Virtual Pull Systems

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SYNCHRONOUS MANAGEMENT

INTRODUCTION

Have you implemented kanban yet? Have you been unable to roll it out – or just abandoned it? Most companies who begin kanban implementation struggle to finish the job. In too many cases, the following questions not only go without answers, they go without asking:

- How do we size and resize supermarkets to reflect process and demand changes?
- How do we kanban hundreds or thousands of parts?
- How do we schedule a level load and mix when we have batch production?
- How do we account for make-to-order requirements?
- How do we use our pull system to focus process improvements?

As a result, two major problems persist. First, kanban quantities may not account for all major supply and demand constraints. Often, chaos still reigns and improvements in service and lead times remain elusive. Second is the assumption that kanban systems must be manual to be visual. So, most pull/kanban implementations occur via "kaizen" events. A team is structured and trained, and kanbans are made and implemented on a few items in a few days. Almost always, this approach loses steam because the struggle to apply it over and over again to additional products is difficult and costly.

On hundreds of implementations, our clients have overcome these stumbling blocks with Virtual Pull systems. Virtual Pull views "pull" as a system, not as a series of kaizen events. The nature of pull systems is that they connect value streams and loops with each other; they cannot be effectively implemented locally. So, Virtual Pull:

- Quantifies inventories based on constraints in supply and demand.
- Calculates, by item, the maximum inventory required to maintain material flow.
- Eliminates non-value-adding kanban cards, containers, and boards.
- Provides visual schedules accessible anywhere on your network.
- Incorporates mixed-model level-loading (heijunka) into the scheduling process.
- Incorporates non-kanban demand into level-loaded visual schedules.
- Reduces non-value-added scheduling and expediting effort by up to 90%.

Virtual Pull is being used to size supermarkets and to level schedules in a wide variety of environments. These include offshore procurement, consumer products distribution, and daily production scheduling. The results are reductions in ***total*** enterprise inventories of 20-40%, improvements in service levels to ***all customers*** to 99%+, and 70-90% reductions in scheduling workload ***across the organization***.

Of course, other lean tools (e.g. cells, changeover reduction, zero defects) are important to the long-term success of an enterprise. But, Virtual Pull does not require that any of them be in place before implementation. And it does not use proprietary software. Your Virtual Pull system is constructed in MSExcel or MSAccess using data you already have available.

This article is an introduction to the concepts of Virtual Pull - not a guide to implementation. For reasons we will discuss later, the real world is too complicated for that. Although we assume that the reader has a basic understanding of at least some lean terminology and concepts, we have included at the end of this article a glossary of lean terms used.

IMPLEMENTATION

Virtual Pull is implemented in two phases. The first is to calculate supermarkets - or maximum inventories required - item by item. With such a model, we can also recalculate the supermarkets on demand as conditions change (e.g. engineering changes, new products, process improvements).

The second phase is the actual execution of pull and the level-loading of suppliers – both internal and external. If supplier level-loading is not required (e.g. nuts, bolts, fasteners), then this phase of Virtual Pull can be skipped. The application of inventory replenishment tools such as order point or min/max may suffice.

Sizing Supermarkets

A supermarket is inventory of an item which is strategically sized and placed to perform several functions. First, it ensures an uninterrupted supply of material. Replenishment is triggered based on actual consumption – not a forecast. Second, it links and protects the flow within and among value streams. Third, because it is quantitative, it can be deconstructed into its root causes. This provides a valuable means for focusing additional value stream improvements.

A Virtual Pull model is typically constructed using commonly available data from your planning and scheduling system, including:

- Historical usage or shipment patterns
- Forecasted demand rates
- Processing data, such as bills of materials, changeover times and cycle times
- Resource data, such as manning, efficiencies and utilization
- Supplier data, such as lead times, replenishment cycles and vendor inventory agreements
- Part data, such as sourcing, unit costs, container quantities and minimum order quantities
- Current open customer order requirements
- Current on hand, in process and/or in transit inventories

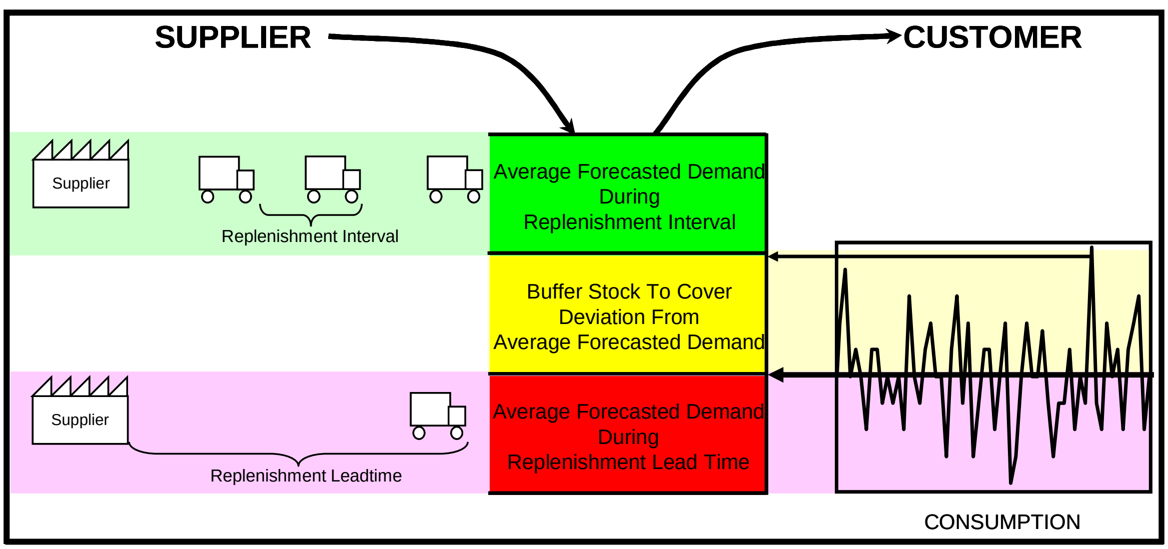
In most cases, all of these data can be automatically downloaded from your requirements planning system each day. Then, changes in supermarkets can be simulated and schedules can be updated at any time.

Each supermarket consists of at least three elements, each of which must be determined separately for each item (see ***Supermarket Elements***):

- *Average Forecasted Demand During Replenishment Lead Time:* This is the average amount of consumption from the supermarket which is expected to take place during the supplier's lead time to resupply.

- *Buffer Stock to Cover Deviation from Average Forecasted Demand:* This is the extra inventory required to cover variation in actual demand. Buffer stock is based on historical average consumption, and deviation from the average, factored for the forecasted demand and required service levels.

- *Average Forecasted Demanded During the Replenishment Interval:* The replenishment interval is the highest frequency with which the supplier can replenish the supermarket. This interval, when multiplied by the usage rate, determines the average quantity to be released or produced. Note that the replenishment interval is related to, but not the same as, the supplier's lead time. For example, if a supplier ships daily, and it takes five days to transport the goods, the replenishment interval is one day, and replenishment lead time is five days. The replenishment interval is the same "interval" referred to in the lean term, "every part every interval (EPEI)".



Supermarket Elements

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Virtual Pull Example

To illustrate the structure and execution of Virtual Pull, let's use a simple case study. ***Shipment History*** shows thirteen weeks of shipment history for seven items (your horizon may be different). Several of the items are made to stock (MTS = supermarkets) and several are made to order (MTO = no supermarkets). ***Shipment History*** shows the calculated average historical weekly demands for all items, and the standard deviations for the stock items.

ITEM	INVENTORY POLICY	WEEKLY AVERAGE	WEEKLY STDEV	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6	WK 7	WK 8	WK 9	WK 10	WK 11	WK 12	WK 13
100001	MTS	3756	1608	5950	4725	4200	2625	5425	2800	5425	875	2625	2450	1925	5075	4725
100002	MTO	569	0	0	2600	200	0	700	0	0	400	2600	200	0	700	0
100003	MTO	1215	0	100	1100	0	4200	0	0	3300	1800	1100	0	4200	0	0
100004	MTS	2014	1549	5400	1200	1600	5000	1600	3200	1000	1800	1800	1600	1200	1400	4380
100005	MTO	23	0	0	0	0	1700	0	0	0	0	0	0	1700	0	0
100006	MTO	500	0	0	0	1100	0	0	0	4300	0	0	1100	0	0	0
100007	MTS	3239	2459	6670	9710	4220	2160	2750	3040	3530	1870	2550	1770	1180	1770	890

Shipment History

Forecast shows the forecasted average weekly demand for each item. The forecasted average demand is used by the model to calculate all three components of each MTS supermarket. Each MTS item's historical standard deviation is factored by its forecast to produce a forecasted standard deviation which in turn can be used to calculate its buffer stock.

ITEM	INVENTORY POLICY	HISTORICAL WEEKLY AVERAGE	HISTORICAL WEEKLY STDEV	FORECAST WEEKLY AVERAGE	FORECAST WEEKLY STDEV
100001	MTS	4003	1608	5000	2141
100002	MTO	488		500	
100003	MTO	1313		1300	
100004	MTS	2350	2474	2500	3071
100005	MTO	213		200	
100006	MTO	675		700	
100007	MTS	4244	2459	4000	3036
TOTAL		13284		14200	

Forecast

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Next is the calculation of the replenishment interval. Let's assume that one machine is required to produce these seven items, that they are the only items produced on that machine, and that each item requires one week of further processing after it is machined. ***Production Processing Data*** shows the processing information (changeover and cycle times), the calculation of the number of hours required to produce one week's forecast for all items, and the number of hours required to cycle through the changeovers on all items.

ITEM	WEEKLY AVERAGE	CHANGE OVER HOURS	CYCLE TIME (MINS)	WEEKLY RUN HOURS
100001	5000	0.5	0.2	16.7
100002	500	0.2	0.2	1.7
100003	1300	0.5	0.2	4.3
100004	2500	0.2	0.1	4.2
100005	200	0.3	0.2	0.7
100006	700	0.5	0.1	1.2
100007	4000	0.5	0.1	6.7
TOTALS		2.7		35.3

Production Processing Data

	WEEKLY HOURS AVAILABLE	40.0
Times	UPTIME PERCENTAGE	95%
Equals	NET HOURS AVAILABLE	38.0
Minus	WEEKLY RUN HOURS REQUIRED	35.3
Equals	WEEKLY CHANGOVER HOURS AVAIL	2.7
Divided into	CHANGEOVER HOURS/INTERVAL	2.7
Equals	INTERVAL (WEEKS)	1.0

Replenishment Interval

Replenishment Interval shows the calculation of the interval. Assuming the machine is manned 40 hours per week, and its uptime is 95%, then 38 hours a week are available to run product and to conduct changeovers. If 35.3 hours a week are required to run product, then 2.7 hours a week are available to perform changeovers. If 2.7 hours are required to set up all items one time, then all items can be set up and run once per week. Thus, the replenishment interval in this case is one week.

Supermarket Calculations shows the calculation of the supermarkets of the MTS items, based on current supply and demand constraints. Note that the two week lead time includes the replenishment interval plus one week of further processing, and the service level used to calculate buffer stock is 95%. The average order quantity will be one week's worth, although the actual quantity released may vary from week to week depending on consumption. And, as input conditions change (e.g. demand patterns, changeovers, forecasts), the supermarkets can be recalculated dynamically.

ITEM	INVENTORY POLICY	FORECAST WEEKLY AVERAGE	FORECAST WEEKLY STDEV	LEAD TIME (WEEKS)	REPLENISH-MENT INTERVAL (WEEKS)	DEMAND DURING LEAD TIME	BUFFER STOCK (95%)	AVERAGE ORDER QUANTITY	MAXIMUM INVENTORY (UNITS)	MAXIMUM INVENTORY (WEEKS)
100001	MTS	5000	2141	2	1	10000	4980	5000	19980	4
100002	MTO	500		2						
100003	MTO	1300		2						
100004	MTS	2500	3071	2	1	5000	7143	2500	14643	6
100005	MTO	200		2						
100006	MTO	700		2						
100007	MTS	4000	3036	2	1	8000	7063	4000	19063	5
TOTAL		14200								

Supermarket Calculations

Executing the Schedule with the "Fuel Gauge"

Now that we have a way to calculate supermarkets, let's look at how a visual Virtual Pull system might be executed. ***Open Customer Orders*** shows the current customer order backlog (i.e. sales orders), by future ship week. Even with MTS items, we want to make sure we have visibility of spike demands on their supermarkets. We also want to include MTO demand in the production schedule.

ITEM	INVENTORY POLICY	CUSTOMER ORDER BACKLOG					
		WK 1	WK 2	WK 3	WK 4	WK 5	WK 6
100001	MTS	4200	2625	9000	2800	5425	1925
100002	MTO	200		700			
100003	MTO		4200			3300	4200
100004	MTS	600	6000	600	4200		200
100005	MTO		1700				1700
100006	MTO	1100				4300	
100007	MTS	4220	2160	2750	3040	3530	1180

Open Customer Orders

Fuel Gauge 1 shows the supermarkets and customer order requirements for each item in a Gantt chart format (weekly buckets). In order not to exceed the maximum allowable inventories for MTS items, the horizon shown for each MTS item is limited to the size of its supermarket in weeks (from ***Supermarket Calculations***). For MTS items, the larger of forecast and customer orders is displayed for each week, and for MTO items, total customer orders are displayed. Current on hand and in process inventories are also shown.

The red shaded weeks are covered by on hand inventory and the yellow shaded weeks are covered by in process inventories. Weeks with no shading are not yet covered. Our intent is to level load the machine for the next week at the forecasted rate of 14,200 units (see ***Forecast***), So, the scheduler's task is to determine the next 14,200 units to be released to production, while balancing both inventory and customer order requirements.

ITEM	INVENTORY POLICY	UNITS IN PROCESS	UNITS ON HAND	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6
100001	MTS	5000	5000	5000	5000	9000	5000		
100002	MTO		950	200		700			
100003	MTO		1500		4200			3300	4200
100004	MTS	2500	8000	2500	6000	2500	4200	2500	2500
100005	MTO		317		1700				1700
100006	MTO	900	702	1100				4300	
100007	MTS	4000	7553	4220	4000	4000	4000	4000	
TOTAL		12400	24022						

Fuel Gauge 1

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The scheduler generates the schedule for the next week by entering a value in the WEEKS TO COVER column (***see Fuel Gauge 2***). The Virtual Pull model then calculates and displays the number of units to make for each item to cover the specified number of weeks. Since the quantities in week 1 are already covered with on hand and on order inventory, let's begin by setting the WEEKS TO COVER to two weeks. ***Fuel Gauge 2*** shows the resulting UNITS TO MAKE, with coverage indicated by the green shading. However, the resulting schedule is for only 4,083 units, far below the level-loading requirement.

ITEM	INVENTORY POLICY	FORECAST WEEKLY AVERAGE	WEEKS TO COVER	UNITS TO MAKE	UNITS IN PROCESS	UNITS ON HAND	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6
100001	MTS	5000	2		5000	5000	5000	5000	9000	5000		
100002	MTO	500	2			950	200		700			
100003	MTO	1300	2	2700		1500		4200			3300	4200
100004	MTS	2500	2		2500	8000	2500	6000	2500	4200	2500	2500
100005	MTO	200	2	1383		317		1700				1700
100006	MTO	700	2		900	702	1100				4300	
100007	MTS	4000	2		4000	7553	4220	4000	4000	4000	4000	
TOTAL		14200		4083	12400	24022						

Fuel Gauge 2

Let's extend the coverage to four weeks. ***Fuel Gauge 3*** shows the result – over 27,000 items would need to be produced. This far exceeds the machine's capacity for one week – again not a level load.

ITEM	INVENTORY POLICY	FORECAST WEEKLY AVERAGE	WEEKS TO COVER	UNITS TO MAKE	UNITS IN PROCESS	UNITS ON HAND	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6
100001	MTS	5000	4	14000	5000	5000	5000	5000	9000	5000		
100002	MTO	500	4			950	200		700			
100003	MTO	1300	4	2700		1500		4200			3300	4200
100004	MTS	2500	4	4700	2500	8000	2500	6000	2500	4200	2500	2500
100005	MTO	200	4	1383		317		1700				1700
100006	MTO	700	4		900	702	1100				4300	
100007	MTS	4000	4	4667	4000	7553	4220	4000	4000	4000	4000	
TOTAL		14200		27450	12400	24022						

Fuel Gauge 3

Finally, let's cover three weeks, as shown in ***Fuel Gauge 4***. The total units to make are now 14,250, approximately equal to one week of forecast – a level load – and a customer-driven mix! The final schedule for the next week is shown in ***Machine Schedule – One Week***. And, Virtual Pull, the schedule can be easily reset ***at any time*** during the week if any of the input conditions change.

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ITEM	INVENTORY POLICY	FORECAST WEEKLY AVERAGE	WEEKS TO COVER	UNITS TO MAKE	UNITS IN PROCESS	UNITS ON HAND	WK 1	WK 2	WK 3	WK 4	WK 5	WK 6
100001	MTS	5000	3	9000	5000	5000	5000	5000	9000	5000		
100002	MTO	500	3			950	200		700			
100003	MTO	1300	3	2700		1500		4200			3300	4200
100004	MTS	2500	3	500	2500	8000	2500	6000	2500	4200	2500	2500
100005	MTO	200	3	1383		317		1700				1700
100006	MTO	700	3		900	702	1100				4300	
100007	MTS	4000	3	667	4000	7553	4220	4000	4000	4000	4000	
TOTAL		14200		14250	12400	24022						

Fuel Gauge 4

ITEM	INVENTORY POLICY	UNITS TO MAKE
100001	MTS	9000
100003	MTO	2700
100004	MTS	500
100005	MTO	1383
100007	MTS	667
TOTAL		14250

Machine Schedule - One Week

So, what have we accomplished? We have established maximum inventory levels required for stock items. We have quantified the constraints in both supply and demand. We have established a level-loaded, mixed-model schedule. This schedule fits our capacity and maximizes our customer service – on both stock and non-stock items – and it is easy to change. Finally, we have simplified the process to the point where we can reset supermarkets and generate schedules on demand for hundreds or thousands of items in minutes - without non-value-adding manual effort!

VIRTUAL PULL APPLICATIONS

Of course, these are only seven finished goods items. You will have to deal with many more, along with component items. With Virtual Pull all make-to-stock and make-to-order demand, at all levels of production and procurement, can be level-loaded and scheduled with the best possible mix and the least possible effort. Virtual Pull makes it easy. For example:

- One New England company buys raw goods from China in large batches and long lead times and finishes the products locally. Releases from China are managed via a monthly fuel gauge which is updated weekly and level-loaded by vendor (see ***Monthly Fuel Gauge*** screen shot).

				FORECAST, BACKLOG, ONE-TIME BUYS, SAFETY STOCK AND INVENTORY BUILD											
				1	2	3	4	5	6	7	8	9	10	11	12
ITEM	Primary_supplier	PERIODS TO COVER USED	QTY TO ORDER	0609	0709	0809	0909	1009	1109	1209	0110	0210	0310	0410	0510
[illegible]	AX	5		557	494	720	663	464	319						
[illegible]	AX	5		379	336	490	451	316	217	231					
[illegible]	AX	5		273	290	321	260	257	147	161					
[illegible]	AX	5		259	274	304	246	243	139	152					
[illegible]	AX	5		191	202	224	182	179	103	112	364	479			
[illegible]	BX	5	403	253	268	297	241	238	136						
[illegible]	CY	5		73	77	86	69	68	39	43					
[illegible]	CY	5		304	269	392	361	253	174						
[illegible]	FC	5		122	130	144	116	115	66						
[illegible]	FC	5		40	42	47	38	37	21	23	30	84			
[illegible]	HU	5		42	45	50	40	40	23	25	121	148			
[illegible]	LI	5	370	343	363	402	326	322	185	202					
[illegible]	LI	5		497	527	584	473	467	268						
[illegible]	PL	5	2,213	1890	2004	2219	1798	1776	1018						
[illegible]	PL	5		633	671	743	602	595	341						
[illegible]	PL	5	1,542	1430	1516	1679	1360	1344	770						
[illegible]	PL	5		3358	3559	3942	3194	3155	1809						
[illegible]	PL	5	3,701	3434	3639	4030	3265	3226	1849						
[illegible]	PL	5		1746	1851	2050	1661	1640	941						
[illegible]	WI	5		325	288	420	387	271	187	198					
[illegible]	WI	5	1,558	459	486	538	436	431	247						
[illegible]	WI	5	1,134	961	589	1449	2656	653	499						
[illegible]	WI	5	1,729	1052	645	1586	2908	715	546	1309					
[illegible]	WI	5		541	332	816	1496	368	281						
[illegible]	WI	5	4,652	891	546	1343	2462	605	462	1108					
[illegible]	AX	5		5694	6035	6684	5415	5349	3067						
[illegible]	FC	5	2,616	2427	2572	2849	2308	2280	1307						

Monthly Fuel Gauge

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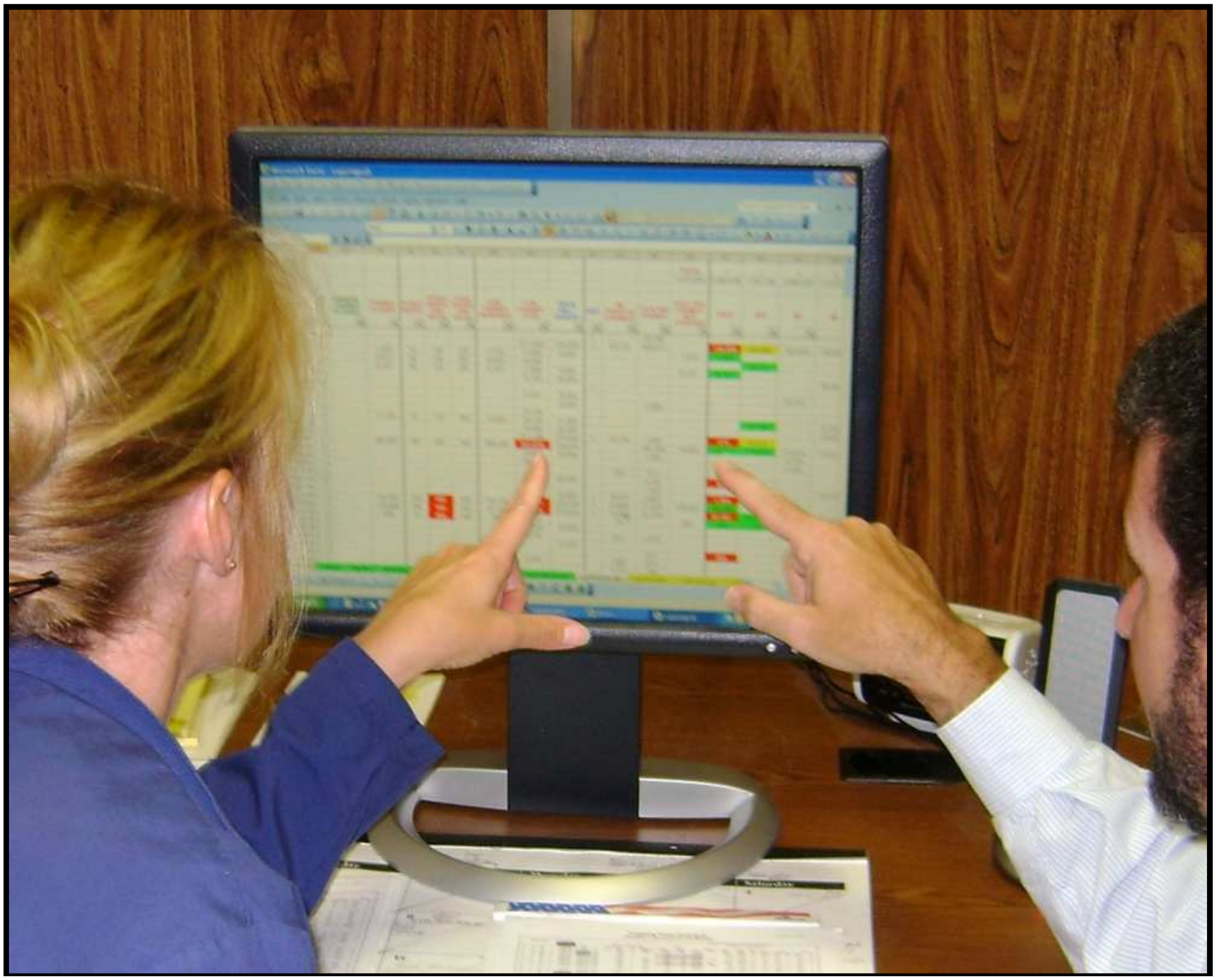
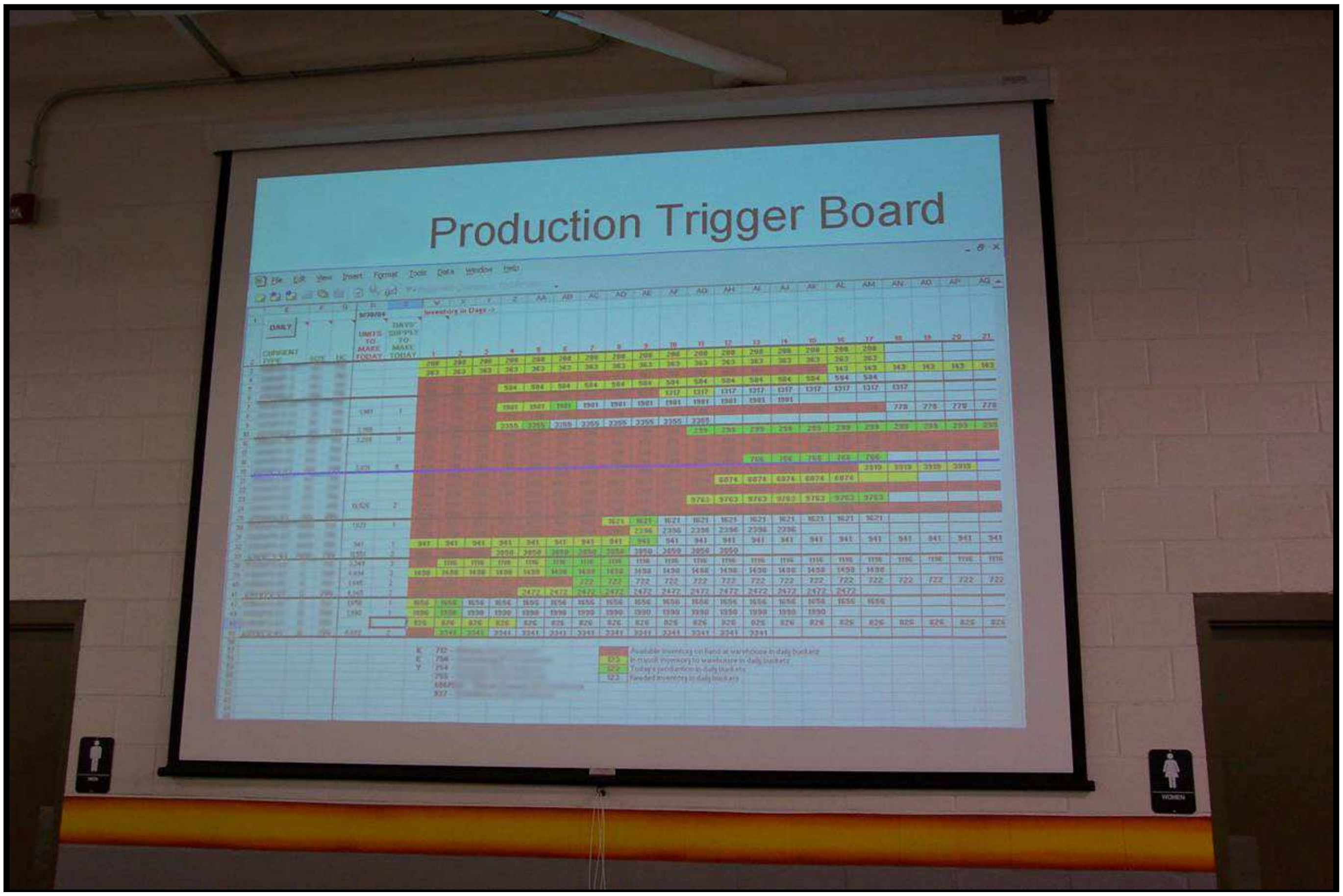
- To schedule production releases to one Midwest metal fabrication plant, the cell leaders and production schedulers collaborate with a weekly fuel gauge, updated daily (see ***Weekly Fuel Gauge***).



Weekly Fuel Gauge

- One Southeast maker of consumer products posts the fuel gauge directly on the shop floor in the packaging cell; this fuel gauge and the cell are managed in real time by the cell leader – no scheduler is involved (see ***Daily Shop Floor Fuel Gauge***).



Daily Shop Floor Fuel Gauge

OTHER ISSUES

This introductory article has used a very simple set of data to illustrate the concepts of Virtual Pull. You will certainly face many more complicated supply and demand constraints.

Typical Demand Constraints

In our example, we have used weekly buckets. Daily or monthly buckets may be more appropriate for your environment. You will have to set your own definitions of make-to-stock vs. make-to-order. You may not have item forecasts available, and you may have to calculate or extrapolate them separately. For dependent demand items, you may have to use bills of materials, historical usage and future gross requirements instead of shipments and forecast. And, you may need to adjust your supermarkets over time to accommodate seasonal inventory builds or product introductions and phase-outs.

Typical Supply Constraints

On the supply side, you may need to adjust supermarkets for plant shutdowns, unreliable supply, or inventory inaccuracies. You may have dependent (major/minor) changeovers, fixed run sequences, or labor constraints. Out-of-pocket startup scrap or large changeover to cycle time ratios may limit how far batches can be reduced. Periods to cover may have to be adjusted on individual items to account for availability of raw material, capacity or family changeovers. And, larger batches and longer lead times could extend your scheduling horizon.

FINALLY. . .

Virtual Pull is not a proprietary software system; it is developed for your company using simple tools, such as Microsoft Excel and Access. The data for Virtual Pull are maintained in your current system - not on cumbersome kanban cards, and Virtual Pull is interfaced with your existing systems. Then, as changes are made to your data, the supermarkets are reset automatically.

Virtual Pull is also updated in real time as customer orders are received and shipped and as inventories are consumed and replenished. It provides scheduling and planning with the “control valves” they need to optimize flow and service. The Virtual Pull fuel gauge can be accessed or displayed anywhere in the plant (and to outside suppliers) to provide immediate visual control of all scheduling requirements. Since Virtual Pull does not require physical kanban cards or trigger boards, it can easily be applied to hundreds or thousands of items at once – at a small fraction of the effort required for manual systems. All of this, without making a single kanban card!

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GLOSSARY

The following are terms relevant to this article. For more definitions see The Lean Lexicon by the Lean Enterprise Institute.

Buffer stock: Extra inventory required to cover non-linear demand.

Changeover time: The elapsed time to prepare a resource for the production of a part different from the one currently being produced.

Constraint: Any factor which limits the ability to improve flow or to reduce waste.

Cycle time: The time on a resource between the completion of one item to the next item of the same part number.

Heijunka: The leveling of production mix over the minimum period of time over which average customer demand approximates average capacity.

Inventory: All of the money invested in goods intended for sale.

Kaizen event: A group activity, lasting several days, in which a team identifies and implements a significant process improvement.

Kanban: A signal of the authorization to produce in a pull system. A production kanban authorizes production; a withdrawal kanban authorizes the movement of material from a remote supermarket to the point of use.

Loop: A section of a value stream, usually separated from other sections by a supermarket in a repetitive pull system, or by critical resources in a non-repetitive pull system.

Pull system: An information system for controlling and improving the flow of materials and information based on actual consumption – not forecast. Repetitive pull systems are inventory-based; non-repetitive pull systems are based on availability of critical capacity.

Push system: A scheduling approach wherein procurement and production priorities, quantities and dates are set based on lead-time offsets from forecasted end item demands.

Replenishment interval: The minimum time period over which a resource can change over and run some of every item it produces.

Replenishment lead time: The time between the recognition of need and the resupply of a supermarket.

Service level: Percentage of customer orders to be covered by buffer stock.

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Supermarket: A strategically sized and placed inventory of an item which triggers replenishment based on consumption, protects the flow of material, links and protects loops in a value stream, and provides a quantitative basis for focusing flow improvement activities.

Uptime: The percent of scheduled time a resource is available after accounting for lost time because of maintenance, meetings, breakdowns, or absenteeism.

Value stream: All of the steps required to bring a product from raw material to shipment.

Virtual Pull: A pull system in which supermarkets are calculated based on constraints in supply and demand, and which provides visual scheduling signals on make-to-stock and make-to-order requirements without a physical component to the system.