Production Scheduling in Pull Production Including Synchronization and Balancing

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Abstract: Lean manufacturing is a powerful system that focuses on the continuous reduction of all waste within the system to supply a quality product on a consistent basis. One of the most powerful tools of lean manufacturing is the pull system of manufacturing. The Toyota Production System promotes "pull" scheduling to reduce the production of parts that do not comply to what the customer needs. Starting in the 1940's, Taiichi Ohno began evolving a system that would enable Toyota to compete with American automakers.

Index Terms: Lean manufacturing, Pull system of production, Kanban , Just in time, Autonomation.

I. INTRODUCTION

To understand why and how pull came about, it is necessary to first appreciate the environment that preceded it, namely the world of MRP. Prior to the dominance of the computer in manufacturing, inventory was controlled using reorder-point/reorder-quantity (ROP/ROQ) type methods. During the 1960's, Joseph Orlicky, Oliver Wight, and George Plossl along with others developed a new system, which they termed Material Requirements Planning (MRP). Orlicky obviously believed that they were on to something big; he subtitled his book on the subject "The New Way of Life in Production and Inventory Management"[1] . After a slow start, MRP began to gather steam during the 1970's fueled by the "MRP Crusade" of the American Production and Inventory Control Society (APICS). Orlicky reported 150 implementations in 1971[1] . By 1981, the number had grown to around 8,000[2] . As it grew in popularity, MRP also grew in scope, and evolved in the 1980's into Manufacturing Resources Planning (MRP II), which combined MRP with Master Scheduling, Rough-Cut Capacity Planning, Capacity Requirements Planning, Input /Output Control and other modules. In 1984 alone, 16 companies sold $400 million in MRP II software[5] . By 1989, over $1.2 billion was sold to American industry, constituting just under one-third of the entire software industry[3] . MRP is considered to be the classical example of a push system.

While MRP was steadily dominating the American production control scene, history was taking a different course in Japan. There, perhaps because it lacked a strong indigenous computer industry, the computer was far less pervasive in production and inventory control. Instead, several Japanese companies, most notably Toyota, developed the older ROP/ROQ methods to a high level. Starting in the 1940's, Taiichi Ohno began evolving a system that would enable Toyota to compete with American automaker but would not depend on efficiencies resulting from long production runs that Toyota did not have the volumes to support. This approach, now known as the "Toyota Production System," was designed to "make goods, as much as possible, in a continuous flow" .

According to Ohno, the Toyota Production System rests on two "pillars":

1. "Autonomation"
2. Just-in-time production

Autonomation, or "automation with a human touch," is the practice of determining the optimal way to perform a given task and then making this the "best practice" standard method. Autonomation also involved "fool proofing" or "poke yoke," which involved using devices to quickly check dimensions and other quality attributes to allow workers to be responsible for their own quality. If problems were found, the production line stopped until the problems were corrected. This eliminated the need for rework lines and, eventually, eliminated most scrap. The Toyota Production System also promoted "5S," Seiri, Seiton, Seiso, Seiketsu, and Shit- suke which are organization and housekeeping techniques aimed at achieving Autonomation and Visual Control.

Just-in-time production according to Ohno involved two components: Kanban and Level production. Kanban or "pull production" became the hallmark of the Toyota Production System (which was also frequently refer[red to as Just-In-Time) to the point where many thought they were synonymous. But Kanban was just a means to an end. Ohno famously described his inspiration for Kanban as coming from a visit to the U.S. during the 1950's in which he was more impressed with American supermarkets than with American manufacturing. The idea of having all goods available at all times was, to Ohno, novel and revolutionary. He said: "From the supermarket we got the idea of viewing the earlier process in a pro¬duction line as a kind of store. The later process (customer) goes to the earlier process (supermarket) to aquire the needed parts (commodities) at the time and in the quantity needed. The earlier process immediately produces the quantity just taken (re-stocking the shelves)".

A pull system, thus looks at the manufacturing process from the other end, i.e. from the perspective of the finished item. The production controller works on the basis that his/her orders represent firm customer requirements. The time horizon is understandably short. The orders are broken down from the highest level and the controller checks whether sufficient component parts are available to produce the finished product. If the components are available, the product is produced. However, if they are not, components are pulled from the preceding work center. A similar procedure is followed right back through each production stage and extending all the way back to include outside vendors. Such a system places great demands on the production system and vendors. These demands can be met either by having all component parts in inventory or, alternately, having the capability to respond and make them available in a very short time (i.e. short lead time).

Lin et al [7] found that the product return rate is the key parameter in influencing bullwhip performance of a pullcontrolled hybrid system. Product demand frequency is another important factor for system dynamics performance of the hybrid system.

Vega et al[8] suggests that the even though logical challenge persists, but the principle of pull processes can be applied in the healthcare sector also to eliminate a different type of waste.

II. WASTE AND ITS ELIMINATION

In lean manufacturing waste is defined as any activity that does not add value for the customer. It can be seen in the use of any resource over the minimum; equipment, personnel, space or energy. Waste is created in so many ways; unnecessarily long set-up times, inspections, material movement, transactions, rejections and inventory are just a few. When Shigeo Shingo developed TPS he identified seven kinds of waste that are now known simply as the seven wastes:[6]

1. Waste of overproduction
2. Waste of stocks (inventory)
3. Waste of Waiting
4. Waste of transportation
5. Waste of motion
6. Waste of defects
7. Waste of processing

In order to understand the importance and value of pull manufacturing we must understand what .the seven waste are, where they occur and most importantly why they are waste. This is especially true for the wastes of overproduction and inventory because these two wastes are the most often ignored while being the most costly for the plant.

III. THE PULL SYSTEM

Pull manufacturing is a tool within lean manufacturing that identifies and then targets the two most costly forms of waste, overproduction and inventory. The Pull System is a method of production control in which downstream activities signal their needs to upstream activities. Pull production strives to eliminate overproduction and is one of the three major components of a complete just-in-time production system.

In pull production, a downstream operation, whether within the same facility or in a separate facility, provides information to the upstream operation, often via a Kanban card, about what part or material is needed, the quantity needed, and when and where it is needed. Nothing is produced by the upstream supplier process until the downstream customer process signals a need. This is the opposite of push production.

Three basic types of pull production systems

i. Supermarket Pull System

In a supermarket pull system each process has a store—a supermarket—that holds an amount of each product it produces. Each process simply produces to replenish what is withdrawn from its supermarket. Typically, as material is withdrawn from the supermarket by the downstream customer process, a Kanban or other type of information will be sent upstream to the supplying process to withdraw product. This will authorize the upstream process to replace what was withdrawn.

ii. Sequential Pull System

A sequential pull system—also known as a b-type pull system—may be used when there are too many part numbers to hold inventory of each in a supermarket. Products are essentially "made-to-order" while overall system inventory is minimized. In a sequential system, the scheduling department must set the right mix and quantity of products to be produced. A sequential system creates pressure to maintain short and predictable lead times. In order for this system to work effectively, the pattern of customer orders must be well understood. If orders are hard to predict, production lead time must either be very short (less than order lead time) or an adequate store of finished goods must be held.

iii. Mixed Supermarket and Sequential Pull System

Supermarket and sequential pull systems may be used together in a mixed system—also known as a c-type pull system. A mixed system may be appropriate when an 80/20 rule applies, with a small percentage of part numbers (perhaps 20%) accounting for the majority (perhaps 80%) of daily production volume. Often an analysis is performed to segment part numbers by volume into (A) high, (B) medium, (C) low, and (D) infrequent orders. Type D may represent special order or service parts. To handle these low-running items, a special type D Kanban may be created to represent not a specific part number but rather an amount of capacity. The sequence of production for the type D products is then determined by the method the scheduling department uses for sequential pull system part numbers.

IV. IMPLEMENTING PULL SCHEDULING THROUGH KANBAN

Pull manufacturing is a manufacturing methodology that controls production from the end of the process. Pull manufacturing reduces waste by limiting overproduction and inventory in a systematic way.

The goals of pull manufacturing

i. Reduce inventory through capacity control
ii. Increase throughput by identifying bottlenecks
iii. Better product mix through improved line balancing
iv. Allows constraints to be identified and eliminated

The core principle of a pull system is that any activity should only be performed when it is needed and that can be effectively achieved by means of Kanban . A Kanban is the signal sent from a work center to its supplier requesting a specific action. If the work center receives a request for 5 parts they produce and ship 5 parts, no more, no less. (Milk man example: The milkman is an example of a Kanban system, if he sees a milk bottle he replaces it, if he sees two he replaces two. If there are no milk bottles he does nothing.). A Kanban signals production, by telling the workcenter what to produce and when. In most cases the “what” is included in the Kanban signal itself and the “when” is immediately upon receiving the signal (If the milkman sees a white bottle and a brown bottle he replaces one normal milk and one chocolate milk. The color of the bottle signals the type of milk that needs to be replaced). If the supplier doesn't receive a Kanban then they do nothing, they produce nothing, move nothing and store nothing. This transaction initiates the pull mechanic between the two work centers with the downstream work center in control. This extends from final assembly back to the first process and, if possible, to the supplier. Kanban set the pace for the entire system by linking workcenters together. The lowest capacity workcenters, the bottlenecks, set the pace for the entire system, the upstream workcenters don't overproduce and the downstream workcenters are supplied in a level fashion.

Following are the eight rules of Kanban

1. Never build past Kanban ceiling
2. No material moves without a Kanban
3. Never pass a defect
4. First in first out
5. Customer pulls material from supplier
6. Only active material at work center
8. Reduce Kanban to expose constraints

Following are the different Styles of Kanban .

Kanban come in many styles but they all serve the same purpose, a signal that authorizes production. The specific style of Kanban should be selected based on what type of signal is most useful between any two given work centers.

Visual Kanban is a simple open space between two work centers that holds in process inventory. This can take the form of a small taped off region on a table or a pigeon hole between two work centers.The number of available slots controls the amount of total inventory between the processes. This system of Kanban can be used when transportation and storage times between two work centers are negligible, such as two adjacent machines. This Kanban is also the most responsive because only material that has been used is replaced. A typical Visual Kanban is shown in figure 1.

Fig. 1 Visual Kanban

Container Kanban is a signal in the form of a container that holds a set amount of material and travels between work centers. Each container is designed to hold a set amount of material which comprises a single Kanban . The number of containers controls the total amount of inventory that exists, if there are 6 containers each holding 100 units then there can be a maximum of 600 units of inventory. This Kanban system works well between two work centers that are far enough apart that travel time is a concern, the containers allow inventory to be in transit between them. This Kanban is also useful if the material is relatively small and is controlled in large amounts. Like the previous method the system for control is very simple to enforce, produce only when a container is present and only enough to fill that container. This Kanban system is less visible then the first because some of the material will always be in transit. This Kanban system is also less responsive because material can only be produced in lots of the container size. A typical Container Kanban is shown in figure 2.

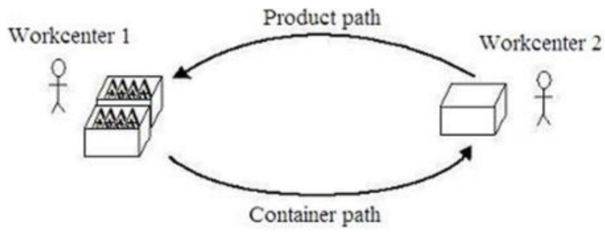
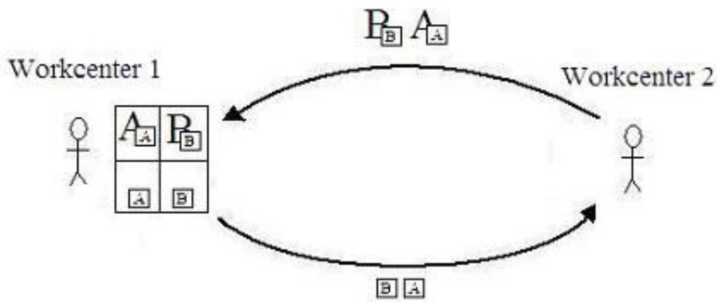


Fig. 2 Container Kanban

A Card Kanban is a slip of paper that authorizes production. Kanban cards will need to have information such what the card authorizes, the amount each Kanban authorizes and, authorized it and if necessary where it should be sent. The number of cards control the total level of inventory in the same way as the container, each card representing a segment of the total allowable inventory. This method of Kanban is useful when the material is difficult to control or store in another fashion, such as large products like a car or when the material is controlled by mass instead of units. The card method also serves when two work centers are separated by a large distance making containers impractical, the downstream work center might make a production request every time it uses a component but does not receive shipments until a set amount has been reached. A typical Card Kanban is shown in figure 3.



Fi. 3 Card Kanban

An Electronic/computer Kanban can also be used. It is possible to use computers or other electronic systems to initiate a Kanban pull, but this is generally not advised. Electronic signals are less visible which makes it more difficult to use a computer tool without exceeding the Kanban ceiling. o An electronic system removes much of the human aspect from the Kanban system, forced customer/supplier interaction is one of the chief advantages of a pull system and this is lost with electronic Kanban o In those situations where an electric signal is needed to communicate Kanban , such as orders placed over great distances, it is still valuable to include visual card systems; the customer moves a card to a wall to represent a placed order, and the suppler removes a card from their wall and adds it to the production line.

V. BALANCING PUSH AND PULL FOR OPTIMAL RESULTS

Why choose between a push or pull approach to replenishment? Marrying the two together can bring out the benefis and minimize the faults in each approach. Businesses should take a two step approach to balancing their pull and push replenishment strategies:

1. Bring inventory into the distribution network based on anticipated consumer demand. Companies should leverage the pull approach to ensure they understand consumer-buying behaviours and that they're placing demand-driven replenishment orders.

2. Push product out to consumers as fast as possible.

Allocation rules that focus on push principles will ensure that product is available to customers as soon as possible to increase the likelihood that it will be purchased at full price. Balancing push and pull strategies will help retailers increase inventory turns, resulting in a faster return on investment.

VI. SYNCHRONOUS MANUFACTURING

Synchronous Manufacturing is an operational strategy that incorporates lean principles, but adds flexibilty to the process. Where lean manufacturing is oriented toward a repetitive manufacturing environment, synchronous manufacturing applies to low-volume/high mix type of order characteristics. It also applies to environments where a large degree of customization or "customerization" is required, or a make-to-order environment.

Lean manufacturing applies best when the order characteristics are high-volume/low-mix. In these cases, components are identical, or differences lie in scale or size. WIP inventory is low in variety and can be controlled with ease. In contrast, in a low-volume/high-mix environment, the componentry tends to vary greatly, and the WIP inventory mix is characterized with a much greater variety, and is more difficult to control.

Synchronous manufacturing employs the synchronization between customer orders and work stations. In other words, the first order worked on in the first work station is the first work order worked on in the second station, and so on. This requires a good systems scheduling algorithm often using a first-in/first-out method to scheduling customer orders. Synchronous manufacturing can be applied within an Agile Manufacturing strategy.

The characteristics of synchronous processes are:

- ✓ Make to order
- ✓ Synchronized production
- ✓ Just-In-Time materials/pull scheduling in early stages
- ✓ Synchronized scheduling in later stages
- ✓ Short cycle times
- ✓ Highly flexible and responsive processes
- ✓ Highly flexible machines and equipment
- ✓ Quick changeover
- ✓ Continuous flow work cells
- ✓ Collocated machines, equipment, tools and people
- ✓ Compressed space
- ✓ Multi-skilled employees
- ✓ Empowered employees
- ✓ High first-pass yields with major reductions in defects

VII. CONCLUSIONS

Lean manufacturing is a powerful system that focuses on identifying and eliminating waste wherever it is. This process begins with an understanding of what waste is and why it should be eliminated. Waste is the name for any activity that adds costs to the supplier while adding no value to the customer. This concept is further broken down into seven basic forms of waste: Overproduction, inventory, transportation, waiting, defects, motion and unnecessary processing.

Pull manufacturing is a tool within lean manufacturing that identifies and then targets the two costliest forms of waste, overproduction and inventory. The pull system does not allow any product to be produced unless it is needed, this simple rule prevents most forms of overproduction and strictly controls the amount of inventory within the system.

Kanban are the tool that regulates a pull system, they are the signal to produce. The rules that allow Kanban to function are simple but powerful regulator methods that allow a pull system to function. Following the rules of Kanban allows a pull system to function smoothly and consistently, making orders on time while limiting production. Different Kanban systems allow for control in different supply situations. Specialty Kanban are used to control non-production activities and special situations within the plant such as component restocking and rework control. Proper Kanban calculations set the Kanban ceiling at a level that limits inventory while keeps all workcenters fed.

The final step is to make use of the freed production time that results from ceasing overproduction. The operators can engage in total productive maintenance in which maintenance issues are identified and pre-emptively prevented. Operators can engage in 5-S activities to keep workcenters clean and organized. Operators can also take part in SMED, studying the set-up procedures and brainstorming methods to shorten them. All of these activities increase the capacity of a workcenter so that it can better respond to demand.

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