Eliminate Production Bottlenecks; Manage Manufacturing Constraints

Bottlenecks and constraints are two terms often used interchangeably in Demand-Driven Manufacturing as well as in discussions on Lean Manufacturing and flow. It's easy to use one term accidentally when you actually mean the other. However, since these two limiters on throughput need to be addressed differently, it's important to understand the distinction.

In this paper, we'll define what we mean by both production bottlenecks and constraints, look at their similarities and differences, and recommend strategies for dealing with each. We'll also share several stories of how manufacturers have implemented constraints management techniques to increase flow in their facilities.

What's the Difference Between a Bottleneck and a Constraint?

A bottleneck represents a temporary overload on a resource. The cause of the overload can be wide-ranging: a malfunctioning machine, an absentee operator, missing tools, unexpected materials shortage, newly hired personnel, etc. While a bottleneck can cause serious delays, these are all issues which can be "fixed." A constraint, on the other hand, is a long-term and persistent limiter to flow. For example, the constraint might be a work center that cannot go any faster

BOTTLENECK
A temporary overload on a resource.

CONSTRAINT
A long-term and persistent limiter to production flow.

because the equipment is already operating at maximum speed or a process, such as a chemical reaction, that takes a set amount of time.

There are other types of constraints on throughput that don't have to do with production capacity. For instance, an onerous regulation or a persistent shortage of raw materials can limit your ability to fill orders. In this paper, however, we will just consider internal production constraints as these are the constraints over which production managers have the most control.

Problem or Opportunity for Continuous Improvement?

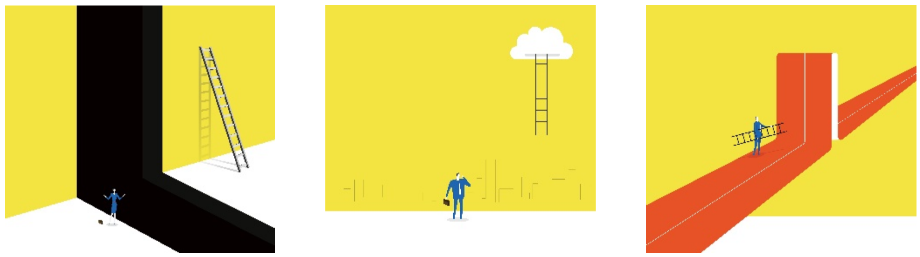
While bottlenecks are a problem, Lean practitioners might look at them as an opportunity for continuous improvement. For example, a bottleneck issue associated with missing tools can be addressed through better tools management and maybe a kaizen event in the work center. If it's taking too long to get operators up to speed, you can strengthen your onboarding processes. Malfunctioning machines can be put on a preventative maintenance program. Unfortunately, fixing a bottleneck isn't always cheap or easy, but it can be done.

Constraints, as mentioned, are more persistent and not so easily addressed. If you've ever read the business novel *Velocity*, you might remember the autoclave the production team nicknamed "Godzilla." It took a set amount of time to process components through Godzilla, and not a minute less. Initially, the team spent a lot of time improving processes elsewhere in the flow, but because Godzilla was the constraint, none of these improvements had the expected impact on the bottom line.

Though constraints are persistent, they also present an opportunity for improvement. For example, you might be able to outsource the process to someone who can do it faster. Or maybe you just outsource some of the processing for additional capacity. You might also decide to invest in new capital equipment. But the bottom line is, unless you do something, your flow rate will never be faster than the constraint.

Constraints also serve a positive role in a manufacturing environment by giving operations managers the levers they need to control throughput. Without them, all resources are viewed as equally important, making it challenging to know where to focus when you want to increase (or decrease) throughput. Furthermore, when you treat all resources equally; a disruption to any one of them can impact flow. By focusing on the constraint, operations managers have a much more manageable and controllable environment.

CONSTRAINT or BOTTLENECK?



Why You Should Always Try to Remove (Non-Constraint) Bottlenecks

In our view, so long as a bottleneck isn't also a constraint, you should always try to remove it even if it isn't preventing you from meeting demand. That's because bottlenecks are usually unpredictable: You don't know exactly when that machine is going to break down, that employee isn't going to show up for work, or that supplier's shipment is going to be late.

Uncertainty is always a problem in manufacturing because it puts you in a reactive mode. Suddenly you need to find replacement parts, call in someone on their day off, find an alternative supplier, etc. But more than that, you need to adjust your production schedule to accommodate the delay. Not only is that a headache, but it can also cause ripples throughout your facility that extend to your suppliers and customers.

Sometimes bottlenecks are easy to identify. Although their timing is unpredictable, you know with certainty they will happen. Let's say you source critical components from a vendor whose on-time-delivery history is less than stellar. You don't know which deliveries will be late or by how much, but you know that some inevitably will be. These are the bottlenecks you can get ahead of before they become a problem. In this example, you can work with the supplier to improve performance or find another source. This aspect of vendor performance management isn't so much about decreasing lead times as it is about improving predictability.

Other types of bottlenecks are not so easy to predict. A piece of equipment that appears to be operating perfectly suddenly breaks down, or an operator is feeling under the weather and not able to keep up their normal pace. The signs of impending problems are often there, but unless you have clear visibility into your shop floor, they are easy to miss until you notice that production is backing up or someone raises the alarm.

SyncView manufacturing visualization and communication software gives production managers a bird's eye view of their area from any device, so they can take quick action to eliminate bottlenecks.

Know When to Eliminate a Constraint; When Not To

You can never eliminate all constraints, nor would you necessarily want to. It really all depends on whether the capacity of your constraint is sufficient to meet demand.

Let's take a look at a very simple example where production passes through three work centers in sequence: A, B, and C. (Figure 1.) Work center A can process ten pieces an hour, work center B can process eight, and work center C can process twelve. Clearly, output from the line is restricted by work center B and will never be able to produce more than eight pieces an hour. If the factory never sells at a higher rate than that, eight pieces an hour is sufficient, and the factory managers don't need to add capacity.

Figure 1. Work center B is the constraint.

In this particular factory, however, they need to ramp up production due to demand, so they refurbish an older piece of equipment and place it back into service. It’s not very efficient, but combined, work centers B1 and B2 can now produce thirteen pieces an hour. (Figure 2.) Now, the constraint has moved to work center A, and the new maximum capacity is ten pieces an hour. If that’s sufficient to meet the higher demand, the factory does not need additional capacity. If it is not, they will now need to find a way to augment the capacity at work center A.

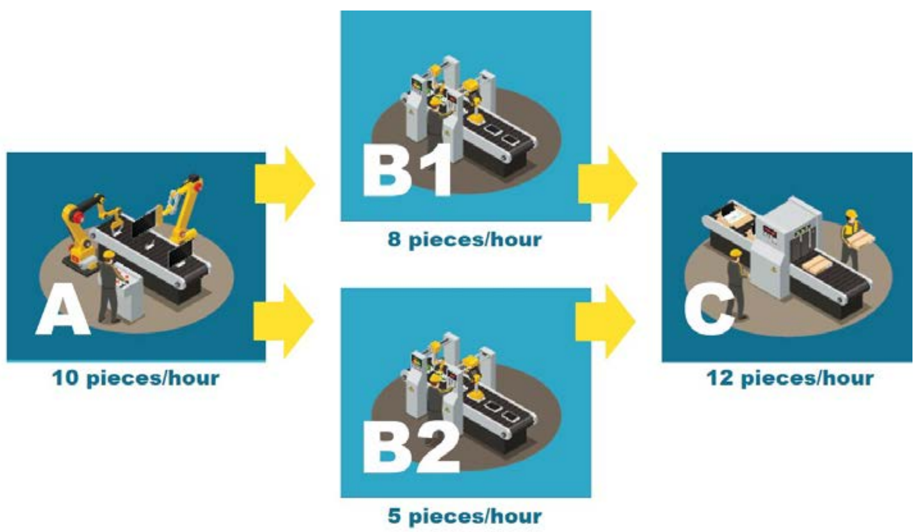
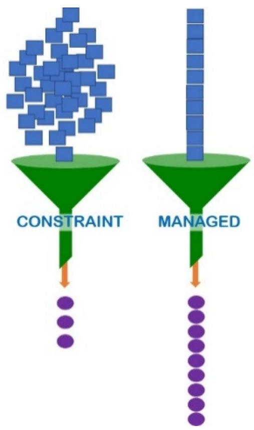


Figure 2. Adding capacity anywhere but at the constraint is a waste.

This example is almost painfully simple, but it makes an important point very clear. Adding capacity anywhere but at the constraint is waste. (Eliminating this kind of waste is a key concept in constraints management or the Theory of Constraints.) Unfortunately, a lot of effort is put into adding capacity at non-constraints or in situations where demand may not warrant it. See *Smart Capital Investing in a Recovering Economy*.

That said, there are times when you want to focus on a non-constraint. For example, if work center A is producing an average of ten pieces an



When flow is not properly aligned to the constraint, pre-constraint resources may overproduce, causing WIP to pile up in front of the constraint.

hour, but the range is anywhere from two pieces to 25, reducing variability at work center A can reduce the need for buffer WIP in the system. See the section on Variability for more information.

The Dangers of Ignoring a Constraint

Just because you may not need to eliminate a constraint, doesn't mean you can just ignore it. A poorly managed constraint can create three major issues:

Inability to meet demand – In effort to maximize capacity utilization, the factory manager may focus on improving utilization rates. On the surface, this seems logical. There are only so many hours in a shift, and you want your constrained resource in use for as much of that time as possible.

However, focusing exclusively on utilization rates for the constraint - especially if these metrics are used to gauge facility or worker performance - can lead to poor decision making. For example, an operator may process orders out of priority or process more parts than are needed in an effort to minimize change over time. This may raise the constraint's utilization rate, but it can also result in delayed delivery of other orders and negatively impact the line's on-time delivery (OTD) performance.

Excess pre-constraint WIP – When flow isn't properly regulated to a constraint, pre-constraint resources may also overproduce, causing WIP to pile up in front of the constraint. This is especially an issue if the performance of these resources is also based on traditional utilization or productivity metrics.

Excess post-constraint WIP – When operators at the constrained resource run larger batches to raise utilization rates, this also creates excess WIP after the constrained resource because the work center is creating materials that are not yet needed. WIP material piles up in front of the downstream resource while it waits to be processed.

In addition to improving hard metrics like WIP and OTD, constraints allow operations managers to focus their efforts. Ignoring your constraints while trying to "fix" everything else to improve key metrics, is a recipe for a chaotic, unpredictable manufacturing environment.

VARIABILITY

One of the benefits of managing to constraints is that it lowers WIP. However, reducing WIP to near zero levels isn't realistic for most manufacturers as you will likely always have some level of variability. You want WIP to be at a level where it protects against disruption from the current rate of variability. Often, time or inventory buffers are used to strike the right balance.

In the basic DBR model (Figure 3) the buffer in front of the constraint ensures that the constraint always has enough materials to keep working even if the output of the upstream work centers drops off temporarily, but not so much WIP that it reduces the velocity of the system. The more variable the upstream work centers are, the more protection is needed.

BUFFER STOCK
Protects the ***customer*** in the event of a disruption or demand change.

SAFETY STOCK
Protects the ***manufacturer*** in the event of a disruption from suppliers or upstream processes.

Strategies for Constraints Management

Demand-Driven Manufacturing (sometimes called pull-based or respond manufacturing) practitioners manage production flow based on constraints. This is where the principles of constraints management or the Theory of Constraints (TOC) comes into play in a Demand-Driven Manufacturing environment. This section explores some of the strategies these practitioners use to manage constraints.

The Drum-Buffer-Rope Method

The drum-buffer-rope (DBR) method is a planning and scheduling strategy based on the Theory of Constraints. DBR seeks to maximize the utilization of the constrained resource and, as the name implies, there are three main components.

The drum: The constrained resource that sets the pace for production. In Figure 3, that would be work center B since it is the slowest of all the work centers in the line.

The buffer: Time that is represented in the form of inventory that protects against material shortages and allows us to maximize utilization of the constraint. In Lean, buffer inventory is not precisely the same thing as safety stock, so be wary of lumping these two concepts together.

The rope: The pull signal that tells the upstream work centers when more material is needed at the work center.

Our simplified manufacturing line now looks like this when viewed from the perspective of drum-buffer-rope:

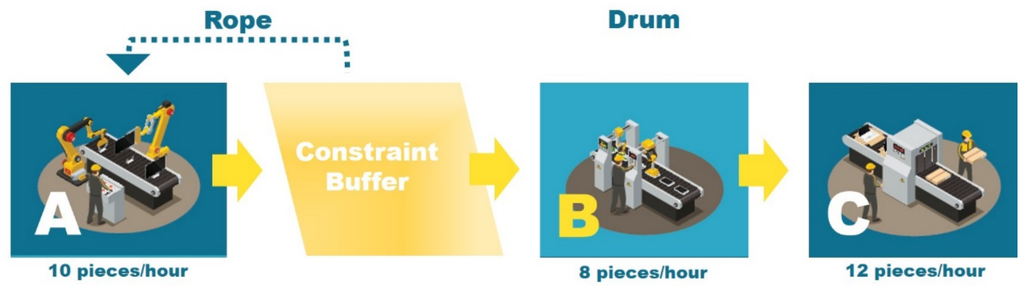


Figure 3. Drum-Buffer-Rope is a Constraints Management/ Theory of Constraints (TOC) principle which seeks to maximize the utilization of the constraint resource.

Most manufacturing environments, however, are more complex than the example shown in Figure 3. When work cells or lines are working concurrently on an order and need to converge at some point in the process, additional buffers and ropes are introduced to synchronize all activity to the pace of the constraint. The DBR three buffer system (Figure 4) is an example where multiple lines or work cells are working to complete an order.

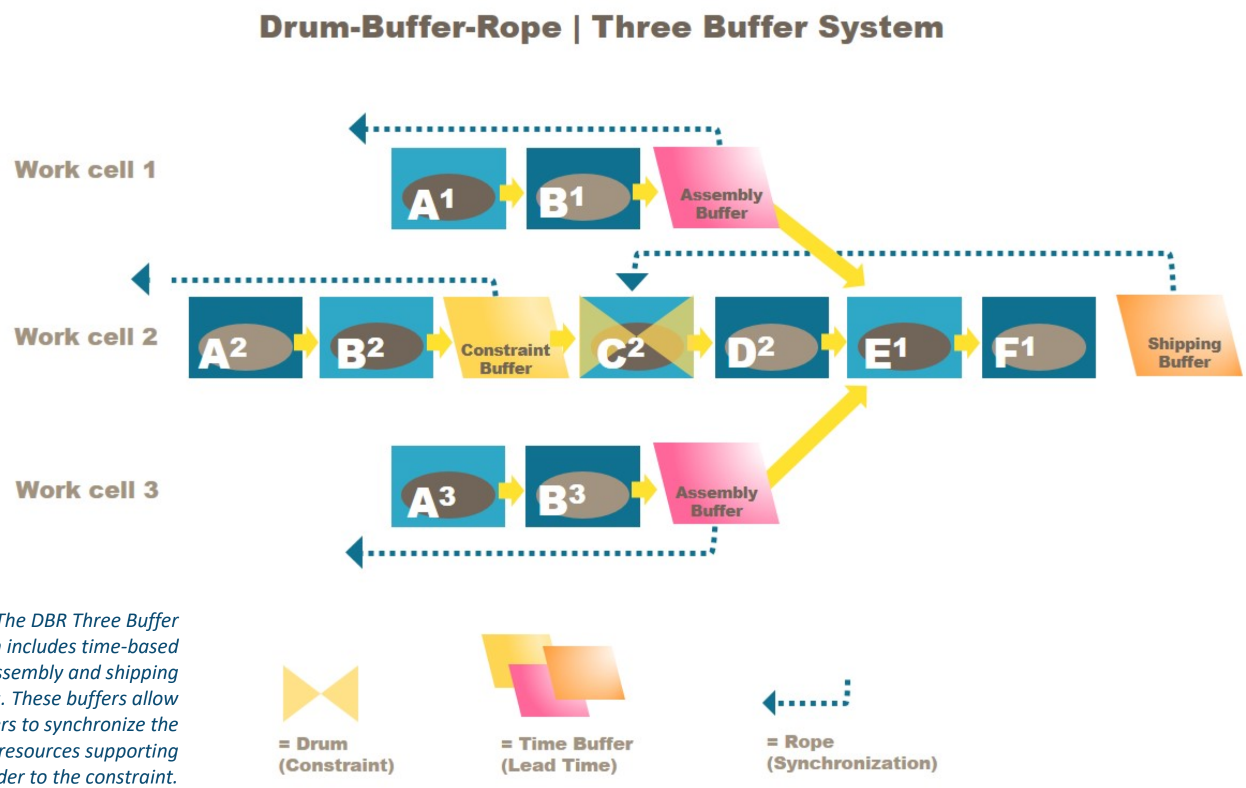


Figure 4. The DBR Three Buffer System includes time-based constraint, assembly and shipping buffers. These buffers allow manufacturers to synchronize the schedule of all resources supporting the order to the constraint.

The DBR method works great when executed successfully, and there is a newer, simpler option, aptly named Simplified Drum-Buffer-Rope (S-DBR). Like DBR, in S-DBR, the schedule is created by working backwards from the customer's delivery date (Figure 5). Unlike DBR, S-DBR assumes there is only a single, external constraint: The variability of the market. This removes the need for constraint and assembly buffers and assumes the shop can produce all orders on time with a single shipping buffer accounting for variability.

Because it doesn't account for internal constraints, S-DBR fails to address the key component for driving flow: Managing and releasing work into production based on the pace of the drum (constraint).

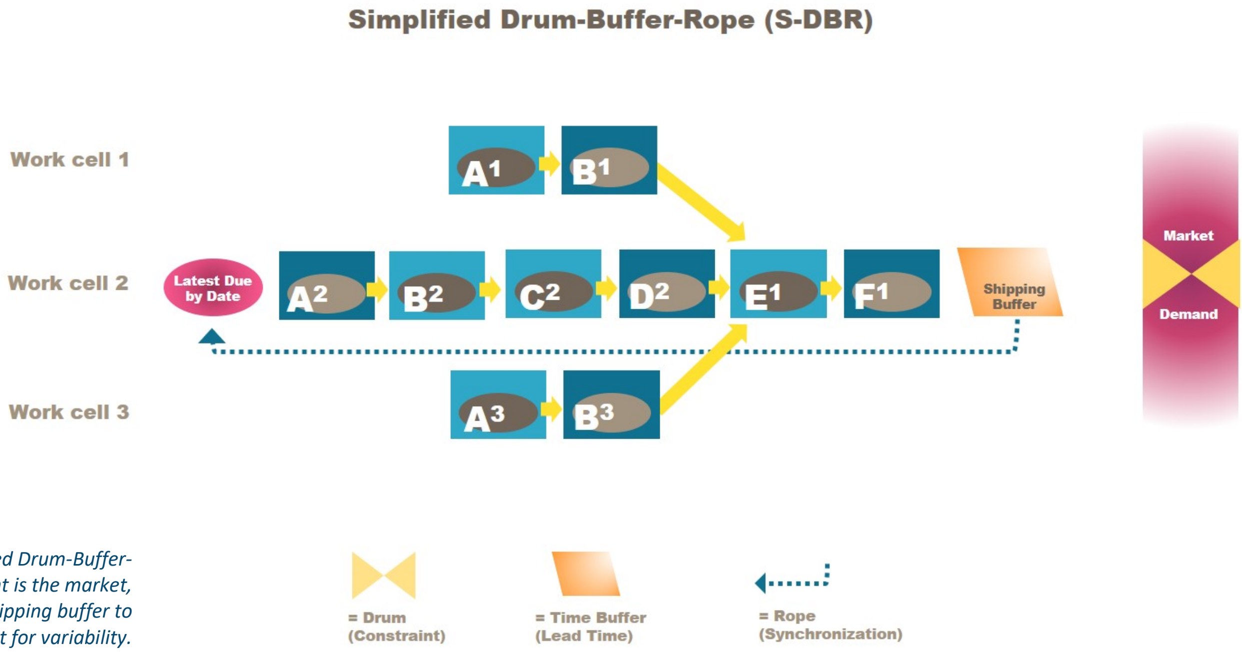


Figure 5. In Simplified Drum-Buffer-Rope, the constraint is the market, requiring only a shipping buffer to account for variability.

Constraints Management for Today's Manufacturing Environments

Technology has enabled the evolution of DBR and S-DBR into a more automated, holistic process. CONLOAD™ technology from Synchrono® allows manufacturers to manage and synchronize the entire value stream to the pace of the constraint(s), creating an environment where work flows throughout the production process.

CONLOAD™ is a patented scheduling algorithm included in Synchrono® SyncManufacturing® software. Unlike DBR/S-DBR, SyncManufacturing software with CONLOAD™ fully automates the synchronization of all elements required to execute the order – people, materials, equipment, processes and data – and establishes a capable to promise date (CTPD) based on the customer's need (which is monitored throughout production). The schedule is created based on the coordination of these three factors: CTPD, synchronization of order elements, and the pace of the drum (e.g., capacity of the constraint). The software operates in real-time, automatically setting priorities and adjusting for variability. [Watch this video to see how CONLOAD™ works.]

CONLOAD™ Scheduling Technology

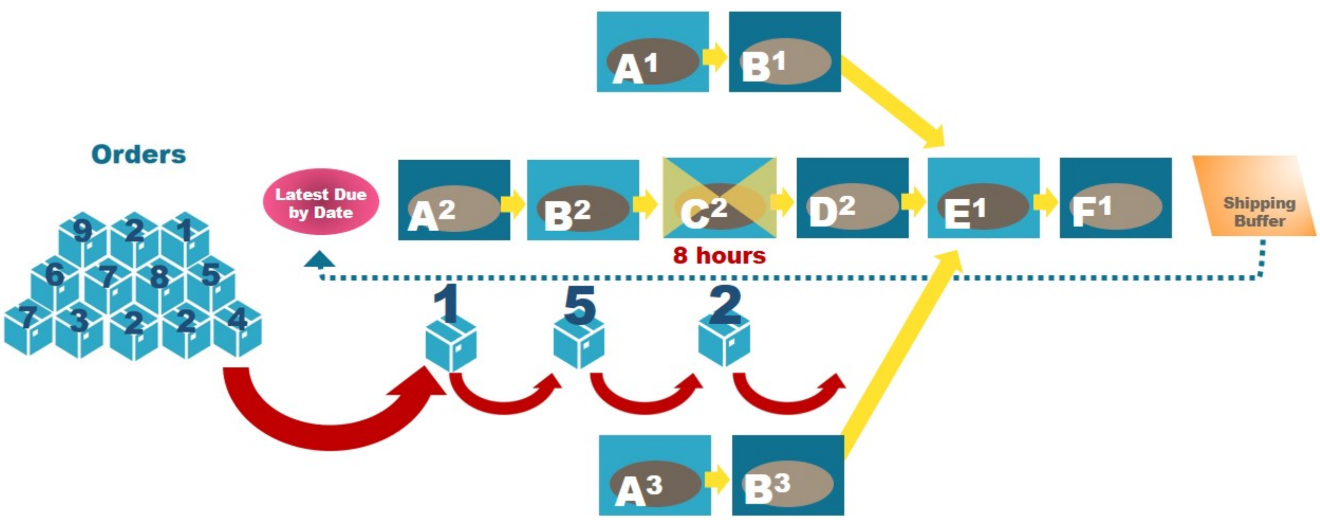


Figure 6. CONLOAD™ releases work into production based on how many hours the order takes on the constraint(s). In this example, work center C² is the constraint (Drum). Because 8 hours' worth of WIP is enough to keep work center C² from running out of work, CONLOAD sets the WIP cap at 8 hours.

Managing Flow to Your Constraints

Let's add the orders waiting to be released into the production system to complete our picture of how CONLOAD™ technology automates the process for scheduling and constraints management. These orders are shown in Figure 6. The numbers on the boxes represent the work load, or run time, of the order on the constraint.

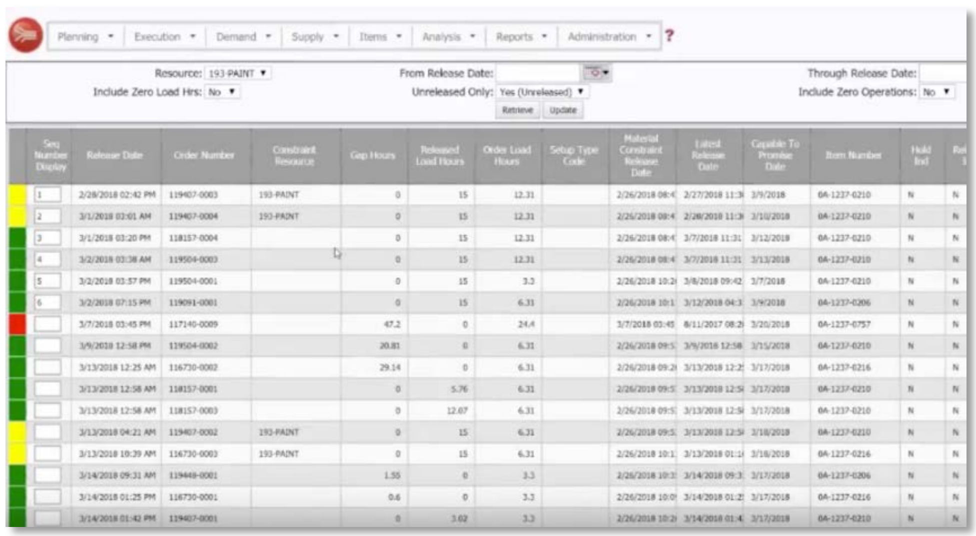
Once the optimized WIP level is released to the shipping buffer, any further release is tied to the rate of the constraint. In the example, work center C^2 is the constraint (Drum). Because it takes 8 hours to complete an operation on C^2, CONLOAD™ establishes the pace of the constraint at 8 hours and releases work into the production system such that the maximum work load from the point of release through C^2 is no more than 8 hours. If more than eight hours of work load is queued into production (this is possible because an order might be for more than the constraint can handle or the next order in line raises the number above eight), CONLOAD™ will wait to release more orders until work center C^2 sends enough orders to work center D^2 to drop the total number of hours at, and preceding work center C^2, to less than eight.

CONLOAD™
= Consistent Load

1. Maximize throughput
2. Eliminate negative effects of too much WIP
3. Maintain consistent queues and cycle times
4. Create a more predictable environment
5. Increase flow throughout production
6. Reduce lead and cycle time

In environments with more than one constraint, CONLOAD™ will evaluate the constraints associated with each order and release work into production based on the pace of the most over-loaded constraint.

CONLOAD™ is always on and always monitoring the pace. Should the constraint work faster or slower than expected, CONLOAD™ will adjust the release of orders accordingly so that production flow is always optimized, and throughput is maximized.



The Master Scheduling screen in SyncManufacturing® software helps prioritize the release and flow of work according to Lean, Constraints Management and pull-based manufacturing principles.

Because SyncManufacturing® software with CONLOAD™ synchronizes the entire value stream, it has the ability to make real-time adjustments for variability while keeping the end goal in mind: The customer's desired delivery date. The shipping buffer provides further assurance of customer satisfaction and the achievement of high on-time delivery metrics.

To learn more about how CONLOAD™ works, watch the YouTube video: *Manage Manufacturing Constraints and Optimize Production Flow With CONLOAD*.

Driving Real Results Through Constraints Management

Theory is all well and good, but manufacturers inevitably want to know what kind of bottom line benefits they can expect from implementing principles like drum-buffer-rope and CONLOAD™ for automated constraints management. Here are three examples that can help you explore what applying these concepts might mean for your organization.

Sumiden Wire – This manufacturer had a constraint that was only being used at 65 – 70% of capacity. They wanted to increase utilization in order to meet demand for their steel wire products. By using Synchrono® SyncManufacturing® software to manage the release of orders into the system, they were able to deliver approximately $60,000 dollars to the bottom line through increased constraint utilization in one month alone. *Read the full story*.

"Our production planner can now see which orders have all the raw materials available and issue those orders to production even if they are not due immediately. In the past, the planner would have to sift through too much information to see that. As a result, we'd just shut down the machine. Since we've had Synchrono, that machine has run continually."

- Brian Burr, Deputy General Manager and Manager of Business Planning, Sumiden Wire

Rex Materials Group – This manufacturer is a big believer in the Theory of Constraints and had implemented drum-buffer-rope principles in their factory in the 1990s. However, they had outgrown their manual systems and wanted to replace them with an automated system that would allow them to take their application of drum-buffer-rope to the next level. *Read the full story*.

"The biggest change for us has been reducing our lead times. Before we generally needed three to four weeks lead time. Today, we ship between 30% and 40% of our products within five days of receiving an order. For some products, we receive the order today, make it tonight and ship it tomorrow with no extra effort."

- David Rex, President and CEO, Rex Materials Group

Orbital ATK (now Northrop Grumman Innovation Systems) – Like the fictitious manufacturer in the business novel, *Velocity*, Orbital ATK manufactures carbon fiber components for the aerospace industry, and their autoclaves can be a constraint. Though it should be noted that any resemblance between Orbital ATK's business and Hi-T, the manufacturer in Velocity, is purely coincidental, Orbital ATK's story gives TOC and Demand-Driven Manufacturing practitioners an excellent, real-world look at how an actual aerospace and defense manufacturer manages flow through its facilities. *Read the full story*. Or, watch the on-demand webinar: *How Orbital ATK Enabled the IIoT and a Visual Factory*.

	DBR (3 Buffer System)	S-DBR	CONLOAD™
Type of Constraints Managed	Internal	External	Internal/External
Constraints Management Strategy	**Schedule to the customer's desired delivery date** using three time-based buffers - Constraint, Assembly and Shipping – that synchronize all resources supporting the order to the constraint.	**Schedule to the customer's desired delivery date.** Manage market variability through a time-based shipping buffer.	**Schedule to the customer's desired delivery date** by managing and synchronizing the entire value stream to the pace of the constraint(s). Involves the coordination of three factors: •Synchronization of all order elements •The capacity of the constraint (pace) •The customer capable to promise date (CTPD).
Pro Tips	**The shortfall in implementing DBR is often in execution.** Avoid expense and frustration by investing in a experienced resource/consultant who has a track record of successful DBR implementations.	**Simplified DBR is only suited for simple, linear environments focused on market variability** – not on increasing production flow and throughput	**Investment in automation can produce significant results.** Focus your business case on the ability to quickly take action on and improve performance-based metrics such as those referenced in the *Manufacturing Operations Metrics for Action Guide.*

An overview of three methods for constraints management addressed in this paper.

The Bottom Line

Manufacturers have struggled for decades to match capacity with demand. It seems there's always too much of one and not enough of the other. Demand picks up, and you just can't seem to make product fast enough. Then, as soon as you invest in additional capacity, things slow down again, and you end up with overinflated inventories of materials and finished goods.

Managing flow based on your constraints has a number of benefits: It can lessen the need for capital equipment and facility investments by maximizing resource utilization; it can decrease inventory levels, and it can reduce cycle times. By implementing Demand-Driven Manufacturing software such as SyncManufacturing®, everything is done in real time, eliminating the need to always play catch up to the reality of your shop floor and market demand.

Layer Your Existing Systems with Modern Demand-Driven Technology

Transitioning to a Modern Demand-Driven Manufacturing environment doesn't mean you need replace all your existing systems. Web-based Synchrono® solutions were developed to work with your existing ERP and other systems/data sources, helping to preserve those investments and extend their value.

STRATEGIES

- Digitize
- Synchronize
- Visualize

- Adaptive production planning, scheduling and execution
- Supply and capacity planning to align with projected demand
- Automated inventory replenishment for supply chain execution and collaboration
- Real-time, synchronized, visualization and communication
- Connect and aggregate data from any source to analyze, predict, prevent and automate activity. *Powered by Savigent*
- Real-time alert notification and escalation management

GAME-CHANGING REALITIES

Request a software demo at Synchrono.com.

synchrono manufacturing software