FabTime Cycle Time Management Newsletter

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Information

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

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Welcome

Welcome to Issue #5 of FabTime's cycle time management newsletter. The newsletter is a free monthly publication, distributed primarily by email to people interested in wafer fab cycle time. To subscribe, just send an email to Jennifer.Robinson@FabTime.com. This printed version is also available, for those prefer a print format. This month Frank Chance continues his discussion on Theory of Constraints by comparing TOC to just-in-time (lean) manufacturing. Sometimes these two methodologies seem to offer directly conflicting advice. Frank tackles this issue, and its implications for wafer fabs.

Thanks for reading! -- Jennifer

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Theory of Constraints and Just-in-Time Manufacturing

Introduction

As we discussed last time, the theory of constraints is commonly seen as a systems-improvement methodology consisting of these five steps:

1) Identify the system's constraint(s)
2) Decide how to exploit the system's constraint(s).
3) Subordinate everything else to the above decision.
4) Elevate the system's constraint(s).
5) If in the previous step a constraint has been broken, go back to step 1, but do not allow inertia to cause a system's constraint.

In The Goal, Alex applies this methodology to a variety of situations, including:

a) His company's performance measurement system.
b) His son's boy scout troop on a hike.
c) His factory floor.
d) His company's sales process.

Our concern here is the factory floor implications of the theory of constraints. In particular, one implication is that utilization of manufacturing resources should be intentionally unbalanced. The result is an identifiable bottleneck that is managed to optimize the throughput-accounting performance measures (throughput dollars, operating expense, and inventory dollars). Non-bottleneck resources are managed to support the bottleneck, not to maximize utilization.

Does an unbalanced line, however, conflict with just-in-time manufacturing? More generally, are the recommendations of the theory of constraints fundamentally at odds with those of just-in-time? To address this question, we must first specify what we mean by "just-in-time manufacturing."

Just-In-Time Manufacturing

Just-in-time manufacturing, as we will discuss it here, refers to the mindset spearheaded by Taiichi Ohno at Toyota Motor Company (see Chapter 4 of Factory Physics, 2nd edition, for a nice historical review that we are summarizing here). In an effort that dates to the 1940's, the company developed and implemented a number of improvement techniques aimed at two basic goals:

1. Just-in-time delivery of material precisely when it is needed.
2. Autonomation, or machines that are both automated and fool-proofed.

It is these two goals that drive just-in-time manufacturing. Several just-in-time manufacturing techniques have become quite well-known. These include setup reduction, total quality management, and kanbans. Kanbans in particular have developed a strong association with just-in-time manufacturing, which can cause considerable confusion. It is important to remember that kanbans are simply a means to an end within the just-in-time mindset. Just as drum-buffer-rope (an implementation technique) should not be confused with the theory of constraints (a methodology), kanbans should not be confused with just-in-time manufacturing.

We refer to just-in-time manufacturing as a mindset because it consists of a set of goals, e.g. a statement about what is important. By contrast, the theory of constraints is a systems-improvement methodology, e.g. a series of steps to take to improve system performance. To keep everything straight, we think of it like the table shown at the top of the next page.

Mindset:	Just-In-Time Mfg.	"Goal" Manufacturing
Goals:	Just-in-Time Delivery Autonomation	Increase Throughput $ Decrease Operating Expense $ Decrease Inventory $
Methodology:	Scientific Method	Theory of Constraints
Sample Implementation Technique:	Kanbans	Drum-Buffer-Rope

For the idea that just-in-time manufacturing relies implicitly on wide-spread use of the scientific method, see "Decoding the DNA of the Toyota Production System" by Spear and Bowen, Sept. 1999, Harvard Business Review (we are grateful to Russell Barton of Penn State for bringing this article to our attention). We should also mention that the theory of constraints methodology could be applied to just-in-time manufacturing - just as the scientific method is applicable to goal manufacturing. The table above simply shows our perception of common practice.

Returning to our earlier point, we believe that kanbans should not be confused with just-in-time manufacturing. As pointed out by Spear and Bowen, many companies have not been able to replicate the just-in-time manufacturing success of Toyota. The authors hypothesize that these latecomers have skipped past the methodology, going straight to the implementation techniques (similar to the calculus student who looks in the back of the book for an answer rather than working it out for himself). Spear and Bowen argue that the methodology is part of the magic - if a latecomer attempts to short-circuit the process with direct application of a technique like kanbans, the improvement will be minimal. Or it could be that an application of just-in-time methodology to the latecomer's particular situation would result in an entirely different set of implementation techniques.

"The methodology is part of the magic"

Similarly, drum-buffer-rope may be the logical answer when we apply the theory of constraints methodology to job-shop manufacturing. However, drum-buffer-rope may not be the answer if we apply theory of constraints thinking to a radically different manufacturing environment.

Unbalanced Lines

Having finished our rather lengthy discussion of just-in-time manufacturing, we return to our central question, namely: Do the manufacturing recommendations of the theory of constraints (an unbalanced line being one of these) conflict with just-in-time manufacturing? Or to rephrase the question: How do we reconcile Toyota's success with Jonah's quote in The Goal that "the closer you come to a balanced plant, the closer you are to bankruptcy"?

[Note the implicit assumption we are making that theory of constraints thinking would always lead to an unbalanced line, while just-in-time thinking would always lead to a balanced line. Is this assumption valid?]

To resolve this apparent conflict, consider a factory composed of a single tool. This tool processes jobs one at a time, with process times that are independent, identically distributed exponential random variables. Incoming jobs are delivered to the tool one at a time by a warehouse operator. Assume the round-trip travel times to the warehouse are independent, identically distributed exponential random variables. Let lambda = the arrival rate of jobs (jobs per hour) = 1 / (mean round-trip time), and let mu = the service rate (jobs per hour) = 1 / (mean process time). We know that if

lambda = 0.99 mu,

then the factory is very close to its capacity, and in the long run we will see huge fluctuations in the size of the waiting queue (the factory is simply an M/M/1 queue). The factory will achieve nearly its maximum theoretical output (long-term throughput will be 0.99 mu jobs per hour), but at a the price of very high average WIP - nearly 100 jobs on average.

"The closer you are to a balanced plant, the closer you are to bankruptcy."

Consider what happens, however, if we change the operating practice of our factory ever so slightly. Suppose the warehouse operator is instructed to stop deliveries when the pile of waiting jobs reaches 20, and to restart deliveries when the pile of waiting jobs falls to 10. Assuming perfect workmanship from the warehouse operator, our tool rarely falls idle (only when an extraordinarily long round-trip to the warehouse causes the tool to use up its buffer of queued jobs), but its queue of waiting jobs never rises above 20. In this case, the factory achieves a long-term throughput only slightly less than the above case, but with a much smaller average WIP. Doesn't this contradict queueing theory?

In fact it does not, because the modified factory is no longer an M/M/1 queue. The new operating practice means that the inter-arrival times of jobs are no longer identically distributed, they are not all exponentially distributed, and they are certainly not independent of the processing times. The factory has switched from a push system to a pull system.

Isn't This Sneakily Similar to Kanbans?

Yes, the modified factory looks very much like it has installed a simple kanban system to limit the WIP located in front of the tool.

Isn't This Also Sneakily Similar to Drum-Buffer-Rope?

Right again. The modified factory looks very much like it is using the constraint (the single tool must by definition be the constraint) to control the release of work from the warehouse to the factory.

How does this relate to balanced lines vs. unbalanced lines?

Consider the original, unmodified factory. Suppose instead of a single tool it contained 100 tools in sequence, each with the same process time distribution (e.g. equal processing rates), and with instantaneous deliveries of WIP from one tool to the next. Over the long run, each tool would have average WIP of about 100 jobs, or a total average factory WIP of 100 * 100 = 10,000 jobs! This is a perfectly balanced factory, and it is exactly this situation that Jonah refers to when he says that pursuing a balanced factory is equivalent to pursuing bankruptcy.

The theory of constraints solution is to recognize the logistical difficulty of coordinating 100 perfectly balanced tools, and to instead strive for a situation that is much easier to manage. That is, a factory in which only one of the tools is running nearly at capacity (an unbalanced line), and then tying factory releases to this tool via drum-buffer-rope.

The just-in-time solution is to modify the system via a set of WIP-limiting techniques (such as kanbans), and to systematically reduce sources of variability in the system so as to make these techniques viable. After all, one of the benefits of WIP is to protect against variability, and to really limit the WIP at every tool in a balanced line, just-in-time manufacturing must radically reduce such variability.

A Reconciliation

So we can reconcile Jonah's quote with Toyota's success if we recognize that both the theory of constraints and just-in-time manufacturing use WIP-limiting techniques - the difference lies in the extent to which these techniques are applied throughout the factory. In fact, Jonah's quote might more accurately (but with less dramatic effect) be restated as:

> "the closer you come to a balanced plant, without an effective WIP-limiting technique and without an effective variability reduction program, the closer you are to bankruptcy."

Implications for Wafer Fabs

If you are going to adopt a just-in-time manufacturing mindset, or a goal manufacturing mindset, set aside sufficient time to apply the entire process. Saving time by skipping to the answers (e.g. using existing implementation techniques such as kanbans or drum-buffer-rope) will likely result in little long-term gain. To our knowledge, there is little documented proof of substantial long-term gains from either of these techniques in wafer fabs. Perhaps the perfect implementation technique for wafer fabs is just waiting to be discovered… but it's likely to be a lot of work finding it.

Next Time

Performance measures typically used in wafer fabs, and how (and why) they sometimes conflict.

Recommendations

■ The Crazy About Constraints website (www.rogo.com/cac/) was one of the first websites developed for TOC. It includes definitions, software descriptions, links, and even (for better or for worse) a section on TOC humor.

■ The Lean Manufacturing (www.cre8tivetraining.com/lean/index.html) website, by Creative Training, includes a nice glossary of terms, as well as overviews of concepts like Kanban, focused factory, pull methods, SMED, etc.

■ An excellent online research database is available at citeseer.nj.nec.com/cs. It's maintained by NEC Research Institute, and includes many technical articles. What's cool about it is that for included articles, you get links to entries for the references, to other articles that referenced that article, and to other "related articles." There are lots of semiconductor-related articles. I noticed in particular many articles by our friends at the University of Wuerzburg (see http://www-info3.informatik.uni-wuerzburg.de/ for their website).

Community News

Job Change - Scott Mason

Scott J. Mason recently completed his PhD in Industrial Engineering at Arizona State University, and has recently started work as an assistant professor at the University of Arkansas. He is teaching the Electronics Manufacturing Processes course at Arkansas and will be establishing a semiconductor back-end research lab in the near future in concert with the university's High Density Electronics Manufacturing facility (HIDEC). If you have any comments or suggestions for Scott, he can be reached at mason@engr.uark.edu or at 501-575-5521.

IE Job Availability Notice

Read-write head maker Headway Technologies of Milpitas, California---a TDK company---is looking for an industrial engineer. Specific duties will be: continually gathering information about the current operation of Headway's rapidly changing wafer fab, compiling and entering the new information into Headway's Factory Explorer model, using the model to conduct capacity and what-if analyses to optimize the performance of the fab, reporting the results of these analyses (in writing and verbally), participating in and leading process-improvement teams, and learning how to update and build new versions of the model so as to be able to cover for the Lead Industrial Engineer during his absence and perhaps assume his responsibilities in the future as the department evolves. Resumes should be submitted via Headway's web site at www.headway.com, where a more detailed job description also resides. Questions can be directed to Lead Industrial Engineer Bob Kotcher at (408) 934-5405.

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