FabTime Cycle Time Management Newsletter

Volume 11, No. 3 September 2010

Information

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

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. New features in this month include Lot Line Yield trend/pareto/list charts and support for SQL restriction within object filters.

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Welcome

Welcome to Volume 11, Number 3 of the FabTime Cycle Time Management Newsletter! Our apologies for the six-month gap since the last newsletter was published. I (Jennifer) had a baby in early April. She was born 10 weeks earlier than expected (below the target cycle time, but not a stellar example of on-time delivery). This threw my plans for pre-writing some newsletter issues before the baby came out the window. However, she's doing well now, and I'm ready to get back to the business at hand.

I hope that this issue finds all of you doing well, as the semiconductor industry (in contrast to the US economy as a whole) seems to be progressing reasonably well. Here at FabTime, we've been keeping busy with existing customers and new installations (including a couple of assembly/test sites). We're certainly finding it a better year than 2009. In this issue, we have three community announcements: the results of the raffle for a complete set of past FabTime newsletters; a notice about the upcoming Fab Owners Association meeting; and a conference announcement for the ISMI's Manufacturing Week. Our FabTime user tip of the month is about setting goals for Pareto charts. We also have one subscriber discussion question about data structures for capacity models.

In our main article this month we discuss some of the computation issues that go along with using OEE (overall equipment effectiveness) as a metric. At its simplest, OEE measures the actual good units produced on a tool relative to the most units that could have been produced on that tool if everything went perfectly (no scrap, no rework, no downtime, no wasted time). Much of the value of OEE lies not so much in the actual OEE values, but in analyzing the underlying components, and understanding why a particular tool is not performing as expected. We last wrote about OEE in the newsletter in detail back 2002. In this article, we revisit the basics of OEE, with emphasis on calculating OEE values from fab performance data. We also specifically address the issues of calculating OEE for batch tools and estimating planned OEE.

Thanks for reading!—Jennifer

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Community News/Announcements

Raffle Results

Back in the last issue, we announced a raffle to win a complete set of past issues of the FabTime newsletter (on CD). The three lucky winners are:

- **Dan Rea** from Analog Devices in Limerick, Ireland
- **Mindy Poorman** from Micron
- **Paul Liston** from the University of Limerick

Hard not to make a comment on the luck of the Irish, isn't it? Many thanks to everyone who entered. And of course you'll always have access to the complete set of FabTime newsletters if you install our web-based dashboard software ;-). The CDs to the winners have been sent out.

Those of you at FabTime customer sites can find all of the past issues available in html format from the Help Table of Contents. If you would like PDF versions, email your request to newsletter@FabTime.com (and please be sure to include your company and site name).

Fab Owners Association

The next quarterly meeting of the Fab Owners Association (FOA) will be held at X-Fab in Lubbock, Texas on November 11th. Jennifer Robinson is planning to represent FabTime at this meeting. FabTime will also be one of the sponsors for the FOA golf tournament associated with the meeting. Recent new members of the FOA include device manufacturer Spansion, as well as associate members LG Innotek, SurplusGLOBAL, Inc., and Tokyo Electron America. The FOA is an international, not for profit, trade association of semiconductor & MEMS fab owners and associates who meet regularly to discuss and act on common manufacturing issues, combining strengths and resources to become more competitive. More information is available at http://www.waferfabs.org.

Conference Announcement: ISMI Manufacturing Week

The International Sematech Manufacturing Initiative (ISMI) annual Manufacturing Week will be held in Austin, Texas from October 31st to November 4th. Here's the announcement: "Make your plans now to be a part of ISMI Manufacturing Week—the only conference focused on productivity and cost-savings solutions that can be implemented immediately in today's fabs. This year ISMI Manufacturing Week attendees will gain even more benefit by the addition of the AEC/APC Symposium to the week's events. For over 20 years, the AEC/APC Symposium has been accelerating the effort to move toward more efficient and more intelligent manufacturing through data-driven and automated decision making. In addition, ISMI Manufacturing Week will again feature the ISMI Symposium on Manufacturing Effectiveness, the industry's premier manufacturing conference focused entirely on increasing productivity and reducing expenses through advances in equipment, processes, resources, fab design, and manufacturing methods." More information can be found at http://ismi.sematech.org/ismisymposium/

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

FabTime User Tip of the Month

Setting Goals for Pareto Charts

We've talked in past tips about how to set goals in FabTime. Today, we're going to talk specifically about how to set goals for Pareto charts. With all FabTime charts, in order for a goal line to appear on a chart, a goal has to be configured with the exact same set of filters included on the chart. The trick with Pareto charts is that goals have to be configured for each object on the chart. For example, suppose you have an Operation Cycle Time Pareto chart sliced by ToolGroup. You'll need to set a goal for Operation Cycle Time filtered for ToolGroup A, set another separate goal for Operation Cycle Time filtered for ToolGroup B, etc. This is because ToolGroup A and ToolGroup B might have different cycle time goals, and because the Operation Cycle Time Pareto chart might be displayed with different slice by variables. So it's not enough to just say "our operation cycle time goal is 24 hours". You need to specify, "our operation cycle time goal for ToolGroup A is 24 hours, and for operation 1200 is 36 hours, etc."

Of course this flexibility could result in the need to create quite a large number of goals. FabTime is happy to work with you to import goals from an external database or spreadsheet. Alternatively, you may be able to use the (any) filter to cut down on the number of goals that you need to configure. If you have the same operation cycle time goal of 24 hours per visit for most of your ToolGroups, with just a few exceptions, then what you can do is create an operation cycle time goal with the goal = 24, and the period length = 1, and then enter "(any)" (without the quotation marks) in the ToolGroup filter for the goal. If you then generate an Operation Cycle Time Pareto chart, sliced by ToolGroup, and set to display your own personal goal, then you'll see a goal of 24 hours/visit for all of the ToolGroups. If you need to override that default for one ToolGroup, just create another goal, and enter that ToolGroup name in the ToolGroup filter. The (any) filter will fill in the goal for any ToolGroup that doesn't have another specific goal set up.

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

Data Structures for Capacity Models

An anonymous subscriber wrote: "I'm facing an issue with the data structures of my current fab. The problem is one process step recipe is associated with multiple actual equipment recipes which in turn give multiple process time. To me this is a nightmare for capacity modeling because the there is only ONE process time that's in the database. I'm wondering if there is a way out of this problem. So far I can only think of changing the data structure to a unique relation."

FabTime Response: While we have certainly worked with our individual software customers on data structure issues, we haven't published any general results on this question. Thus, we thought that we would open up the topic to our subscribers for feedback.

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

Computational Issues in Estimating OEE

Introduction

OEE (Overall Equipment Efficiency, also know as Overall Equipment Effectiveness) is a well-established metric used in the semiconductor industry for measuring equipment performance. At its simplest, OEE measures the actual good units produced on a tool relative to the most units that could have been produced on that tool if everything went perfectly (no scrap, no rework, no downtime, no wasted time).

OEE is calculated from the components availability efficiency, quality efficiency, and performance efficiency. In the semiconductor industry, OEE tends to be used as a metric for assessing bottleneck tool performance, since these are the tools that require the highest operational efficiency. OEE values for non-bottleneck tools are generally lower, but are still frequently reported. Much of the value of OEE lies not so much in the actual OEE values, but in analyzing the underlying components, and understanding why a particular tool is not performing as expected.

We last wrote about OEE in the newsletter in detail back in Issues 2.4 (*In-Depth Guide to OEE Resources*) and 3.1 (*OEE and Cycle Time*). In this article, we will revisit the basics of OEE, with emphasis on calculating OEE values from fab performance data. We'll also specifically address the issues of calculating OEE for batch tools and estimating planned OEE.

OEE Calculations

The recommended formulas for calculating OEE are widely reported on the Internet (there's an OEE Wikipedia page, in fact), and are available in various books (for example, there's a newly published OEE Primer by D. H. Stamatis available from here). The industry-specific version of the calculations can be found in the E79 SEMI standard for definition and measurement of equipment productivity. Here's a quick summary:

OEE = Availability Efficiency x Performance Efficiency x Quality Efficiency

Availability Efficiency is equipment uptime expressed as a percentage of total time. That is:

Availability = Equipment Uptime / Total Time

where

Equipment Uptime = Productive Time + Standby Time + Engineering Time.

[Note: See SEMI E-10 standard for term definitions.]

Equivalently:

Availability = (Total Time - NonScheduled Time - Unscheduled Downtime - Scheduled Downtime) / Total Time.

Performance Efficiency is a factor consisting of Rate Efficiency (ideal process time over actual process time) and Operational Efficiency (time spent processing vs. time available for processing). That is:

Performance Efficiency = Rate Efficiency x Operational Efficiency

where

Rate Efficiency = Ideal Process Time / Actual Process Time = (Theoretical Production Time for Actual Moves) / (Productive Time).

and

Operational Efficiency = Total Productive State Time / Equipment Operational Uptime.

In the above, Total Productive State Time is time that the tool is busy processing regular production wafers, engineering production wafers, or rework wafers. Equipment Operational Uptime is the sum of productive, engineering, and standby states (from SEMI E-10). So we have:

Operational Efficiency = Productive Time / (Productive Time + Standby Time + Engineering Time).

Quality Efficiency is simply good wafers processed divided by total wafers processed. That is:

Quality Efficiency = ((Total Wafer Processed - Rejects)/(Total Wafers Processed)) x 100.

Or, more specifically:

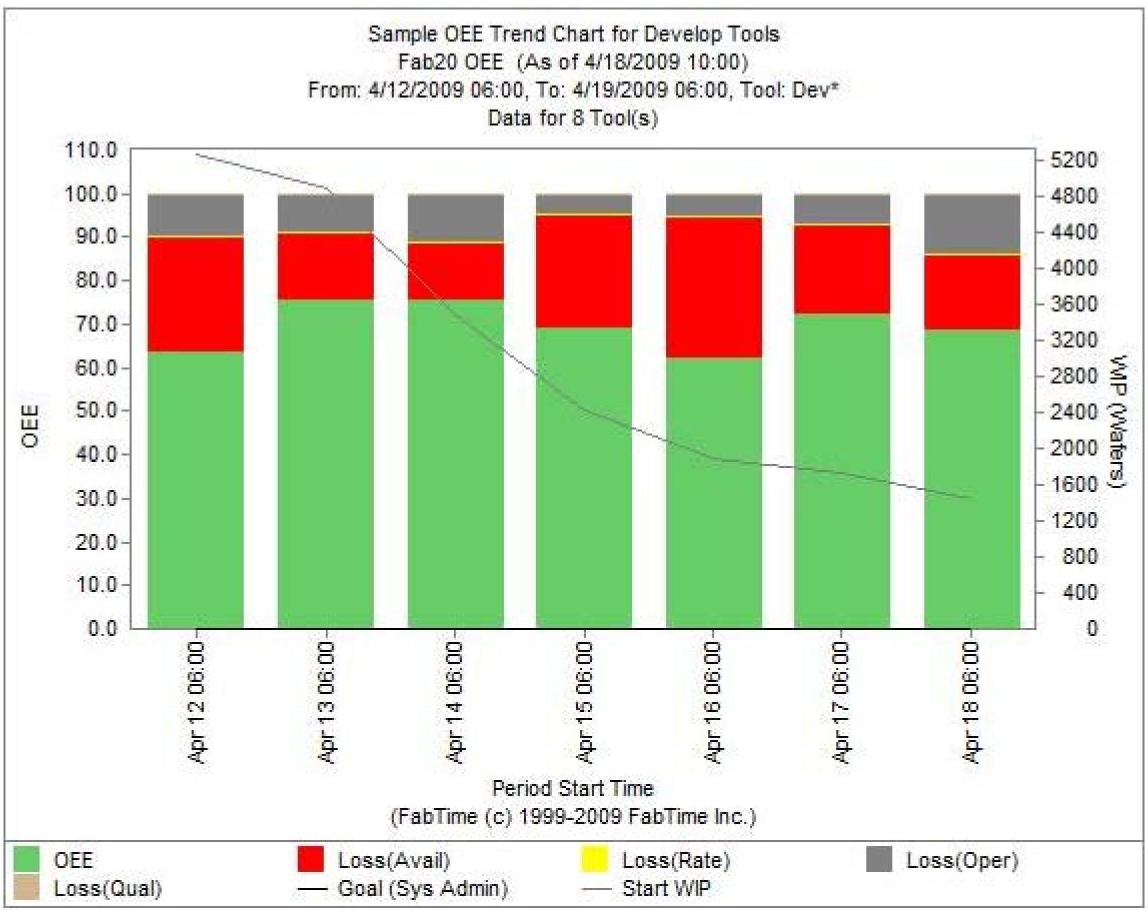
Quality Efficiency = (Total Moves - Scrap - Rework Moves) / Total Moves.

An example of an OEE trend chart from FabTime's software is shown below. The tools pictured (six develop tools) have minimal quality losses due to rework, and no speed losses reported. A portion of the data table from the same chart is shown at the top of the next page.

Computational Notes for Estimating the Above in Practice

If Theoretical Production Time for Actual Moves = 0, or Productive Time = 0, data required for the Rate Efficiency calculation is missing. To avoid distorting the results, Rate Efficiency should be set to 100%. When calculating Theoretical Production Time for Actual Moves, it's best to only include moves that have non-zero theoretical units-per-hour values available. Otherwise the zero values will distort the results.

When estimating Operational Efficiency, actual productive hours in the time period can be calculated solely from tool-state transactions for the tool. It is the sum of the time when the tool was in the E-10 productive state. In FabTime's software,



Start Time	End Time	OEE	Availability Efficiency	Performance Efficiency	Quality Efficiency	Rate Efficiency	Operational Efficiency	Total Moves (Wafers)	Rework Moves (Wafers)	Scrap (Wafers)
(Hide)	(Hide)	(Hide)	(Hide)	(Hide)	(Hide)	(Hide)	(Hide)	(Hide)	(Hide)	(Hide)
Apr 18 06:00 Area	Apr 18 10:00	68.54	81.04	84.58	100	100	84.58	503 List	0	0
Apr 17 06:00 Area	Apr 18 06:00	72.35	78.35	92.4	99.94	100	92.4	3477 List	2	0
Apr 16 06:00 Area	Apr 17 06:00	62.01	65.67	94.42	100	100	94.42	2929 List	0	0
Apr 15 06:00 Area	Apr 16 06:00	68.93	72.34	95.48	99.79	100	95.48	3362 List	7	0
Apr 14 06:00 Area	Apr 15 06:00	75.61	85.81	88.21	99.89	100	88.21	3586 List	4	0
Apr 13 06:00 Area	Apr 14 06:00	75.27	82.97	90.72	100	100	90.72	3609 List	0	0
Apr 12 06:00 Area	Apr 13 06:00	63.72	71.1	89.61	100	100	89.61	3052 List	0	0

we calculate this according to the inputs from the MES in combination with auto-productive/auto-standby transactions generated based on lots entering and exiting the tool. That is, when the tool is empty, and a lot enters it (through a StartProcess or BeginRun transaction), we set the tool state to productive. When a lot exits the tool via MoveOut or EndRun transaction, if there are no other lots currently in process on the tool, then we set the tool state to standby.

It should be noted that actual productive hours will not be the sum of process times for lots processed on the tool. This is because there may be overlapping lots processed on the tool (for example, for linked tools and for batch tools). If there are overlapping lots processed on a tool, this means that actual productive hours will, in general, be less than the sum of the process time of the lots processed on the tool, because actual productive hours is the sum of the time when the tool was non-empty (thus counting overlapping lots only once, no matter how many might be in the tool at any given time).

OEE and Batch Loading

We've been asked recently about where maximum batch size is used in calculating OEE for batch tools. The answer is that maximum batch size is not used explicitly in OEE calculations at all. It does play a part in Performance Efficiency, however. The most efficient use of a batch tool, in a capacity sense, is to always run it full (though this may not be best for cycle time, as discussed in other newsletters). This means that when thinking about OEE, Theoretical Production Time for Actual Moves for batch tools should be based on the time that it would have taken to process all of the actual wafers IF full batches were run. Or in other words, the UPH rate for each move should be based on running the tool full. If the batch loading is accounted for in this manner, then it is not necessary to factor batch loading into the Operational Efficiency. To do so would be double-counting the inefficiency from non-full batches.

Actual OEE vs. Planned OEE

While it would be nice to think that planned OEE for tools should be 100%, in practice this isn't feasible. Very few tools in a wafer fab have 100% availability, for example. And few tools are planned to be run 100% of available time. In our software, you can enter a goal for OEE, as an average value to be used across the fab as a whole, or by individual tool. How should planned OEE be calculated? Let's look component by component.

First we have:

Availability Efficiency = Availability Efficiency = 100 - Unscheduled Downtime - Scheduled Downtime - Non-Scheduled time.

Calculating planned Availability Efficiency is quite straightforward, and simply requires using planned values for nonscheduled time, unscheduled downtime, and scheduled downtime. So we have:

Planned Availability Efficiency = 100 - Planned Unscheduled Downtime - Planned Scheduled Downtime - Planned Non-Scheduled time.

Next we have:

Quality Efficiency = (Total Moves - Scrap - Rework Moves) / Total Moves.

If we have expected values for units scrapped or for rework moves, we can use those to calculate a planned Quality Efficiency value. Alternatively, it may make sense to set the planned quality efficiency to be 100% (because we never really want to encourage scrap or rework, do we?). But in general we have:

Planned Quality Efficiency = (Planned Moves - Planned Scrap - Planned Rework Moves) / Total Planned Moves.

Planned Availability and Quality Efficiency are fairly straightforward. It's when looking at planned Performance Efficiency that things become a bit trickier. We have:

Rate Efficiency = (Theoretical Production Time for Actual Moves) / (Productive Time).

and

Operational Efficiency = Productive Time / (Productive Time + Standby Time + Engineering Time).

It probably makes sense to set planned Rate Efficiency to 100% in most cases, unless you have some situation in which you plan to run lots through a tool more slowly than they could be run (perhaps for yield improvement purposes?). However, setting a planned Operational Efficiency of 100% on any tool, even a bottleneck tool, is likely to be unrealistic for two reasons:

1. Most tools in a fab are not planned to run without any standby time. In fact, planning to run a tool without any standby time is equivalent to planning for ever-increasing cycle time. This is because (as has been discussed many times in this newsletter) in a variable environment like a fab, sometime a tool is forced to be idle (because WIP is held up at earlier tools, or because no operator is there to load the tool). Some catch-up capacity is needed to keep things stable. The less catch-up capacity that is provided, the higher the cycle time will be on the tool. It's common in many fabs to plan to run a tool no more than 85% of the time that it's available to manufacturing. Any planned OEE calculation needs to reflect this.

2. Engineering time is non-value-added, in the sense that time spent performing engineering experiments is time not spent producing good wafers. However, engineering time is often necessary for a fab's future success (qualifying the tool for a new recipe, for example). This is especially true for fabs that run development wafers. Thus the planned OEE calculation, for most tools, needs to include some degree of planned engineering time.

So, we might have a planned Operational Efficiency value calculated as:

Planned Operational Efficiency = Planned Productive Time / (Planned Productive Time + Planned Standby Time + Planned Engineering Time).

This is more cumbersome to calculate than just using 100%, but certainly more realistic, especially for non-bottleneck tools.

Calculating planned OEE values, using formulas like the ones in this section, can give you a goal to enter into OEE charts, and a basis for comparison between planned and actual performance. One caveat about using calculations like this is that it will be possible to exceed the planned OEE values in some cases (e.g. if availability is better than expected, or if standby time is less than expected).

OEE for Cluster Tools

As you can imagine, OEE for cluster tools is another level of complexity beyond what we've discussed here. There is a section in the SEMI E79 standard with calculations for flexible-sequence cluster tools, but we also know that several companies have developed their own independent formulas for cluster tool OEE. Whichever route you choose to follow with cluster tool OEE, keep in mind that you'll need formulas that can be explained and defended. Otherwise, you'll spend most of your time arguing about the calculations, and very little time improving productivity!

Conclusions

OEE starts out sounding very simple. Just compare what you are producing to the maximum that you could produce, and always strive to get closer to that maximum. However, as with many things associated with wafer fabs, as you start to dig into the details, and how to do the calculations using real data, things become a bit more complex. Especially when you have batch tools, and you have non-bottlenecks that you wouldn't really run 100% of the time, and you run development wafers in your fab, and you have cluster tools, and so on. OEE is widely used as a metric in the semiconductor industry because the tools that we use are so expensive. It's essential to use those tools to their full potential. In this article, we've recapped the formulas for OEE, and discussed some of the computational issues that go along with using OEE in practice. We welcome your feedback.

Closing Questions for FabTime Subscribers

Do you use OEE in your fab? If so, do you use any planned OEE values in your fab? Or do you simply compare actual OEE values to the target of 100% OEE? Do you make any modifications to your OEE for batch tools, or do you capture batch loading as part of theoretical production time?

Acknowledgements

Our thanks to **Suchit Kalyan** from Anadigics in New Jersey and **Mike Heirene** from International Rectifier in Newport, UK for discussions contributing to this article.

Further Reading

- J. Robinson and F. Chance, In-Depth Guide to OEE Resources, *FabTime Newsletter*, Volume 2, Number 4, 2001.
- J. Robinson and F. Chance, OEE and Cycle Time, *FabTime Newsletter*, Volume 3, Number 1, 2002.
- SEMI E79-1106, *Specification for Definition and Measurement of Equipment Productivity,* 2006. Available from http://webstore.ansi.org/.
- SEMI E10-0304E, *Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)*, 2004. Available from http://semi.org/.

Subscriber List

Total number of subscribers: 2783, from 468 companies and universities.

Top 21 subscribing companies:

- Maxim Integrated Products, Inc. (179)
- Intel Corporation (147)
- Chartered Semiconductor Mfg (86)
- Micron Technology, Inc. (81)
- Western Digital Corporation (77)
- X-FAB Inc. (68)
- Texas Instruments (66)
- International Rectifier (63)
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- Freescale Semiconductor (55)
- Analog Devices (52)
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- GLOBALFOUNDRIES (43)
- Cypress Semiconductor (38)
- Skyworks Solutions, Inc. (36)
- ATMEL (33)
- Seagate Technology (33)

Top 4 subscribing universities:

- Virginia Tech (9)
- Ben Gurion Univ. of the Negev (9)
- Nanyang Technological University (8)
- Arizona State University (8)

New companies and universities this month:

- Bloom Energy
- bTendo
- FSI International
- IXYS Semiconductor GmbH
- Singtel
- First Solar Inc.
- Edwards Ltd.
- Crocus Technology

Note: Inclusion in the subscriber profile for this newsletter indicates an interest, on the part of individual subscribers, in cycle time management. It does not imply any endorsement of FabTime or its products by any individual or his or her company.

There is no charge to subscribe and receive the current issue of the newsletter each month. Past issues of the newsletter are currently only available to customers of FabTime's web-based digital dashboard software or cycle time management course.

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FabTime'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.
- Specific reports for wire bond area are in process (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).