Scheduling a High Mix, Low Volume Lean Value Stream

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Introduction

Scheduling is defined as the process of planning to perform work to meet an objective, specifying the order and allotted time for each element.

While operations with regular volumes and little variation are fairly easy to schedule, as variation increases the challenges of scheduling expand seemingly exponentially. High mix, low volume (HMLV) value streams can be particularly challenging.

Scheduling, however, is not simply a one-time event since no set of operations performs every plan to completion all of the time and every time. Rather, scheduling must include the adjustments to the plans already in place and under way as well as for new work.

Lean principles can greatly simplify the scheduling process allowing operations to smoothly introduce new work while adapting to the inevitable realities of performance variations in actual operations.

Scheduling at One Point in the Value Stream

A fundamental lean principle is that a value stream should be scheduled at a single point. This recognizes the reality that a value stream is not simply a collection of individual processes but a complete network of interdependent processes that must somehow coordinate together to perform optimally. Considering the value stream as a whole, if work can be launched into the value stream at one point, then every other process in the value stream must be able to respond rapidly and smoothly to that one point.

Lean introduces several techniques by which processes may be scheduled based on other activities in the value stream.

1 – One Piece Flow – When multiple processes can be combined so that work flows continually without stopping, once the first process has begun further scheduling of work as it moves along its series of processes is no longer necessary. Each process simply performs the work based on the material that arrives from the prior process.

2 – FIFO Lane - One piece flow however is not always possible. A FIFO lane allows there to be some interruption to continuous flow without adjusting the order in which the work is to be done. A FIFO lane may be introduced to accommodate differences in work schedules or in cycle times. A process being fed by a FIFO lane needs no independent scheduling. The process simply performs its work on the products that are in the inbound FIFO lane. If the FIFO is empty, then the downstream process stops. If the FIFO is full, then the upstream process stops.

3 – Pull Signals or Kanban – Where one piece flow or FIFO are not possible, setting up a supermarket with pull signals for when to replenish the supermarket can be used. A pull

signal is an authorization to the process upstream from the supermarket that more of a product is needed. Pull signals are most often kanban cards but may also be empty trays, containers, vats, hubs or spindles, or anything else that gets emptied and refilled. A process scheduled by pull signals needs no independent scheduling. The downstream process from the supermarket simply withdraws material from the supermarket as needed. As the supermarket stock is reduced, replenishments are authorized depending on reorder polices. The general concept of pull signals incorporates easily any of the following types of pull signaling systems.

- One bin systems
- Two bin systems
- Multi-bin systems
- CONWIP (Constant Work in Process)

The above three techniques of one-piece flow, FIFO and pull allow a value stream to be scheduled at only a single point, where all new work in launched. The rest of the processes in the value stream are scheduled entirely in response to the operation of that single process. This applies to value streams of every complexity whether with only a few processes and a single flow path or with dozens of processes with multiple paths for different products.

Dynamic Rescheduling using Flow and Pull

As mentioned earlier, a significant challenge to scheduling is to adjust the plans in process based on performance variations. Instances of downtime, quality problems, machines running slightly faster or slower, employee absenteeism, changeovers sometimes taking longer than expected, etc. are all part of daily operations. Try as we might, we simply cannot remove all variation. The impact of these variations however must be smoothly adapted by each process in the value stream and incorporated into ongoing operations.

Processes whose operations are based on flow and pull are dynamically rescheduled with no external or independent scheduling effort required. FIFO lanes expand or contract and kanban signals are issued all depending on the actual operation of the processes upstream and downstream. This is a great advantage of lean scheduling over other methods. Monitoring the status of FIFO lanes and inventory levels in supermarkets to ensure that material is not stacking up or fully depleted is easy, simple and often visual. Visual factory guidelines and signals to flag exceptions for attention are highly effective methods that are easy to set up, train and use.

So we see that all processes in the value stream can flexibly respond to normal performance variations either in downstream or upstream processes or their own operation without any independent rescheduling efforts whatsoever. These adjustments are made in real time in the course of normal operation without any additional effort. Only when something goes seriously wrong are exceptions flagged for immediate

attention and resolution. The ability to clearly distinguish "signal", an out of bound condition requiring attention and action, from "noise", the normal variability found in any process, is a key benefit.

The use of flow and pull however requires that the appropriate buffers of FIFO lanes and supermarkets are in place to anticipate the level of normal variation so that operations can flow smoothly. The sizing of supermarkets and FIFO lanes appropriate to the capacity of the value stream is critical as we shall see.

Scheduling at the Pacemaker

Let's now turn our attention to the process at which new work is launched into the value stream, termed the pacemaker process. Normally this is the earliest point in the value stream from which flow to the customer can begin. The pacemaker process then controls the rest of the value stream. Processes downstream are scheduled using one-piece flow or FIFO. Processes upstream are scheduled based on pull signals.

In some value streams, the pacemaker may be the first process so that the entire value stream operates in either one-piece flow or through FIFO lanes. In other situations, an intermediate process may be required to act as the pacemaker even if flow is possible. This would be the case where the lead time through the value stream is longer than the allowable lead time to the customer. In yet other value streams, the pacemaker may be the final process in the value stream with the entire value stream responding to pull signals.

Correct identification of the pacemaker must consider the business model as well. Make to order value streams will have no finished goods supermarket to replenish and therefore cannot be scheduled via pull. Hybrid strategies with some make to order and some make to stock products can be very effective to allow for level loading in order to smooth operations. It however may be awkward to mix pull and flow together in a single process.

Schedules Must Be Achievable

It's critically important that scheduling is realistic, which means that schedules must be consistently achievable. Releasing schedules that cannot be achieved compromises the value stream's ability to maintain high on-time delivery and frustrates workers who want to perform to expectations. Achievable schedules have only two requirements.
1 - Materials are available.
2 - Capacity is available.

The materials requirement is that the right amount of material is available either provided to the process by flow from prior processes or held in inbound FIFO lanes or in

supermarkets. The calculation of the right amount of material to plan for in FIFO lanes or in supermarkets again is critical to smooth operation. By sizing all of the FIFO lanes and supermarkets properly, we ensure that every process in the value stream, not just the pacemaker process, has the material it needs.

Available capacity requires that enough machine resources, people and time are available for the process to perform the amount of work required. In value streams with dedicated equipment running a single product, this is a fairly straightforward determination. In an HMLV value stream however, there may be many different products being produced by a single process. In this case, the changeovers between products must also be considered. Every Part Every Interval or EPEI is the lean metric used to determine available capacity. EPEI is defined as the time period over which all members of the product family may be produced including the changeovers between the individual products. Not only does the EPEI determine the capacity of individual processes but also the sizing of supermarket buffers. For example, an EPEI of 7 days means that each product is produced once every seven days. That means that there must be at least a 7 day supply of the product on hand in order to avoid disrupting downstream processes or customer delivery. Safety and buffer stock can be added to anticipate the normal variability of operations and demand.

Fixed Interval Scheduling at the Pacemaker

Since HMLV value streams produce a number of different products, schedules for the pacemaker must anticipate not only the production run times but the changeovers between products. So again, EPEI is the lean metric to calculate the amount of time needed to produce the required volume and mix of products including the changeovers between products. Running a process to its EPEI reduces the batch size and the requirements for buffer inventory to as low a level as possible within the capacity limitations of machines, people and time.

A schedule for the pacemaker then covers a fixed period of an interval in length allowing adequate time for production and changeovers between products. Factors to anticipate downtime, yield loss, or rework should be added to the EPEI calculation so that the interval is routinely achievable anticipating normal variability.

The schedule itself is most often prepared as a heijunka box or schedule box. In a fixed pitch schedule box, each product is allocated to the number of time slots needed to build the required amount of a product plus any changeover required. The schedule of an interval in length outlines the specific sequence and amount of each product and the time allocated to build that product. Alternately, a floating pitch schedule box shows the changeover time needed and then the total production run time required to build the amount of each product required but without separate slots. This format may be easier when changeovers are substantial. Regardless of format, the schedule box is all that's required to fully schedule the value stream. Work should be launched at the pacemaker

based on the heijunka schedule. This can be a manual and visual process using physical cards in slots or an electronic one based on a spreadsheet or a lean business system.

There are several important implications to fixed interval scheduling. First is the requirement to actually observe the fixed schedule period. There's a great temptation to adjust a schedule continually to accommodate new customer requirements. It may seem to make sense to expand the length of the schedule as new orders come in especially if we haven't yet produced that product yet in the interval. That however risks the smooth performance of the rest of the value stream. FIFO lanes and supermarkets are all sized based on anticipated volumes, intervals and cycle times. Extending a released schedule to attempt to "slide in" more work may delay replenishment resulting in stockouts, downstream processing delays and missed deliveries. Schedule discipline is a critical requirement.

Second, fixed interval scheduling does not require any specific scheduling of individual orders. So long as orders are launched within their lead time, there's no need to establish an individual due date for each order. This is a completely different approach than other scheduling philosophies which are generally based on forward or backward scheduling of individual orders based on their due dates. The implications of this are quite profound for operations. There is no need to identify individual orders on the shop floor. There is no need to reschedule individual orders based on performance variability. The effort involved to manage and control operations on an order by order basis when not necessary is fundamentally waste – the waste of overprocessing. The assumption is that all customers are equally valuable, all orders are of equal importance, and high on-time delivery is required for all orders.

Third, fixed interval scheduling is simple, establishing clear responsibilities. During the schedule period, all of the work that is required of the value stream is known and can be planned. There's no need for resequencing or rescheduling since it's all done in advance. Since a schedule is confirmed for capacity and material availability, the responsibility is clear. Operations must perform to the schedule. Establishing clear accountability rather than allowing a culture of "finger pointing" to affix blame is an important management consideration.

Fourth, by confirming capacity throughout the value stream for each schedule, we know that the value stream as a whole is capable to produce the work released into it. So whether the bottleneck is at the pacemaker, at another process or floats from process to process depending on volume and mix, scheduling is consistent and unchanged.

Leveling Production

Lean seeks to create as steady a state as possible. The ideal value stream is single piece flow from inbound materials all the way to the customer without stops and starts. Standardization of work, work instructions, operator cross-training, etc. are all geared

towards consistency of operation. Standardization is both a prerequisite to and a reinforcement of quality improvement. In fact, one definition of quality is the elimination of variation. So too, the goal of scheduling should be to create as steady a state as possible to allow for smooth operations.

When the value stream was planned, there were a certain number of machines, people and set working schedules that were agreed upon to be able to meet anticipated customer demand. These may have been based on Sales and Operations Planning or other forecasting. See the paper "Planning for a High Mix, Low Volume Lean Value Stream" for an extended discussion of planning. Yet from day to day and week to week, customer requirements are much more unpredictable. The total volume and the mix of products will vary from whatever level was used in planning. In some periods, capacity will be oversold and in other periods, capacity will be available. A goal of scheduling is to equalize as best as possible the work in each interval period.

Leveling the demand requires a buffering strategy appropriate to the business model. For example in a make to stock business, when orders for a period exceed capacity, finished goods inventory can be used to ship what can't be built in the period. And when orders are lower and capacity is available, extra time can be allocated to build additional product to replenish supermarkets to targeted stock levels. In make to order business models, labor may be able to be flexibly assigned either by adding additional workers or working extended hours if requirements exceed capacity. A hybrid of make to stock and make to order is often a very effective strategy with high runner products held in a supermarket to buffer against both volume and mix variation.

A demand leveling strategy then releases a consistent amount of work into the value stream neither flooding nor starving the value stream.

Putting It All Together

A comprehensive scheduling strategy for an HMLV value stream involves the following:

- Establishing one-piece flow wherever possible.
- Establishing FIFO lanes where one-piece flow is not possible.
- Establishing pull signals where flow or FIFO is not possible.
- Identification of the pacemaker process, where work will be launched.
- Calculating the EPEI of each process in the value stream.
- Sizing FIFO lanes and supermarkets throughout the value stream based on anticipated demand levels and capacity constraints.
- Establishing a buffer strategy to level the demand across schedules.
- Confirming overall capacity in the value stream for each schedule period.
- Creating a heijunka schedule for the pacemaker for each schedule period.

Scheduling a High Mix, Low Volume Lean Value Stream

Once the heijunka schedule is created and released to the pacemaker, the operation of the entire value stream is set as each process responds to its downstream or upstream processes and pull signals. Visual factory signals to monitor levels of actual performance can quickly focus attention on problem areas for resolution. Meanwhile, the value stream smoothly adapts to real world performance variation without requirement for independent scheduling. The result is a smoothly performing value stream able to achieve very high on time delivery, with minimal inventory, and smooth operations, all of which work to maximize profitability.

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