of Industrial Engineers (IEs), though we have seen production supervisors and other manufacturing management personnel working in this area, too. The main trait that is needed is a willingness to dig into the data.

As an example, if you miss your moves goal on a critical piece of equipment over some time window, you can check the tool-state, OEE, and WIP numbers during that time period to determine:

- Did we miss the goal due to lack of availability?
- Did we miss the goal due to rate loss on the tool?
- Did we miss the goal due to lack of WIP?

Even if the tool has good availability overall, variability in availability could show up for certain time periods. Engineers could have taken the tool to run experiments. There could have been a quarterly PM. And so on… Similarly, even if the long-term flow of WIP to the tool is as planned, variability in feeding the tool could cause a short-term lack of WIP. This could happen due to upstream availability issues, batch loading policies, lot delivery issues, and more.

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There are plenty of avenues to explore here, contributed by the myriad sources of variability in a fab. But the analysis itself, when you are looking at something like moves on a particular tool, is relatively straightforward. We know the time window in question. We know what WIP arrived at that tool, what WIP was processed and how long it took, and what happened to the tool in terms of downtime.

Things are quite a bit more complex when we try the same type of retrospective data analysis for late lots in a fab. This is because to understand what made each lot late requires looking across a process flow of up to 1000 steps and a time window of weeks or even months. Then when we seek understanding across multiple late lots, the potential complexity is considerable. But we do have ideas, as outlined below.

Retrospective Data Analysis for Late Lots

What options do we have when a lot misses its due date? Obviously there are special cases such as a factory shutdown that might cause an array of lots to be late, as discussed in the subscriber forum above. Or when a key one-of-a-kind tool went down for an extended time, causing everything to be late over some time period. These special cases are painful but relatively easy to diagnose.

In the case of a "regular" late lot, when no catastrophic event has occurred, we need to first look at whether the lot was late because of a problem with the planning numbers or because of an operational problem.

Identifying Problems with Planning Numbers

We can start by looking at a distribution of recent lots of the same product type and comparing actual performance to the plan. If all or most of the lots have cycle times longer than the planning numbers used to set cycle time targets, then we probably need to update the planning numbers. In this case, a more detailed analysis of this particular lot's cycle time may not be productive. But if this lot is in fact an outlier relative to other lots of the same product type, then we should move on to a more detailed analysis that identifies operational issues.

Identifying Operational Issues

The more detailed analysis involves looking at the lot's history and seeking out problems. This analysis can also be broken down into two broad categories: hold time analysis and step-level analysis.

Hold Time Analysis:

The simplest option is to look at the lot's history, filter for hold time, and look for any extended holds. If we find extended holds, we can discuss these holds with the person (or people) who placed them and try to understand the reason for the holds. For example, the Lot History chart shown in Figure 2 at the top of the next page shows a lot that had several holds (the yellow bars), including three lasting about a day each. See FabTime Newsletter 6.06 for a more detailed discussion of the impact of holds on lot cycle time.

Step-Level Analysis:

A more detailed analysis involves looking at the lot's history and filtering for any steps where the actual cycle time exceeds the planned cycle time by more than some accepted buffer amount. Obviously, access to planned cycle time data by step, relative to the plan, is necessary to perform this analysis. What we want is to identify steps where there were significant misses relative to the plan.

Ranking the Problem Steps: There are a couple of different choices that we can use to quantify and rank problem steps. The simplest thing, if the data is readily accessible, is to calculate for each step:

1) Actual Cycle Time - Planned Cycle Time = Cycle Time Delta from Plan

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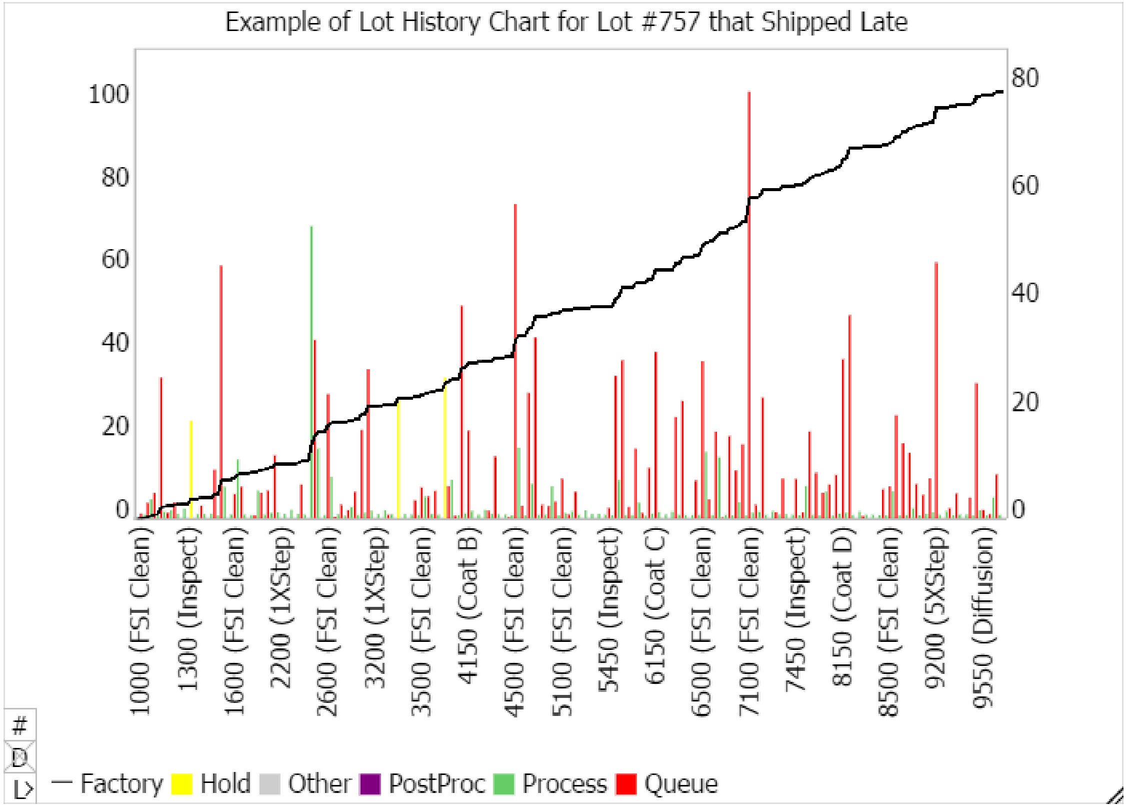

Figure 2. Example of a Detailed History for a Late Lot. Hold Times are in Yellow.

Cycle Time Delta from Plan, if positive, means that the step cycle time exceeded the plan. Sorting to bring the steps with the largest Cycle Time Delta from Plan values to the top is a good indicator of which steps contributed the most to the problem.

Another option is to look at step-level X-Factor values, where you calculate for each step:

2) Actual Cycle Time / Theoretical Cycle Time = Step-Level X-Factor

Using 1) is nice because it tells us in an absolute sense which steps were most directly responsible for missing the overall planning target. However, 2) is useful in identifying places where we did the worst relative to how we could have done. Where these values will diverge most is at steps with long process times, such as large furnace batches.

A third approach is to look at the ratio of Actual X-Factor to Planned X-Factor (if available), because this normalizes the batch steps while still focusing on how far off we are from the plan. Like this:

3) Actual X-Factor / Planned X-Factor =

[(Actual CT)/(Theoretical CT)]/[(Planned CT)/Theoretical CT)] =

Actual CT / Planned CT

So for example, if it took 24 hours to get through a step, but the planned cycle time was only 3 hours and the theoretical cycle time was only 1 hour, then we have

1) Cycle Time Delta = 24-3 = 21 hours

2) Actual X-Factor = 24/1 = 24

3) X-Factor Ratio = 24/3= 8

It took 8 times as long as it should have to get through this step, 21 hours longer than planned.

Compare this to a batch step where the planned cycle time was 48 hours, the theoretical cycle time was 16 hours, and the actual cycle time was 72 hours.

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1) Cycle Time Delta = 72-48 = 24 hours

2) Actual X-Factor = 72/16 = 4.5

3) X-Factor Ratio = 72/48 = 1.5

Here the absolute cycle time delta from plan for the batch tool was slightly longer than for the first tool. However, it only took us 1.5 times as long as the plan to complete the step. The first example, where it took 24 times as long as planned, is perhaps more suggestive of a significant event taking place than the second example, which might be within normal levels of variation for that step. There are pros and cons to using the different sorts, but any of them should bring major cycle time contributors to the top.

Once we have an ordered list of the steps that were furthest off from plan, we can then pick out the top few steps. Then we have to look at the root causes of the divergence from plan.

Assessing Step-Level Root Causes

When looking at any step for which cycle time significantly exceeded the plan, there are usually two primary types of root causes (assuming we've already filtered out above catastrophic special cases, shutdowns, and holds):

A. Tool uptime issues. Here we want to look at the list of tools that were qualified to run that step, and see whether there was some availability issue going on at the time that the lot in question was waiting. Were one or more tools in an unscheduled downtime state? Were there extended PMs going on? Was availability reduced because of engineering time?

Figure 3 (at the top of the next page) shows an example of the tool state trend at a step where the lot from Figure 2 waited an extra four days in queue relative to the plan. Availability issues are clearly visible.

B. WIP-related issues. Here we want to again look at the list of tools that were qualified to run that step, and see whether there was an issue with too much WIP piled up in front of the tools at that time. Or, if it wasn't so much a large quantity of WIP, why did our particular lot wait? Were there hot lots that jumped ahead of it? Was there some soft dedication going on, whereby operators may have been trying to avoid a setup, and let our lot sit? Etc…

Incidentally, while this analysis is easier if there is only a single tool that is qualified to run the step in question, this fact in and of itself suggests a problem since single path tool dedication is a known contributor to high per-visit cycle times. There can also be hidden tool dedication issues in which our data tells us that the lot was qualified to run on any of four tools, but really the operators prefer one particular tool for lots at this step, and that one wasn't available.

Here is where the analysis starts to get tricky. How can we apportion responsibility among the different factors in cases where more than one thing contributed? What if there was arrival variability AND a tool availability issue happening at the same time? Never mind a hidden tool dedication issue that we can't even see directly.

One approach is to create a general list of root causes, and then assign each step to, say, a primary and a secondary root cause. So we might have a list like this, for Lot 1009:

- Step 912: X-Factor Ratio 20. Primary cause: PM on multiple qualified tools. Secondary cause: another tool held for expected rocket lot.
- Step 407: X-Factor Ratio 17.3. Primary cause: Single path tool down for repair, caused WIP bubble. Secondary cause: none
- And so on...

Looking Across Multiple Lots for Root Causes

If we perform the preceding analysis for a set of, say, 10 different late lots that have

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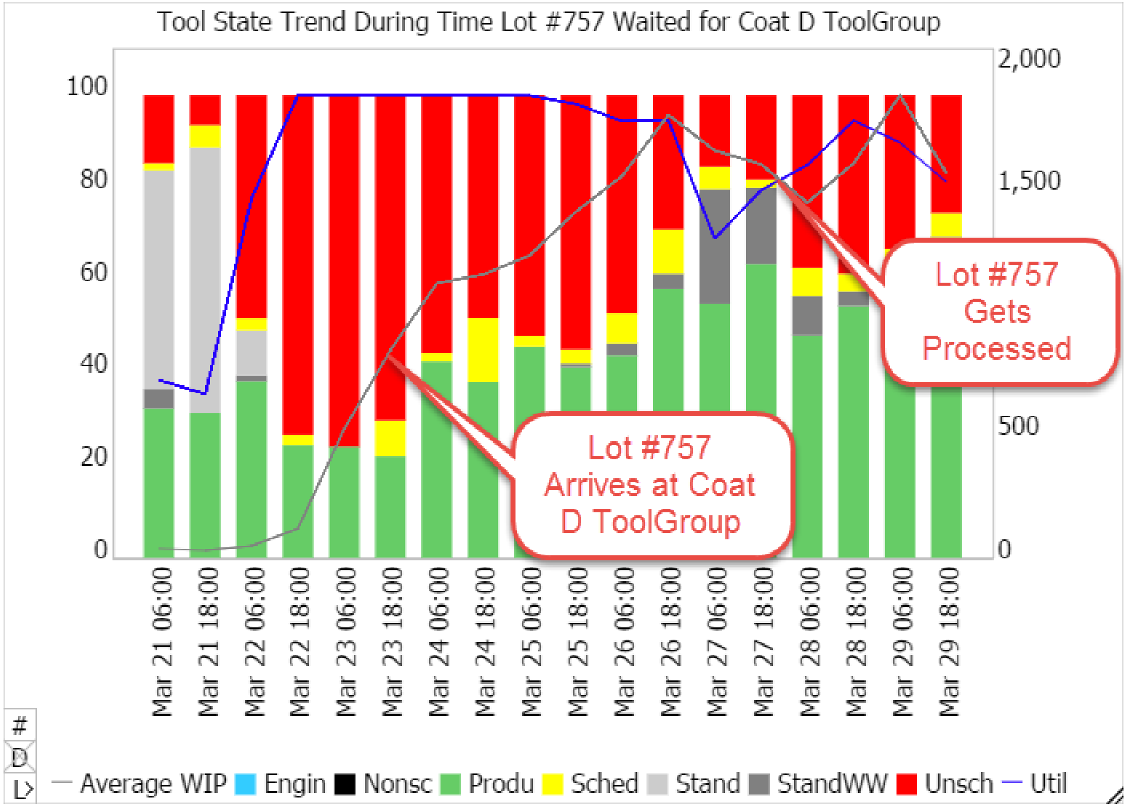

Figure 3. Example of Root Cause Analysis for a Lot that Waited Four Days at Step

similar flows, all of which were in the factory at approximately the same time, then we may be able to start to draw some larger conclusions.

- Which steps show up most frequently in our top-10 list?
- Which steps have the largest average (or cumulative) delta from plan?
- Which root causes show up most frequently?
- Are the same root causes showing up at different steps?
- Are there particular tools that are showing up in multiple problem instances?

If we find that there is a particular step, or a small group of steps, that appear as a problem for multiple lots, then this suggests a starting location for improvement efforts. This is also true for tools, though the analysis is a bit trickier, since there can be overlaps between tool groups (tool A and B were qualified for step 912 but tool B and C were qualified for step 407, e.g.). But if the same two or three tools keep showing up in the analysis, this is a clue that these tools are contributing to due date performance issues.

Looking Forward

The above methodology for digging out root causes across a group of late lots is rather labor-intensive. It would hardly be worthwhile if the only purpose were to understand history: why were these lots late and who or what was responsible? But of course, once we have identified a few steps and/or a few tools that are consistently contributing to late lots, this suggests a target for improvement efforts. Perhaps we need cross-qualification. Perhaps we need better spare parts management, or better coordination between maintenance supervisors and engineers to avoid multiple unavailable tools. Perhaps we have some soft dedication that could be eliminated

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through better enforcement of dispatch lists. There are many possibilities, and this analysis will suggest productive places to start.

We might also be able to use the results of this analysis to set up triggers to catch future late lots earlier, particularly where problems are due to dispatching/loading issues. If we know that lots seem to sometimes get lost at particular steps (because of setup avoidance policies, say), we could set an alert to let a manager know if any lot waits more than some period of time before being processed. This could help to truncate those 24-hour wait times before they get out of hand. The thing to do in general is look back at the root causes list and think, for each one, "When could we have first seen that this was an issue?" And then set some trigger to catch it next time. Maybe we need a new alert for when "Actual CT - Planned CT" exceeds some value for lots that are still in queue. Or for when a particular lot's cumulative cycle time exceeds its plan to this point by some value.

Conclusions

In the highly competitive semiconductor industry, due date performance is a critical metric. Doing root cause analysis to understand why particular lots were late, though potentially complex, can be a useful effort. We should start by eliminating known one-of-a-kind issues that may have led to a due data issue, such as a factory shutdown or critical downtime. Next, it's worth doing the analysis to confirm that planning numbers are accurate. If all of the lots of a particular product line are running late, there may be more of a planning issue than an operations issue. Once we're down to doing detailed analysis of individual lots, then it probably makes sense to first assess hold times, and only after that dig in with a more step-by-step analysis.

In this article we've described a general procedure for doing detailed analysis to identify step-level root causes of due date misses. Performing such analysis for multiple lots, and then comparing across lots, can generate useful insights about which steps, tools, or operating procedures are contributing the most to making lots late. Next steps after that involve improvement efforts that target those steps and tools, as well as finding ways to set triggers to catch lots that are slipping behind earlier, before they end up shipping late.

Questions for FabTime Newsletter Subscribers

Do you do any of this type of detailed analysis for late lots? Or do you think that things change so rapidly in a fab that this type of analysis wouldn't yield relevant information to drive future efforts? What triggers might you use to catch lots that are getting behind schedule earlier in the process, before they ship? We suspect that there is another article to be written here about this latter question, and we would especially appreciate any feedback that might help us towards writing that.

Further Reading

■ J. Robinson and F. Chance, "Cycle Time and Holds," *FabTime Newsletter*, Vol. 6, No. 6, 2005.

■ J. Robinson and F. Chance, "Cycle Time Variability," *FabTime Newsletter*, Vol. 7, No. 4, 2006.

To request copies of either or both of these past newsletter issues, email newsletter@fabtime.com.

Acknowledgement

FabTime would like to thank **Elaine Jacobson from On Semiconductor** for interesting discussions that contributed to this article.

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FabTime's Web-Based Dashboard is Fully Applicable for Assembly & Test Facilities

- Do your customers (internal or external) want more visibility into your factory?
- Is it difficult to look at trends in equipment performance, or tie equipment performance to throughput and cycle time?
- Does your factory lack real-time reporting?

FabTime can help. FabTime saves your management team time daily by turning MES data into information, via a real-time web-based dashboard that includes lot dispatching. FabTime saves your IT staff time by breaking the cycle of custom-developed reports. Most importantly, FabTime can help your company to increase revenue by reducing cycle times up to 20% for regular lots, and even more for high-priority lots.

Although FabTime was originally designed for front-end manufacturing, you can use FabTime for your assembly or test facility. You simply need to have a transaction-based manufacturing execution system. FabTime can link to all commercial systems commonly used in the industry (e.g. WorkStream, Promis, Eyelit, Mesa, FactoryWorks) or can link to internally developed systems. FabTime can pull data from multiple databases if needed (e.g. WIP transactions from the MES, tool transactions from another system). FabTime is currently being implemented in two assembly and test facilities, with no major technical hurdles.

FabTime Applicability for Back-End Factories

- FabTime handles lot merging and splitting, with full tracking of overall cycle times.
- All chart quantities (moves, WIP, etc.) can be displayed as die, with data tables formatted for readability of large quantity values.
- Custom assembly and test parameters (applicable to WIP or tool state transactions) can be mapped.
- Custom site-specific reports for wire bond area have been developed for customers (die and component placements, etc.).
- Custom dispatch factors allow for incorporation of back-end-specific data used in dispatch decisions (e.g. availability of boards, and minimization of sequence-dependent setups).

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