Ten Steps to Effective Kanban Design

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Abstract

Simple Operation, Sophisticated Design

While kanban systems are quite simple in concept and operation, their design may require significant analysis. In the most favorable situations, experienced guesswork may be adequate for a design. In more difficult situations, guesswork often seems to rule out kanban when a more thorough approach would make it feasible. An effective design requires insight into demand patterns at the downstream workcenter, capacity analysis at the upstream workcenter, downstream scheduling practices, setup practices, material handling methods and lot sizing.

From the earliest publications on lean techniques such as Monden and Hall, many authors have described kanban systems in detail and many researchers have explored kanban operations. However, few have explored the intellectual process required to design these systems or proposed a design procedure. This paper presents such a 10-step process in a structured and systematic approach that ensures a successful kanban design.

1. Kanban & Other Production Control Methods

What is Production Control?

At the most fundamental level, Production Control is simply the coordination of two sequential operations. Of course, it gets more complex when considering capacity, staffing, lead time, routings and many other factors. One way to state Ashby's law is that the controlling system ***must be at least*** as complex as the system controlled. In Lean Operations, workflow is simple and straightforward and the production control system should match this relative simplicity.

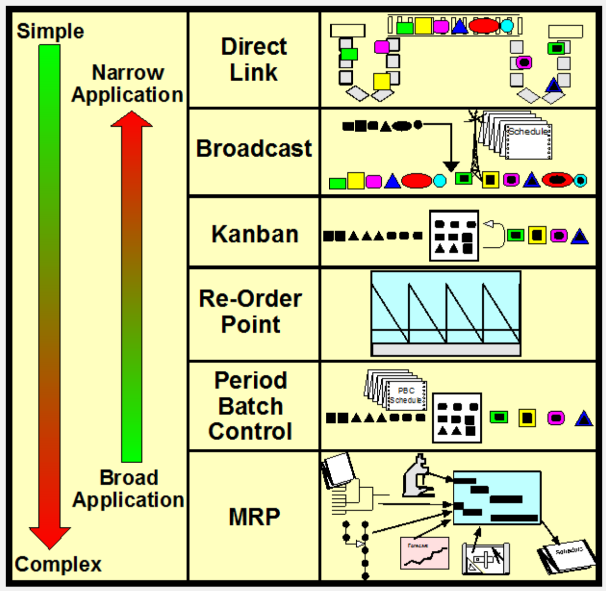

Figure 1 A Hierarchy of Production Control

A Hierarchy of Production Control

Production Control systems fall into several categories based on their fundamental operational principles. Figure 1 shows these categories ordered from the simplest to the most complex.

In **Direct Link**, the upstream and downstream workcenters are physically connected. The connection may be a conveyor, as shown, or the workcenters may be adjacent. In either situation, the downstream workcenter simply works on whatever product emerges from the upstream and does so when it emerges.

A **Broadcast** system is often used when major subassemblies are used on a final assembly line. The subassembly and main assemblies are often custom-made and not interchangeable. In this system, a master schedule is prepared that determines the sequence of and timing of final assembly.

Kanban uses a small stock of product located between the upstream and downstream workcenters. A signaling system informs the upstream workcenter as each withdrawal is made. This allows the workcenter to schedule a replenishment along with any other items it must produce.

Re-Order Point (ROP) systems maintain a stock of each item that may be required at the downstream workcenter. This downstream workcenter pulls stock as required. When stock levels fall to a designated "minimum" or "Re-Order" quantity, a purchase order or other signal is sent to the upstream workcenter for replenishment to the maximum quantity. While some features of ROP resemble Kanban, ROP normally works with larger lot sizes and much longer lead times. Moreover, the replenishment signal is initiated when the stock is at the lowest allowable point, not when it is withdrawn.

MRP/ERP systems from a vast amount of data concerning process, work times, inventory at every stage, suppliers, lead times, sales forecasts and sales orders. With all this complexity, an MRP/ERP system can, in theory, schedule almost every production situation. Practice, however, presents a multitude of problems. The cost, complexity and risk associated with it make MRP the last resort.

Generally, the most complex systems have the broadest application. Broadcast and Direct Link, for example are only feasible under certain very special conditions whereas modern MRP systems can be used in nearly every situation. But the simpler systems, properly applied, work better in many ways. Kanban is about midway in terms of simplicity and range of application.

Here, in this short paper, we focus on kanban systems. However, a given facility may use several or all of the various methods.

2. The Essence of Kanban

Kanban takes place between two workcenters; an upstream supplier and a downstream user. It applies to a single part or SKU. Between the workcenters, a Stockpoint holds a (relatively) small stock. A signal ***immediately*** notifies the upstream workcenter of changes in stock status. Therefore we can define a Kanban system as one that has:

1. Small Stock Available
2. Withdrawal Signal With Immediate Feedback
3. Fast Replenishment, Small Quantities

Figure 2 illustrates with a block diagram and simple example. In this example the operator at the upstream workcenter simply watches the Stockpoint and, with the aid of color codes, determines what he produces next. This is a simple, visual signal that is highly effective. There are many other types of signals as well.

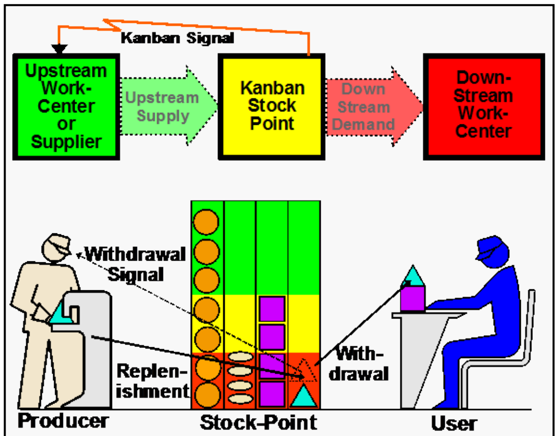

Figure 2 The Essence of Kanban

The Rules of Kanban

Kanban requires a set of rules and procedures and the discipline to carry them out. A simple system as in such as in Figure 2 needs only two basic rules:

- No production without a kanban signal.
- Do not arbitrarily change authorized stock levels.

More complex systems using containers or cards may have some additional rules.

For the system in Figure 2, the "User" or downstream workcenter simply builds what its customer needs immediately and removes the required items from the Stockpoint. The "Producer" or upstream workcenter observes the Stockpoint and decides which items to build based on the stock level. Colored zones make the stock status more obvious:

- Red zone means "make this part NOW."
- Yellow means "be prepared to make this part soon."
- Green means "you may build this part if convenient but only up to the maximum level."

3. The Ten Steps

The author likes to think in terms of ten basic steps to analyze and design kanban systems and these steps are summarized here. For many, perhaps most, systems the steps do not require as much detail, formality and rigor shown in the examples; many times and educated guess is quite adequate. But, the educated part of the guess requires that you know what you are trying to do in that step and why it is important.

Most kanban systems are easy to change. So, a reasonable guess followed by monitoring and fine tuning will result in a near-optimum system with reasonable effort. When the system may be difficult to modify, a more rigorous analysis is in order. Another reason for informality is that accurate data may be unavailable.

1. Analyze Products-Volumes for Upstream Work Center

Upstream work centers may produce multiple products, often for several downstream workcenters. Some of these items may be unsuitable for kanban and this will become clearer with the Product-Volume analysis .

This is also the time to ensure that the upstream work center has adequate capacity to produce this product mix and volume.

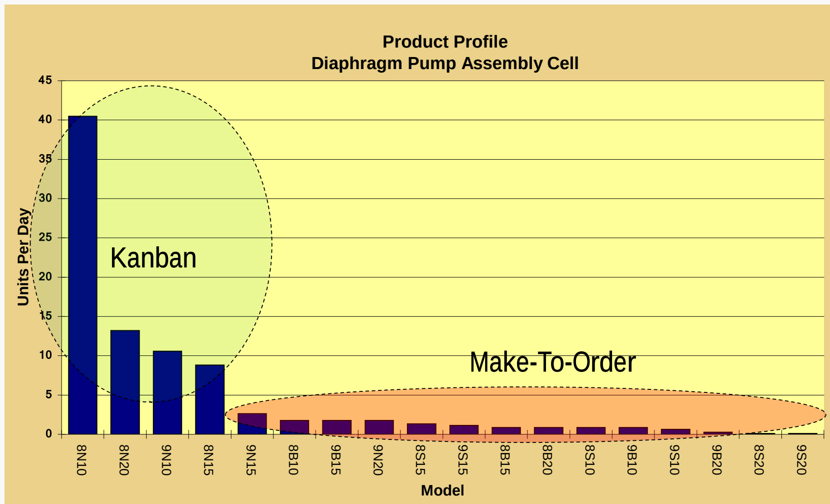

Figure 3 Product-Volume Analysis

2. Analyze Downstream Demand Patterns

The purpose of the Stockpoint is to buffer any differences between downstream demand and the ability of the upstream workcenter to precisely track that demand. If the upstream workcenter can track downstream demand exactly, there is no reason for the kanban system and direct link (a.k.a. FIFO) or a broadcast system is more appropriate for coordinating the two workcenters. The greater the disparity between downstream demand and upstream ability to supply it, the larger the kanban stock.

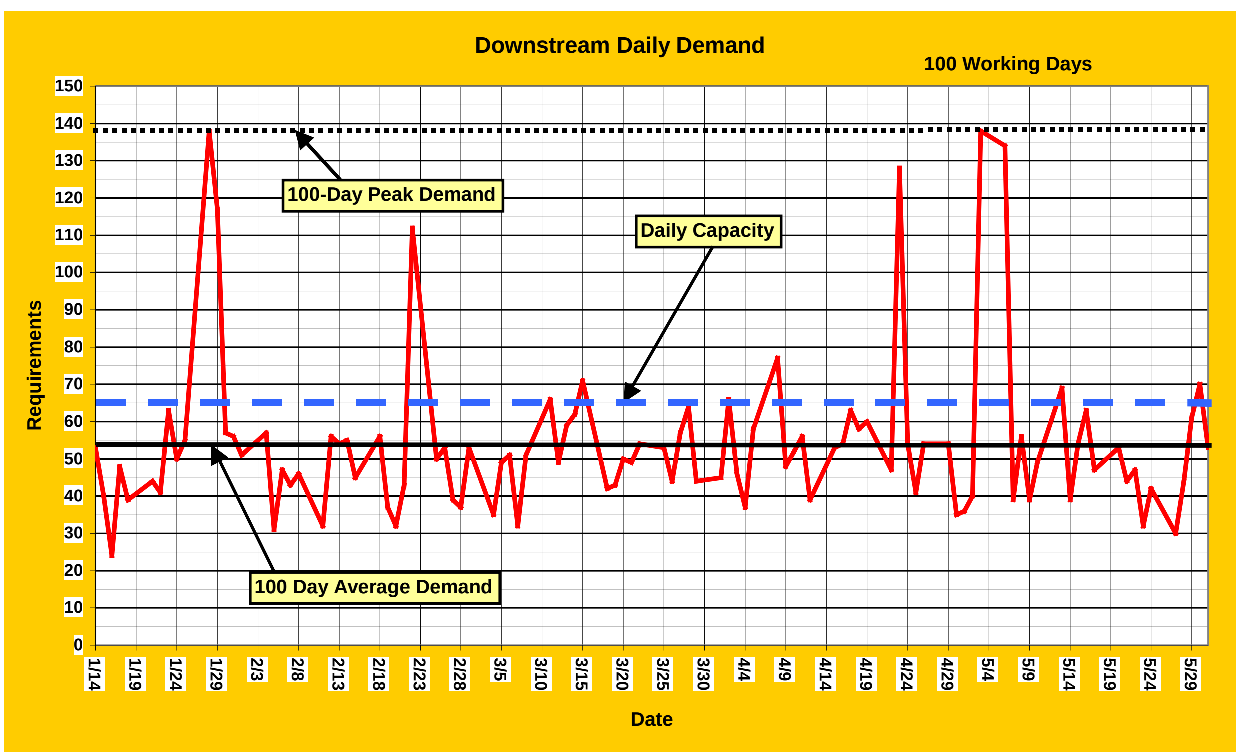

Figure 4 Downstream Demand Pattern Analysis

To examine this downstream demand, prepare a short-term demand chart as shown in Figure 4. Normally this will be a daily demand chart but it might be hourly, weekly or some other period. Figure 4 shows that, for this example, the daily demand over a five-month period exceeds upstream capacity on only six days. Later, we must decide whether to provide enough stock to cover these particular occurrences or cope with them in some other way.

Overall capacity, however, is only one factor that affects the upstream workcenter's ability to track demand. Setup times, lot sizes and downtime are also considerations. It may also be necessary to examine demand on an item-by item basis.

3. Identify Kanban Products

In Step 3, identify those products suitable for kanban. For this example, Figure 3 shows that of the 18 products, only four have enough volume to justify a kanban stock. The remaining twelve will be made to order. It is assumed that the general pattern demand for individual items reflects the overall demand and this may not be the case. For example, Item #9S10 might be sold in a different market that orders in very large lots but these orders are few and far between. Such a pattern does not fit well with kanban and would require a large kanban stock that is used only rarely even though the total volume appears to be mid-range.

4. Identify Appropriate Lot Sizes

Lot sizes are important for both the upstream and downstream workcenters. Generally, the smaller the lot sizes, the smaller the kanban stock and the better the system works. Small downstream lots smooth demand on the upstream workcenter. Small upstream lots enable that workcenter to better track downstream demand.

Contrary to some assertions, Economic Lot Size analysis is still relevant (Figure 5). We can make it irrelevant through SMED techniques that reduce setup time and cost. But, until setup cost is near zero, building in lots will likely be necessary. Until we can build in lots of one, kanban stock is necessary and the amount of that stock is determined partly by lot sizes.

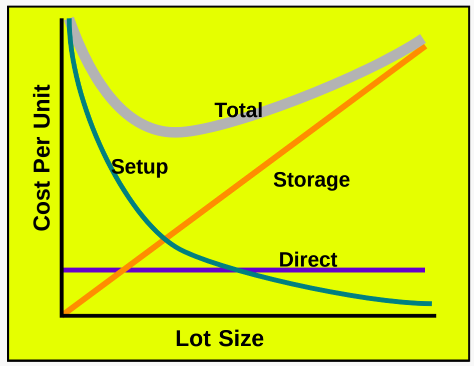

Figure 5 Economic Lot Sizing

5. Identify Containers

Containers are not always used in kanban systems but they offer many advantages, especially for small items. They:

- Protect Contents
- Make Handling & Storage Easier
- Make Quantities Readily Apparent
- Control Maximum Inventories
- Serve As Kanban Signal

Figure 6 Examples of Kanban Containers

Here are some guidelines for container selection:

- Equal to or Smaller Than Upstream Batch Size
- Equal to or Smaller Than ½ Total Kanban Quantity
- May Be Much Smaller Than In Conventional Operations

6. Identify Signal Mechanism

There are many possibilities for the signaling system that informs the upstream workcenter of stock status and withdrawals. One of the best is a simple visual signal, as in Figure 2 where the upstream operator simply glances at the actual Stockpoint. This is enhanced by large labels and color codes. It is even better when both the upstream and downstream operators are in line-of-sight with the Stockpoint.

However, it is not always feasible to have both workcenters adjacent to the Stockpoint. In such cases some sort of remote signal is required such as cards, lights, or empty containers. The most important characteristics are simplicity and speed. Complex systems are difficult to learn, sometimes get forgotten and may not attract attention when unusual situations arise. Computer reports and emails, for example, may not be looked at as frequently as necessary. Here are some examples of Kanban signal systems with illustrations in Figure 7:

- Kanban Cards
- Empty, Returned Containers
- Empty Racks Or Storage Units
- Empty Storage Location On Floor
- Lights With Remote Switches
- Daily Fax Sent To Supplier
- Markings on a Conveyor
- Verbal Request

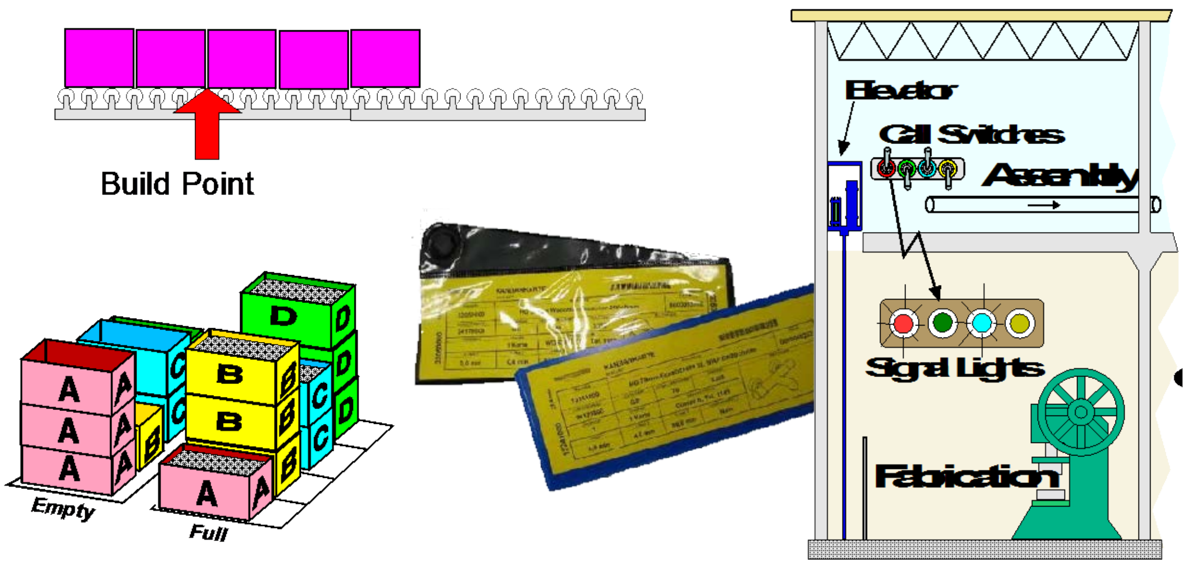

Figure 7 Examples of Kanban Signals

7. Specify Initial Kanban Quantities

Determining the best quantity for the amount of Kanban stock is seldom an exact process. In designing the system we, of course, must make at least an educated guess, estimate or assumption. Following startup, the system should be constantly monitored and the kanban quantity adjusted. The difficulty arises because there are so many variables, so much variation and so little data in most practical situations. Moreover, the optimum quantity will change as operators and managers improve the system. These variables may include:

- Equipment Breakdowns
- Quality Problems
- Operator Training
- Work Time Variation
- Product Mix Changes
- Demand Changes
- Interference from Other Product Demand
- Transport Time Variation
- Raw Material Availability

With all that said, there are some approaches that can help with estimating the initial Kanban quantities. In a particular situation, the designer may use several of these methods in combination.

Computer Simulation

In theory, simulation would be the best approach. It accounts for the probabilistic nature and interactions of many of these factors. However, simulation requires a great deal of time, expensive software and special skills. In many situations there will be dozens or hundreds of different items and simulation is simply impractical. There may be situations where any change to the Kanban quantity is very difficult or expensive and simulation is worthwhile but such situations are somewhat rare.

Boundary Analysis

In this approach we attempt to focus first on the minimum necessary stock if everything is running smoothly or normally. This sets a lower bound on the stock level. Then we focus on the worst reasonable situation where many sources of variability are active and set an upper bound on the stock level. We can compare these boundaries to the stock levels generated by other methods as a sort of sanity check.

Predetermined Formula

Several formulae for calculating quantities have been published. Figure 8 is one example. This is one method for approximating the quantity and may be useful as one of several starting points. However, the formulae usually contain one or more terms that are guesses or they may apply to a particular company and some particular type of process.

In Figure 8, the term “w” is buffer stock that must account for all the variability mentioned earlier. In addition, the Demand Rate is an estimate, at best, and the Lead Time (L) is likely to be highly variable unless the upstream workcenter is dedicated to the particular product or a narrow product family.

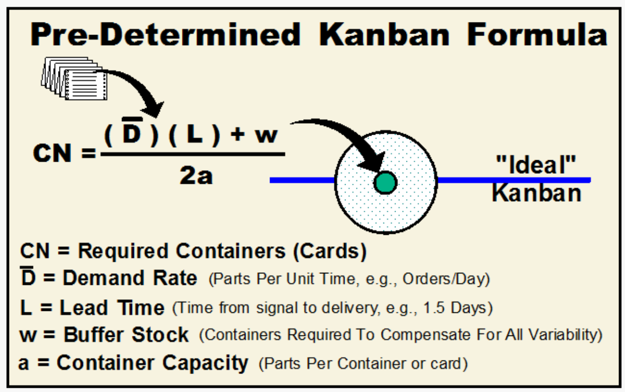

Figure 8 Example of Predetermined Formula

Factor Analysis

In Factor Analysis, we attempt to isolate particular factors that give rise to variability and the need for a buffer stock. The list above is a good start but hardly complete. Considering only one factor at a time, we estimate the buffer required to cope with the variability from that factor. Then we add the various buffer requirements. Since it is highly improbable that all factors will come together and act at the same time, we adjust the result. This, too, is only structured guesswork but that may be better than unstructured guesswork.

Trial & Error

While the methods mentioned above may provide an initial estimate of quantities, ultimately, trial and error is the final test. This simply involves monitoring the stock level over a period of time, usually several weeks or months. If the stock has never or rarely dropped below a certain level, all the stock below that level is excess and unnecessary. So, we remove all or most of it and decrease the authorized kanban quantity.

If there have frequent stockouts or near-stockouts, it indicates that the stock may be insufficient. We might simply increase the stock level but a better approach is to investigate the stockouts, find the source of variability that created the stockout and remedy the problem

This is one of the most important features of kanban; it uses the production control system to drive continuous improvement. In some firms, the authorized stock level is intentionally and gradually reduced to expose problems and improve processes.

8. Design Stockpoint(s)

Task eight designs the stockpoint and this design should specify at least the following:

- Location(s)
- Physical Layout Drawing
- Part# Labels
- Maximum Quantities
- Signal Mechanism & Signal Aids

The ideal location for the Stockpoint is near the upstream workcenter. Placing it there helps those operators to monitor the levels and make production decisions that maintain proper levels. However, the location might be at the downstream location or at some intermediate location, provided that the signal mechanism is simple, clear and fast. There might also be a primary Stockpoint at the upstream location with a smaller Stockpoint at the using location, often referred to as Line Stock.

The stockpoint should have a dedicated location for each SKU or item. Each location should be clearly labeled along with some visual guide indicating stock levels. If at all possible, make labels and indicators large enough that the producing workcenter operators can determine their stock status without leaving their workstations.

Figure 9 shows examples of stockpoints and illustrated the wide variety of possible designs.

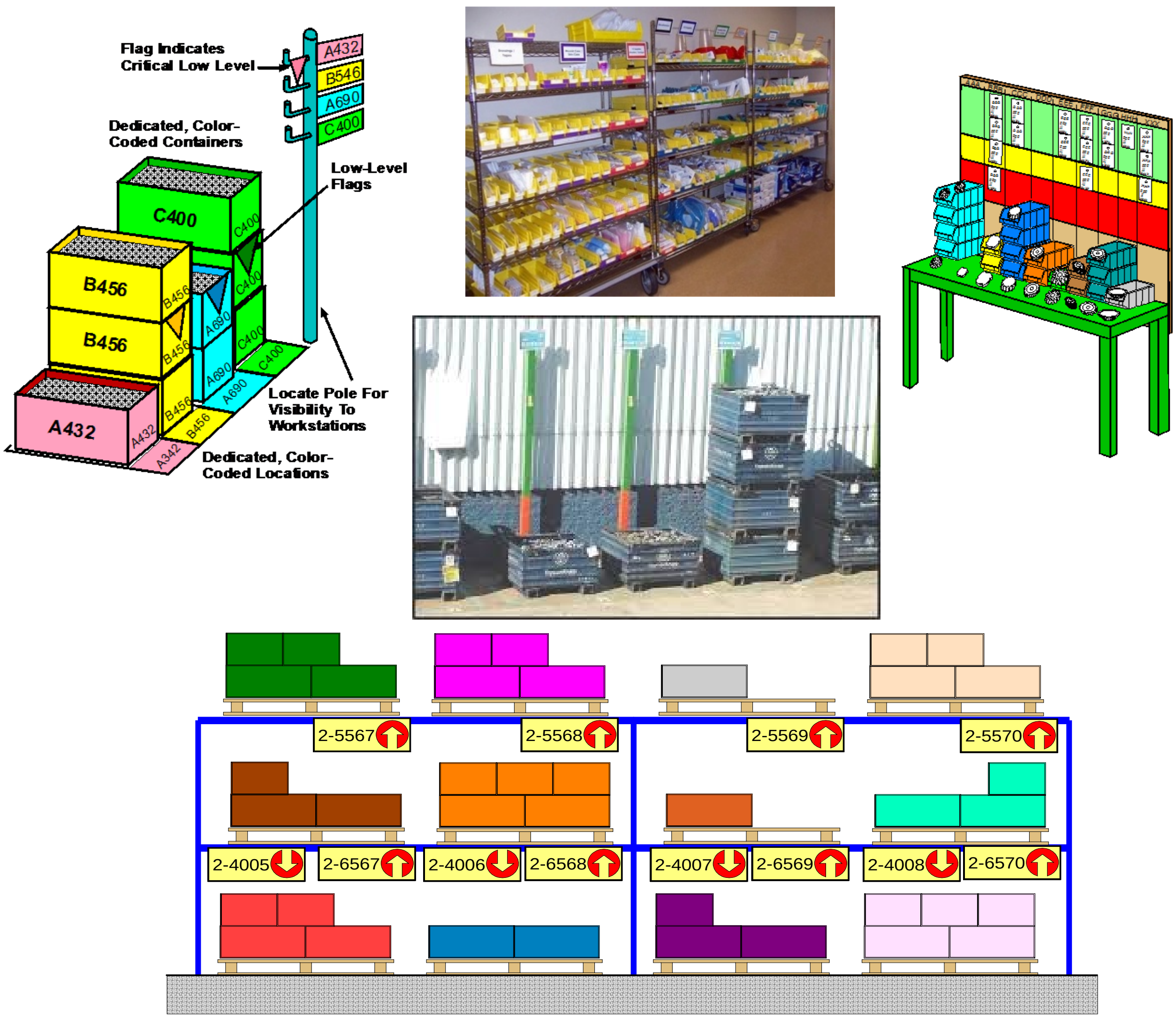

Figure 9 Examples of Stockpoints

9. Develop Upstream Scheduling Algorithm
Kanban signals are sent to the producing workcenter as cards, containers, lights, visual indications or in some other form. In the very simple case where the workcenter makes only one item for a single downstream customer, the scheduling problem is simple: either build or do not build. When that upstream workcenter makes multiple products and/or sends products to multiple customers, some method of scheduling must be in place to decide what to make, when and where to send it.

In most instances, the operators can develop these methods and make these decisions. However, it will be helpful to design the initial system and give operators a starting point for future development. When cards are used for the signal, a Kanban Board as in Figure 10 provides a simple and effective method.

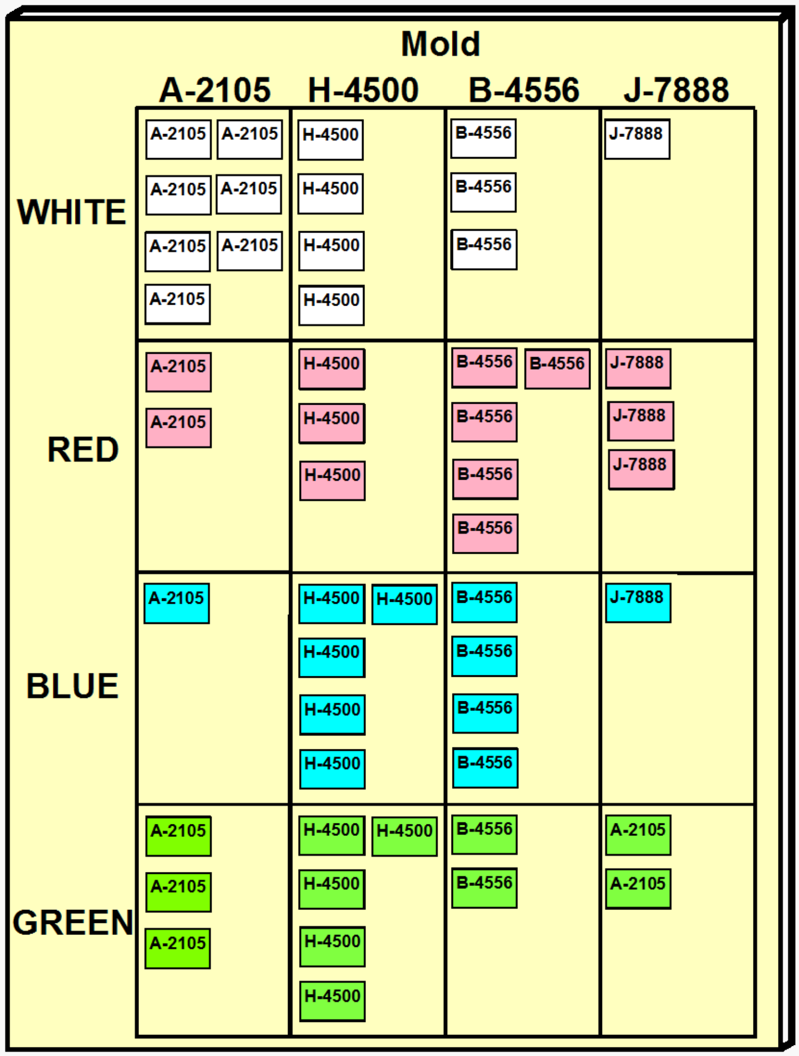

Figure 10 A Typical Kanban Board

The board in Figure 10 is for an injection molding operation. This workcenter produces 16 items for one downstream workcenter. If there were multiple customers the cards would be assigned to particular customers. Some additional points are:

- 4 Molds
- 4 Colors
- Color Change – 0.75 min
- Mold Change – 25.0 min
- Each Card = 100 pcs
- Usage = 800 pcs/day for each item
- Each item has 8 cards

Since a mold changeover is much longer than a color change, it is best to run all the colors for a given mold once it is in the machine. However, we should not run more than the quantity represented by the available kanban cards. Also, if a particular item is in very short supply, it may be necessary to run that job immediately even if it forces an additional mold change.

Cards that are not on the board represent parts that have been built and sent to the Stockpoint. Therefore, the more cards showing on the board, the lower the available stock.

The current status shows that only 100 units of A-2105-White are available. This is less than one hour of average usage. Therefore, the operators need to immediately change to the A-2105 mold and replenish the white parts. Once the white parts are made, they would run the other colors of A-2105 until the board is empty of A-2105 parts. The cards now on the board would be matched to their parts as the parts are made and sent to the Stockpoint along with those parts.

The H-4500 would probably be the next mold change. However, the situation would be re-assessed when the A-2105 parts are complete. If there is a tie, i.e. the same number of cards for two items, operators break the tie based on their general knowledge. In fact, one of the advantages of kanban is that the operators use the scheduling algorithm as a guide but supplement it with current information.

Boards are not the only way to schedule kanban. When empty containers are the signaling device, the scheduling system might amount to arranging the containers as they sit on the floor or shelf. The rule is simple: the highest stack of containers has the highest priority.

10. Operate & Fine Tune

The real test of the design is actual operation in production. Here we fine-tune and modify the system as necessary. Such modifications might include changes or improvements to the signal system, containers or any other aspect of the design. However, the common changes are in the maximum Kanban quantity and the number of containers or cards when containers or cards are used.

Monitoring the quantities is a matter of tracking the stock level over a period of days or weeks. The stock level is then adjusted and/or process changes are made that reduce the need for stock.

5. Summation

In this short paper we have looked at ten steps that will guide engineers through the design of a Kanban system. Much has necessarily been omitted. For example, Kanban should be part of a larger system for production and inventory control that will likely include other methods as well. Kanban is not suitable for every situation. Also omitted is the detail and nuance that is part of every engineering design.

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