



White Paper

[Managing in a Supply Constrained Environment]

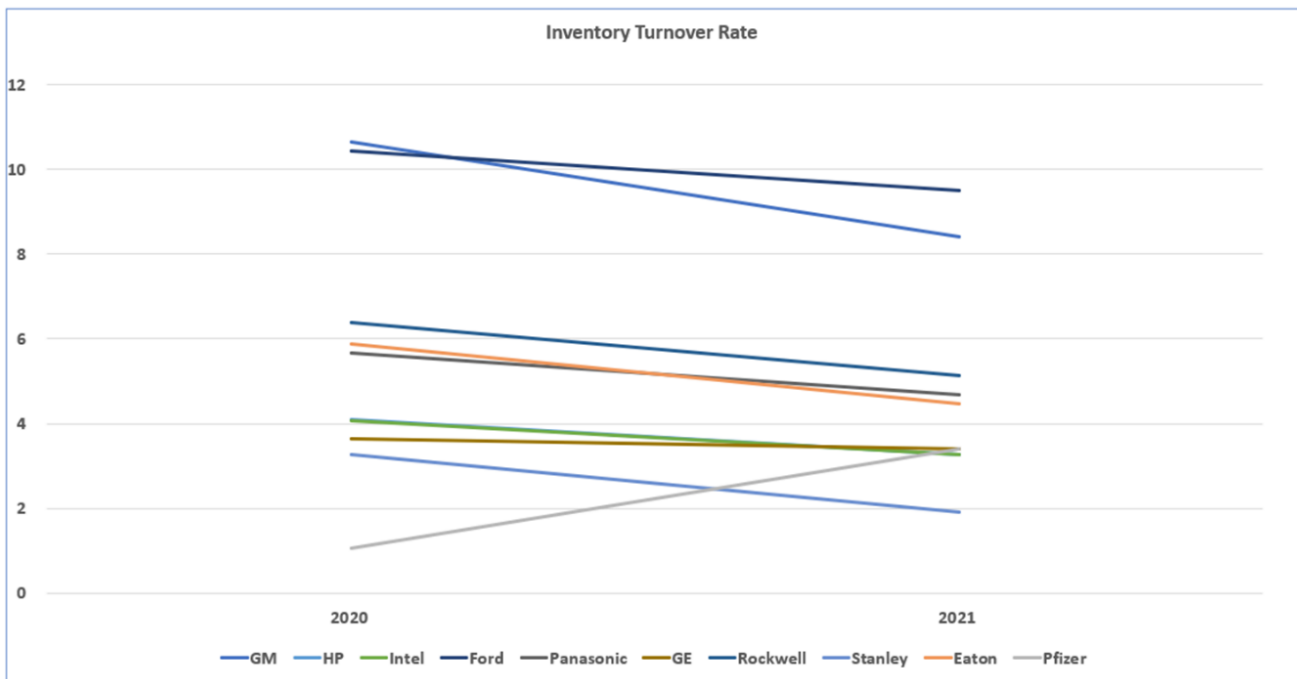


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Since the onset of the COVID-19 pandemic, manufacturers have been working to overcome severe supply constraints in key components of the products they produce. Most notable has been the impact shortages of key electronic components is having on the automotive industry. Chip shortages have restricted total automotive production rates and limited features and capabilities in those vehicles that have been sold.

The result of the supply shortages has been reduced or stagnant revenue growth rates for manufacturers as they've been unable to deliver a growing backlog of orders from their customers. Concurrently, manufacturers are seeing inventories grow well above pre-pandemic levels. Despite severe supply constraints of key materials, manufacturers are seeing substantial growth in the inventory levels of non-constrained materials and components. While finished goods inventory may be constrained, inventory turns overall have suffered.

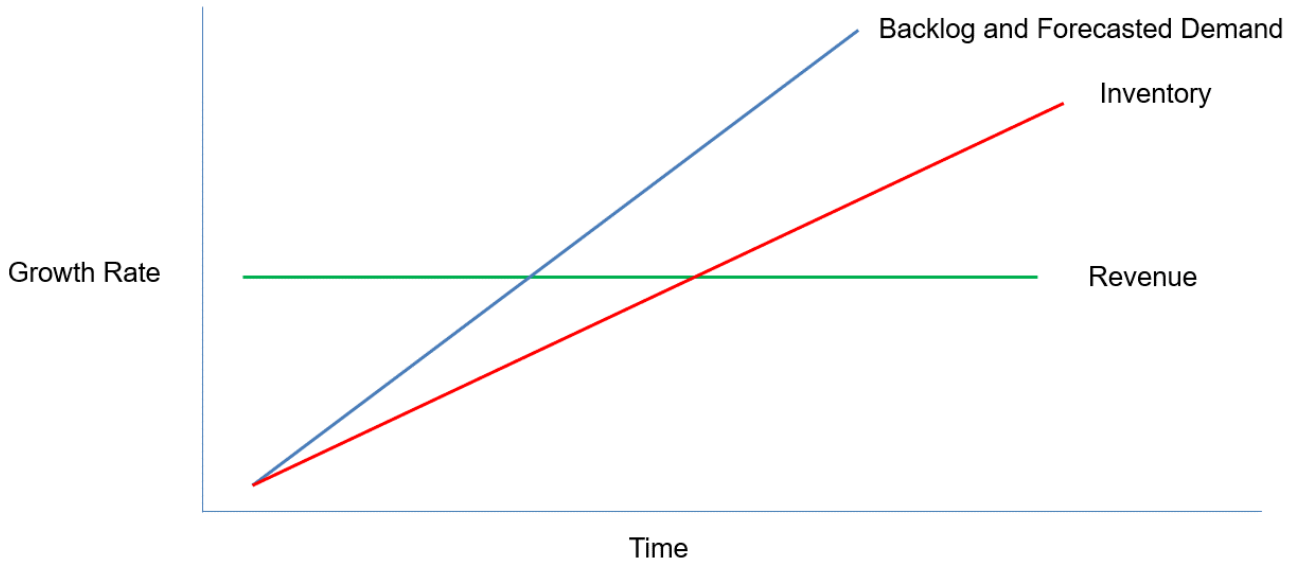
Based on publicly available financial information, the following graph shows the 2020 to 2021 year to year change in inventory turnover rates for a variety of notable companies. All declined with the notable exception of Pfizer which experienced an acceleration, likely due to the impact of their COVID vaccine on their financial results.



The core issue is that material planning systems are generating supply recommendations that are beyond the pace of supply for constrained materials. The result is that those items in the final assembly that are not experiencing a supply constraint will continue being planned to the unconstrained demand the manufacturer is struggling to satisfy. Those materials will continue to be ordered and converted into inventory while the production usage will slow to the rate of supply of the constrained materials.



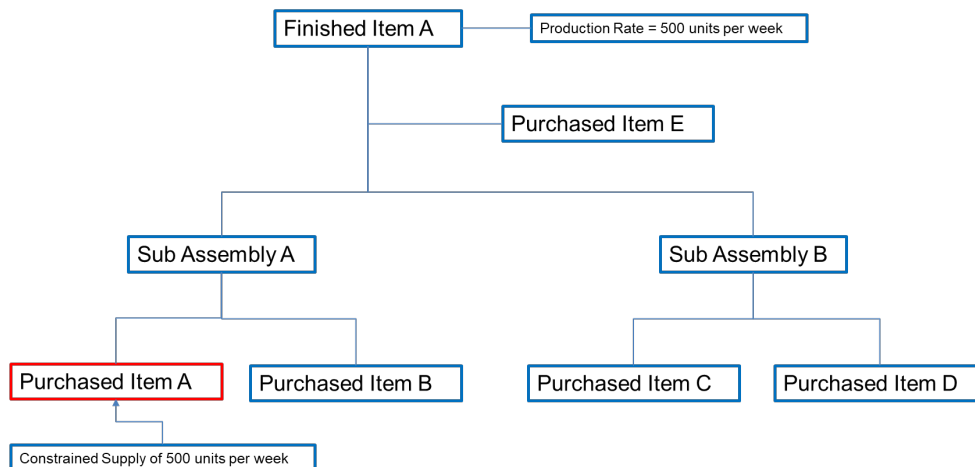
The following graph below illustrates the trends for key supply chain metrics. Companies are facing increasing backlog of past due demand they are unable to satisfy. Revenue growth rates have been slowed or are flat while inventory levels have continued to climb.



The use of systems that continue recommending orders for materials at consumption rates greater than the rate of arrival of constrained materials will result in increasing inventories of non-constrained items.

An Example

Consider the following example of a finished product with a bill of material that includes a purchased item impacted by constrained supply. In this example, there is a 1 to 1 parent to child ratio for all items. In our example, constrained supply means that the rate at which the material will arrive over time is lower than the rate of production that can be achieved for the finished good item.



For this example, we will assume that the production capability exists to produce 1000 units of Finished Item A per week. We'll also assume that market demand for the finished items is also 1000 units per week and that inventory levels of the finished item have been stable at 2 weeks supply or 2000 units prior to the supply constraint emerging.

Supply Constraint Impact on Finished Goods

If the supply of Purchased Item A is restricted by the vendor to 500 units of supply per week, the maximum number of Finished Item A that can be produced is 500 units per week. The table below illustrates the production shortfall and eventual growth of a backlog of past due demand:

	Constrained Supply per Week	Starting Inventory Level	WEEK NUMBER									
			1	2	3	4	5	6	7	8	9	10
Market Demand			1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Purchase Item A supply	500	0	500	500	500	500	500	500	500	500	500	500
Back order demand of Purchase Item A			500	1000	1500	2000	2500	3000	3500	4000	4500	5000
Production shortfall			500	500	500	500	500	500	500	500	500	500
Finished Item A Inventory		2000	1500	1000	500	0	0	0	0	0	0	0
Backlog of Finished Item A Demand			0	0	0	500	1000	1500	2000	2500	3000	3500

The market demand that production is unable to satisfy will consume the starting finished item inventory at the rate of 500 per week and will reduce the finished item inventory to 0 within 4 weeks. Once the finished product inventory is consumed, the market demand will be 500 units per week greater than production capability and will remain in backlog as past due demand. The new demand for 1000 units the company receives each week will result in growing the total order book which will include past due demands plus new weekly market demand.

Impact to Non-Constrained items

Based on the dependent demand for Finished Item A, ordering for unconstrained Purchased Items B – E will continue at the pace of market demand of 1000 units. The inventory for those purchase items will increase rapidly as those materials will only be consumed at the production rate of 500 per week given the limitation in supply of Purchase Item A.

From an MRP (material requirements planning) perspective it will appear that demand and supply are in balance and yet the total purchased item inventory will grow well beyond normal levels. The inventory will grow at the rate of the production shortfall of 500 additional units per week. Within 10 weeks the inventory of each of the non-constrained



items will grow by 5000 units due to production shortfalls and the MRP planning signals. The following table illustrates the build-up of non-constrained inventory:

	Constrained Supply per Week	Starting Inventory Level	WEEK NUMBER										
			1	2	3	4	5	6	7	8	9	10	
Market Demand			1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Purchase Item A supply	500	0	500	500	500	500	500	500	500	500	500	500	500
Back order demand of Purchase Item A			500	1000	1500	2000	2500	3000	3500	4000	4500	5000	
Production shortfall			500	500	500	500	500	500	500	500	500	500	500
Finished Item A Inventory		2000	1500	1000	500	0	0	0	0	0	0	0	0
Backlog of Finished Item A Demand			0	0	0	500	1000	1500	2000	2500	3000	3500	
Purchased Item B Supply Orders			1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Purchased Items B Consumption			500	500	500	500	500	500	500	500	500	500	500
Purchased Item B Inventory		1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	

Impact to Supplier Lead Time

If the supply constraint continues for an extended time, the vendor of the constrained item has no choice but to extend the purchasing lead time for the constrained item. This is due to the large backlog of customer demand the vendor is facing that will take substantial time to bring down to normal levels. The vendor must satisfy the backlog of demand before it can address any new demand coming in and thus, the vendor must extend quoted lead times to the market.

In the example above the back-order demand has reached 5000 units in the 10 weeks of the simulation. The vendor of Purchase Item A must first double their supply rate to 1000 units to keep the backlog from growing further. If we assume they are then able to increase their production rate a further 25% to 1250 units per week, it will then take an additional 20 weeks to clear the 5000 units of backorder demand.

The pace of the recovery to 'normal' volumes will take considerable time. In essence, the duration of the constrained supply will likely represent the length of time it will take to return to resolve the backlog of demand and return to normal production rates.



Managing through a Constrained Demand Signal

The critical requirement to keep inventories of non-constrained items under control is making a change from using an unconstrained demand signal to one that is based on known supply (or production) constraints. By limiting the demand signal to the rate of supply of constrained items we will ensure there will not be excess inventory of non-constrained materials.

Proper generation and use of a Master Production Schedule that is based on a constrained Rough-Cut Capacity Planning view can ensure that dependent requirements for unconstrained materials are in line with the achievable rate of production. This applies whether the constraint is internal or external and will go a long way to reducing the growth of inventory of the unconstrained materials.

In most cases, the constraint that should govern the Master Production Schedule is an internal resource or limitation. Perhaps a complex machining center or test/quality assurance process that restricts the output of the total production flow. These resources are typically well known and accounted for by those responsible for plant production scheduling.

However, properly leveraging a constrained Master Production Schedule becomes much more difficult when the constraint has moved upstream to vendors and suppliers. Establishing the appropriate rate of material flow through the plant for constrained materials requires close collaboration with vendors. Then, the rate of constrained supply must be effectively modeled as a resource limitation that the MPS system will recognize and use in generating an achievable production plan and related material requirements.

The highlighted section in the scenario below shows the impact of pacing the supply of Purchased Item B to the pace of the constrained supply of Purchased Item A.

	Constrained Supply per Week	Starting Inventory Level	WEEK NUMBER										
			1	2	3	4	5	6	7	8	9	10	
Market Demand			1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Purchase Item A supply	500	0	500	500	500	500	500	500	500	500	500	500	500
Back order demand of Purchase Item A			500	1000	1500	2000	2500	3000	3500	4000	4500	5000	
Production shortfall			500	500	500	500	500	500	500	500	500	500	500
Finished Item A Inventory		2000	1500	1000	500	0	0	0	0	0	0	0	0
Backlog of Finished Item A Demand			0	0	0	500	1000	1500	2000	2500	3000	3500	
Purchased Item B Supply Orders			1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Purchased Items B Consumption			500	500	500	500	500	500	500	500	500	500	500
Purchased Item B Inventory		1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	
Purchased Item B Constrained Supply Orders			500	500	500	500	500	500	500	500	500	500	500
Purchased Items B Consumption			500	500	500	500	500	500	500	500	500	500	500
Purchased Item B Constrained Supply Inventory		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000



The Focusing Steps

Borrowing concepts of the Theory of Constraints (ToC) helps us understand the critical need to pace production activity to the rate of the constraint. In a manufacturing environment, this has typically been determined by the rate of output of key production resources considered bottlenecks or constraints in the production flow. The Drum Buffer Rope application of ToC uses the following actions to determine the production and material release schedule for the plant.

1. Identify the constraint
 - a. The resource which typically has the slowest rate of output in the plant
2. Finitely Schedule the constraint
 - a. Ensure that you do not overload the constraint resource
3. Subordinate all other resources to the constraint
 - a. Do not initiate other production activities that exceed the rate of the constraint
 - i. Limit levels of work in process inventory
 - ii. Limit use of production capacity to the rate of constrained supply
 - b. In our example, limiting our schedule to the pace of supply of the constrained item ensures we do not build up work in process or excess inventory of non-constrained materials
4. Elevate the performance of the constraint
 - a. Any improvements in the rate of output of the constraint will improve the output of the entire plant
 - b. In our example, our constraint is in our supplier network. If we can increase the rate of supply, even in small degrees, we can increase the rate of total output and reduce or slow the growth of our past due order backlog

Managing your Supplier Constraints

Manufacturers are facing difficult times in managing supply chain performance. To keep inventory under control, it is critical to gain deep insights into those materials or production capabilities that are constraining flow through the supply chain. By understanding those elements that are restricting overall output we can put ourselves in a position to gain control of inventory levels while stabilizing production.

If external suppliers are constraining production rates, it is essential to develop achievable supply commitments from those vendors. Clearly defining the rate of material supply the vendor can achieve will facilitate building a supply constrained demand plan to drive replenishment of non-constrained materials. The rate of supply of the constrained item should be the determinant of the rate of production for the affected parent items. Understanding the rate of supply of the constrained item requires close collaboration with a company's vendors and gaining their commitment to the rate of supply they can achieve for those materials.

Optimally, the rate of supply should be articulated in daily or weekly commitments to ensure continuous inbound flow of materials. However, batch or minimum order quantity restrictions may lead to less frequent supply arrival and a



greater risk of disruption. Regardless, the availability of materials should be converted to a daily rate to allow generation of a demand plan which respects known supply constraints.

Elevate the Constraint

Having effectively identified your supply constraints and developed a method for limiting your Master Production Schedule to the rate of the constraint, your focus should then shift to finding creative ways to elevate the performance of the constraint. Several tactics may prove helpful. A short list of suggestions follows:

1. Find alternate or supplemental sources of supply – Work with your procurement teams to search for new suppliers that may provide incremental supply of your constrained items. This will help de-risk your dependency on your existing vendors.
2. Utilize internal production capabilities to supplement the constrained supply – Given that the limited of supply will impact production rates, there may be internal resources that offer the opportunity to augment the supply of items and materials you're externally sourcing by producing those in house. In fact, it is quite likely we will see some manufacturers take steps to re-verticalize their business model to gain great control of key materials and components
3. Agree to pay a higher price for the constrained supply – As the constrained supply is restricting overall sales, it may be well worth the additional investment to pay a higher price to your vendor if it yields a greater rate of supply. Your suppliers are likely under similar pressures and the incremental margin this would provide them may prioritize your needs ahead of others
4. Use pareto analysis to focus on those products and materials that drive the greatest revenue and profit. Focusing the organization on a small number of critical priorities is likely to yield greater results. While this may imply discontinuing some of the slow runners, most organizations will benefit from using the current challenges as a driver to rationalize their product portfolio.
5. Get creative – “Desperate times call for desperate measures” – Those firms that unleash the creativity of their teams often uncover innovations that yield greater productivity and control.

Beware the Floating Constraint

By focusing on elevating the rate of supply of constrained materials, you will likely find that a new constraint emerges. Floating constraints emerge when the pace of supply moves from on supplier or production resource to another. Given the challenging conditions companies are facing, it is quite likely that they will encounter this issue.

To address this, it is critical to be diligent and collaborative with your suppliers and operations staff. Awareness of the expected rate of supply for purchased materials along with internal production capabilities allows planners to ensure that the appropriate constraints are driving their Master Production Schedule.



Summary

Supply constraints are slowing revenue for manufacturers as their production of end items is limited by a subset of purchased items which are in scarce supply. Following conventional thinking, manufacturers are continuing to send unconstrained requirements to their suppliers that exceed the ability of the supplier to fulfill resulting in excess inventory of non-constrained materials while further distorting the pressure on the vendor for the constrained items.

By constraining parent item production plans to the rate of supply of constrained materials, manufacturers can substantially reduce inventories of non-constrained components. This will result in deferring material purchases to the time when production rates can improve as the rate of supply of constrained items increases.



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