# Pull Production System Training Guide.

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Why be lean:

The concepts behind lean manufacturing have existed for almost 100 years but have never been fully embraced by the American manufacturing establishment. 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.

This guide is a training manual that will help you understand some of the basic rules for running a pull system in a manufacturing environment. The first section is a look at the concept of waste and waste elimination. It will include a discussion of each of the seven different forms of waste that a plant can have. It is important to understand the concept of waste in lean manufacturing to understand the advantages that pull manufacturing bring. The second section focuses on the proper implementation of a pull system and the use of the kanban tool to control it. It will include a discussion of different forms of kanban as well as the rules that govern proper kanban handling and the calculations for determining the correct number of kanban between workcenters. It will close with a discussion on the kanban as a tool for identifying and eliminating waste and ways that a workcenter can be productive without producing

## Section 1: Waste

**Section 1 Outline:**

Lesson 1: What is Waste

Lesson 2: Waste of overproduction

Lesson 3: Waste of stocks (inventory)

Lesson 4: Waste of Waiting

Lesson 5: Waste of transportation

Lesson 6: Waste of motion

Lesson 7: Waste of defects

Lesson 8: Waste of processing

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:

Waste of overproduction
Waste of stocks (inventory)
Waste of Waiting
Waste of transportation
Waste of motion
Waste of defects
Waste of processing

In order to understand the importance and value of pull manufacturing you 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.

## Overproduction

What is overproduction

- The waste of overproduction is any product that is produced when it is not needed.
- Over production is considered the first waste because it is also the most common but also because it hides and results from all other waste.
- Stopping overproduction is the primary purpose of pull manufacturing.

What Causes Overproduction

- The most common cause of overproduction is the aversion to idleness, most manufacturing organizations see it as a grave sin. As a result idle workers are always put to work, whether or not the work they are doing is needed. It is import to recognize that a worker producing something we don’t need and a worker producing nothing are both adding no value.
- Another cause of overproduction is lot sizes. Often the amount we need is not a multiple of our lot size, this leads to overproduction. For example, if we need 10 units of a product, but our lot size is 7. We produce 14 units to meet the demand but overproduce by 4 units.
- Defects, or the expectation of defects, can also cause overproduction. If we need 10 units but we have a 10% defect rate then we would produce 11 units to cover to expected defect.
- The last cause of overproduction is poor production control. Sometimes a workcenter will finds itself with extra material and will produce whether or not there is call for it.

The Effects of overproduction

- Overproduction hides all other forms of wastes. An organization that overproduces might appear healthy to all the stakeholders but have many hidden problems such as large numbers of defects and long processing and wait times. But none of these issues are seen because all the workers are busy and shipments are made more or less on time.
- By overproducing products we don't need we consume raw materials that might have been gone to products we do need.
- Overproduction results directly in the 2nd waste, inventory.

## Inventory

What is inventory

- Inventory is any material that we have paid for that we are not adding value to.
- A box of parts that sits on a shelf, raw material that hasn't been processes and finished products that don't have a buyer are all examples of inventory.
- There is an exception for products where time does add value, wines for example gain value from an ageing process. But few manufactured parts gain any value from sitting on a shelf.

What causes excess inventory

- The primary cause of excess inventory is overproduction. If a workcenter is able to produce faster than its product is consumed then excess inventory will build up.
- Another cause of excess inventory is the belief that inventory is good. Many organizations record inventory as a revenue or return on investment, but inventory has no value until it is sold and in the mean time it has many costs associated with it.

The effects of inventory

- Inventory is a difficult waste to discuss because it is also a necessary one. No plant is going to be able to function without some level of inventory, but it is important to recognize that inventory is not desirable. In fact reducing and controlling inventory is one of the primary purposes of pull manufacturing.
- Items in inventory gain no value. No matter how long material is stored it will be no more valuable to the customer then if it were used immediately.
- Inventory represents a huge source of cost. It takes space to store it, people to maintain and control it and it may require special equipment to move it around. The biggest cost of inventory is the inventory itself, in some plants the cost of inventory is in the 10's of millions of dollars.
- Like overproduction inventory covers other wastes, it hides production and processing issues and pads long transportation and waiting times.

## Waiting

What is waiting

- Waiting is when any time that could be used productively is not. Whether that time is material time, machine time or operator time.
- For an operator, waiting can very easily be disguised as other work, watching a machine run for example could be wasted time.
- For material waste in waiting is different than waste in inventory. Material that is waiting is scheduled to be worked on but the resources are not yet available. Maybe it's waiting for a machine to be available or for the transportation equipment to get to it.
- Machine waiting time is time when a machine is scheduled to be running but is unable to due to a lack of material or operators.

What causes Waiting

- Waiting can be caused by improper line balancing, when one workcenter takes a long time to accomplish its work the rest of the workcenters can waste lots of time waiting.
- Waiting is the waste that managers try to combat with overproduction, however there are many other activities that can be performed during downtime.

What are the results of waiting

- Waiting is a waste simply because it is time that could be spent doing something productive. However there are ways to be productive without producing. See Section 2 lesson 7 for more details.

## Transportation

What is transportation waste

- Transportation is the time spent moving from place to place. Generally it is material being moved from one workcenter to another, but it could just as easily be operators or machines being moved.
- Transportation is waste because rare does the act of moving from one place to another increase value.

What Causes Transportation waste

- The first cause of unnecessary transportation is poor layout. It is often surprising how far a product will move through the factory.
- Unnecessary transportation is also caused by poor planning. Material may be moved several times or stored in a disorganized manner. In either case unnecessary transportation can result.

What are the results of transportation waste

- The unnecessary distances traveled will result in wasted time but also result in increased lot sizes. Often if material has to be moved a significant distance a large amount must be built up before it is transported. Large lot sizes often result in over production and large inventories.
- Poor planning and communication can result in extra trips as material is moved back and forth.

## Motion

What is wasted motion

- The waste of motion is generally identified as movement that operators perform that does not add value to the product.
- Motion is distinct from transportation in that motion refers to the actions that an operator must perform in the course of regular work, transportation is the process of moving an operator from work site to work site.

What causes wasted motion

- Wasted motion is any activity that the operator performs that does not add value to the product.
- If the operator frequently walks between two distant machines or spends time locating a tool then they are engaging in wasted motion
- Wasted motion is generally the result of a poorly designed or poorly organized workcenter

What are the effects of wasted motion

- Wasted motion results in wasted production time. Every minute that an operator spends looking for a tool instead of using it, or walking to a machine instead of operating it is a waste of motion.

## Defects

What are defects

- A defect is any mistake that causes the product to lose value for the customer.

What causes defects

- The root cause of defects is improper training. This is because improper training leads to all of the direct causes of a defect. Incorrect material handling, poor machine utilization, infrequent or improper machine maintenance, incorrect production methods.
- There is of course such a thing as a simple mistake, but mistakes a still wasteful and the organization that can prevent mistakes will be more successful than one that cannot.

What the effects of defects

- The worst case scenario is that a defect reaches the customer.
- In order to avoid this many plants engage in other forms of waste to minimize the chance of a defect reaching the customer.
- Plants will overproduce to cover any defects and inspect every part to check for defects.
- One practice many plants engage in is passing know defects. In order to keep the line moving they will pass a known defect down the line and then try to rework the product after final assembly.
- Any extra work on a defect is waste because that defect cannot be sold to the customer. A defect that is passed on automatically engages in all other forms of waste.

## Processing

What is wasted processing

- Wasted processing is found within the processing method itself.
- It is not the result choosing the wrong machine, though that can be a factor, it is the result of improper use of the machines that are available.
- A shaping process may require that the part undergo a heating process, but of the heating process could be eliminated by properly calibrating the machine then it is wasted processing.

What causes excess processing

- This waste can result from a poor choice of machines, there could simply be better tools available. However this waste generally focuses of the procedures used with the tools that are available.
- One cause of processing waste is insufficient training for operators that leads to improper use of the tools.
- Another cause is poor machine maintenance which can reduce their effectiveness.

What are the effects of wasted processing

- Just like wasted motion, wasted processing results in wasted production time.
- In it important that every workcenter be used to its full potential, but this is different than being used all the time. Be sure that improving processing does not result in overproduction.

## Section 2: Pull manufacturing

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.

**Section 2 outline:**

Lesson 1: An overview of pull manufacturing: What can pull do, Core principles

Lesson 2: Kanban, the signal for work: what is a kanban?

Lesson 3: The rules of kanban

Lesson 4: Different styles of kanban, what does a kanban look like?

Lesson 5: Kanban systems, brand kanban, generic kanban, specialty kanban

Lesson 6: kanban calculations: How many kanban does the system need?

Lesson 7: How to be productive without producing; Maintenance, 5-S

## 1. An overview of pull manufacturing

The goal of pull manufacturing

Reduce inventory through capacity control
Increase throughput by identifying bottlenecks
Better product mix through improved line balancing
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.

- Material should not be produced anywhere unless it is needed further down the line and ultimately by an external customer
    - The purpose of this rule is to prevent the build-up of unnecessary inventory in the form of material that has been produced, but is not needed

- Material is not moved unless it is needed at its destination
    - Material that is shipped pre-maturely overburdens the receiving work center and prompts the production of more unnecessary material.

- Material is not stored for long periods of time and is always used before more is stored
    - Everything that is produced is an investment of time and money, the longer it goes unused the longer it will take to make back to investment and in the mean time it takes up space and can hide quality issues

- Each work center has a set amount of inventory, more may only be produced if some is consumed.
    - Following this rule forces work centers to only produce material that is needed, once the maximum amount of inventory has been reached production stops.

## 2. Kanban, the signal for work

- 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.

  (If the milkman where to add milk bottles every time he passed a house then the owner would very quickly run out of room for all the excess milk.)

- 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.

  (When you place the milk bottle for the milkman he replaces it, he then sends a signal to the warehouse to replace the milk that he left. The warehouse then sends a signal to the dairy farmer to send more milk. If any of these processes were to send milk before the next process was ready then an excess of milk would form. )

- 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.

- Kanban will result in idling workers

## 3. The rules of kanban

There are not many hard and fast rules for JIT, the method assumes you will do what you can to not compromise the project. However there are 8 rules that must be observed in order for a pull system to operate correctly.

1. Never build past kanban ceiling
   - Whatever kanban ceiling is established must be observed
   - Production must be limited by the kanban system or it becomes completely ineffective
   - It may be necessary to add additional kanban to the system on a permanent basis, in this case the ceiling is raised
   - Occasionally the kanban ceiling may have to be increased, but this should never be done more than a few times a year (1), when this happens extra "emergency kanban" can be added, see "specialty kanban" later in this chapter for more details

2. No material moves without a kanban
    - Material that moved with first being requested is not being pulled and may move unnecessarily
    - Unnecessary movement of material is one of the 7 wastes and should be eliminated
    - The “Two card kanban” system controls the movement of material, one card authorizes production, the other authorizes movement, see the “Two card kanban” system later in this chapter for more details

3. Never pass a defect
    - Passing a known defect is a source of a lot of waste in any production setting
    - Operators should be trained to recognize a defect and to never pass it to another work center, see “The Thinking worker” chapter for more details
    - If the defect can be reworked it should be, but the rework should also be under kanban control
    - Defects can create temporary line imbalances but it is preferable to putting extra work into an already defective product

4. First in first out
    - A work center should proceed through all kanban orders on a first come first serve basis
    - Lin e imbalances and other delays can be created or worsened if this rule is not followed

| |
|---|
| 1. Never build past kanban ceiling |
| 2. Never transport material without a kanban |
| 3. Never pass a known defect |
| 4. First in first out |
| 5. Customers pull material |
| 6. Only active material at a workcenter |
| 7. Everything with a place, everything in its place |
| 8. Reduce kanban to expose constraint |

Table 1, Kanban Rules

5. Customer pulls material from supplier
    - Orders will only come from the work center that will receive the product
    - Generally this system is easy to maintain, however it can be difficult when a single work center is supplied by several others
    - In this case it may be necessary to create a separate queue for each supplier in front of the bottleneck work center
    - When this queue begins to fill a signal is sent to the supplier that tells them to slow production
    - When the queue is full another signal is sent to tell them to stop production, allowing that supplier work center to focus on other priorities

6. Only active material at work center
    - Only material that is in use or will be used shortly is allowed at the work center
    - Excess material clutters the work center and slow production
    - If excess material is present when it is not being worked on then it is a sign that the pull system is not being followed, either an order was placed before the material was needed or the material was sent before it was requested
    - Be sure that only active material is present at a work center

7. Everything with a place, everything in its place
    - Workplace organization is key to maintaining an effective pull system
    - Without an organized workstation it will be difficult to tell what orders have been placed and which have not
    - Different kanban and materials should be stored separately so that inventory levels can be visually inspected

8. Reduce kanban to expose constraints
    - Once the kanban system has been implemented the number of kanban should be slowly reduced in order to expose constraints
    - If the number of kanban cannot be reduced due to, for example, transportation time, then every effort should be made to remove the transportation constrain until the number of kanban can be reduced.
    - One of the most useful features of kanban is how easily they allow the "one less at a time" method to be practiced, simply remove a single unit from inventory by adjusting the kanban values.

## 4. Different Styles of kanban, what does a kanban look like

- 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. Remember that Kanban are most useful as a visual control, so it is generally wise to decide which system to use based on the most visible option available.

- The most 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
    - The control method for this kanban is simple to enforce, if the space is empty the work center builds enough to fill it in, otherwise there is no need to act
    - This kanban is the most visual because it shows at a glance how much material is available between work centers and what material is needed
    - This kanban is also the most responsive because only material that has been used is replaced

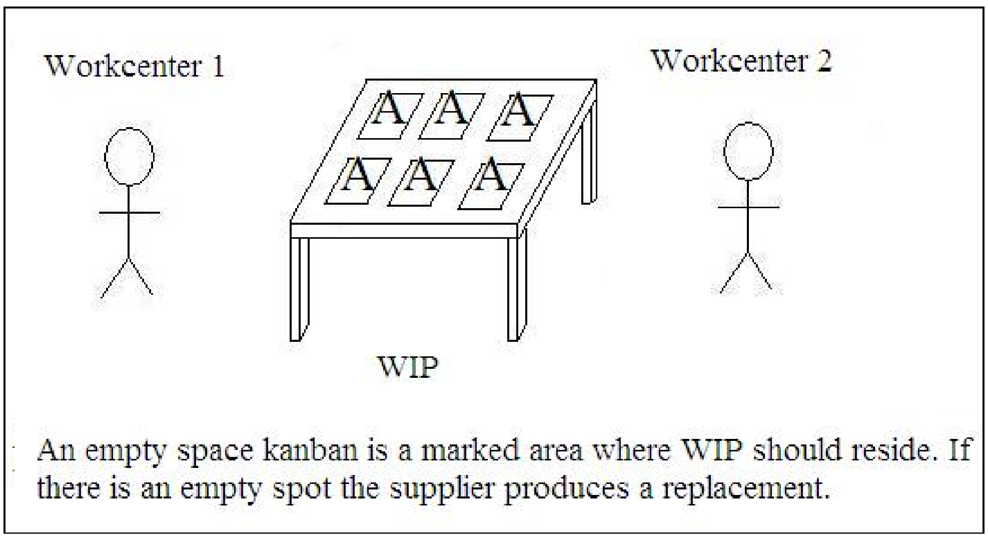



Figure 1, Empty Space Kanban

- 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.

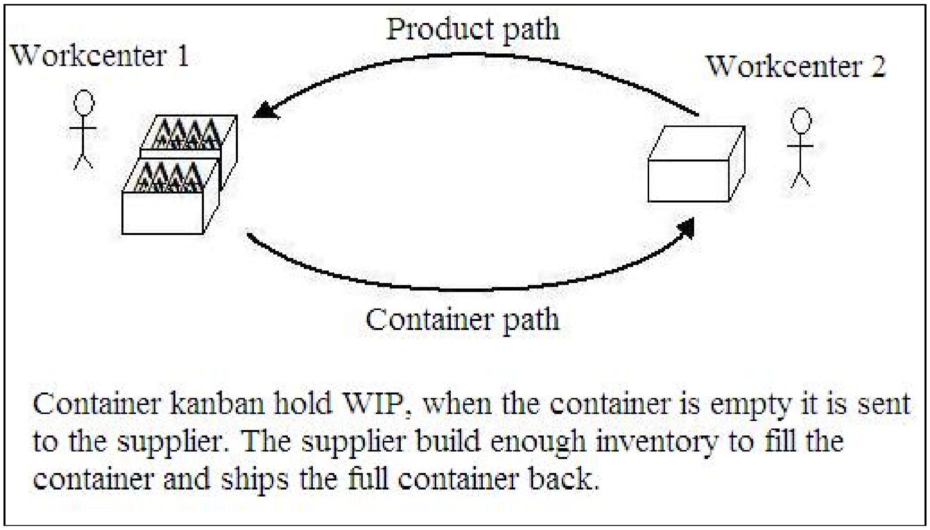



Figure 2, Container kanban

- 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. Note: two if two workcenters are distant from eachother then the signal might be sent electronically. To maintain kanban control each workcenter would have its own cards, when a signal was sent/received a card would be removed from the wall to show that it had been used.

  - This method can be visual if the cards are displayed properly. When in use they should be attached to the inventory that they authorize. When not in use they should be displayed on a board.

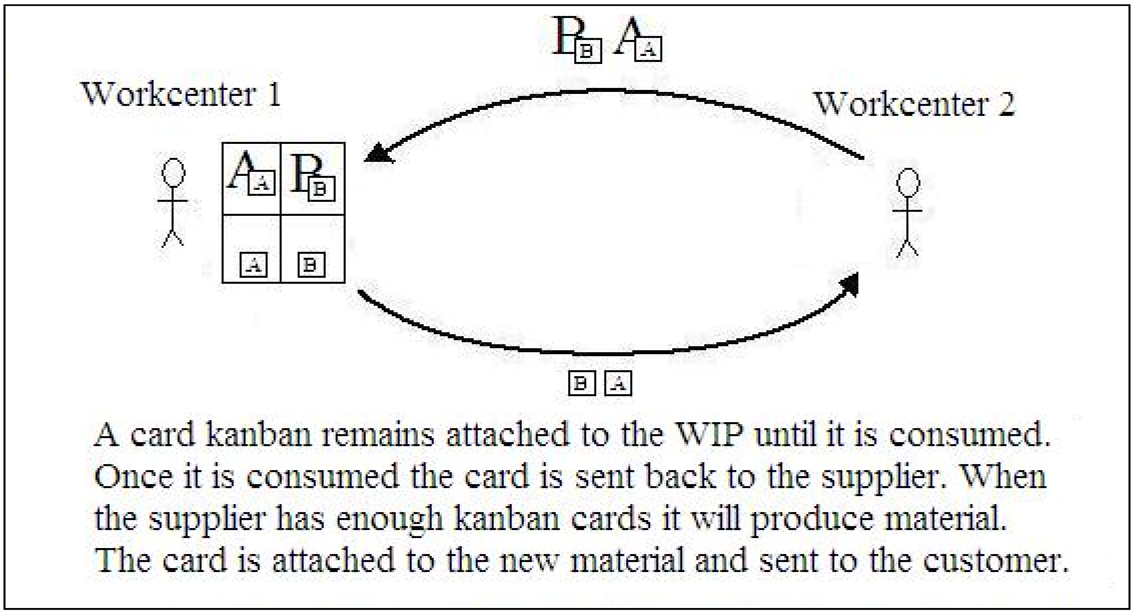



Figure 3, Card kanban

- Electronic/computer kanban
  - 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.
  - 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
  - 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.

## Kanban systems

Now that we have an idea of what a kanban looks like we can begin to study the different methods of kanban and how they work. In the end every kanban must do two things, it must tell the supplier what to build and when to build it. However there are certain systems that are best controlled by more sophisticated kanban.

### Brand kanban

A Brand kanban answers both questions at once.

- Each product has its own unique kanban that signals production for that product only.
- When a kanban is available the product is produced
- When a workcenter receives a kanban it knows what to produce (what the kanban is for) and when to produce (immediately)

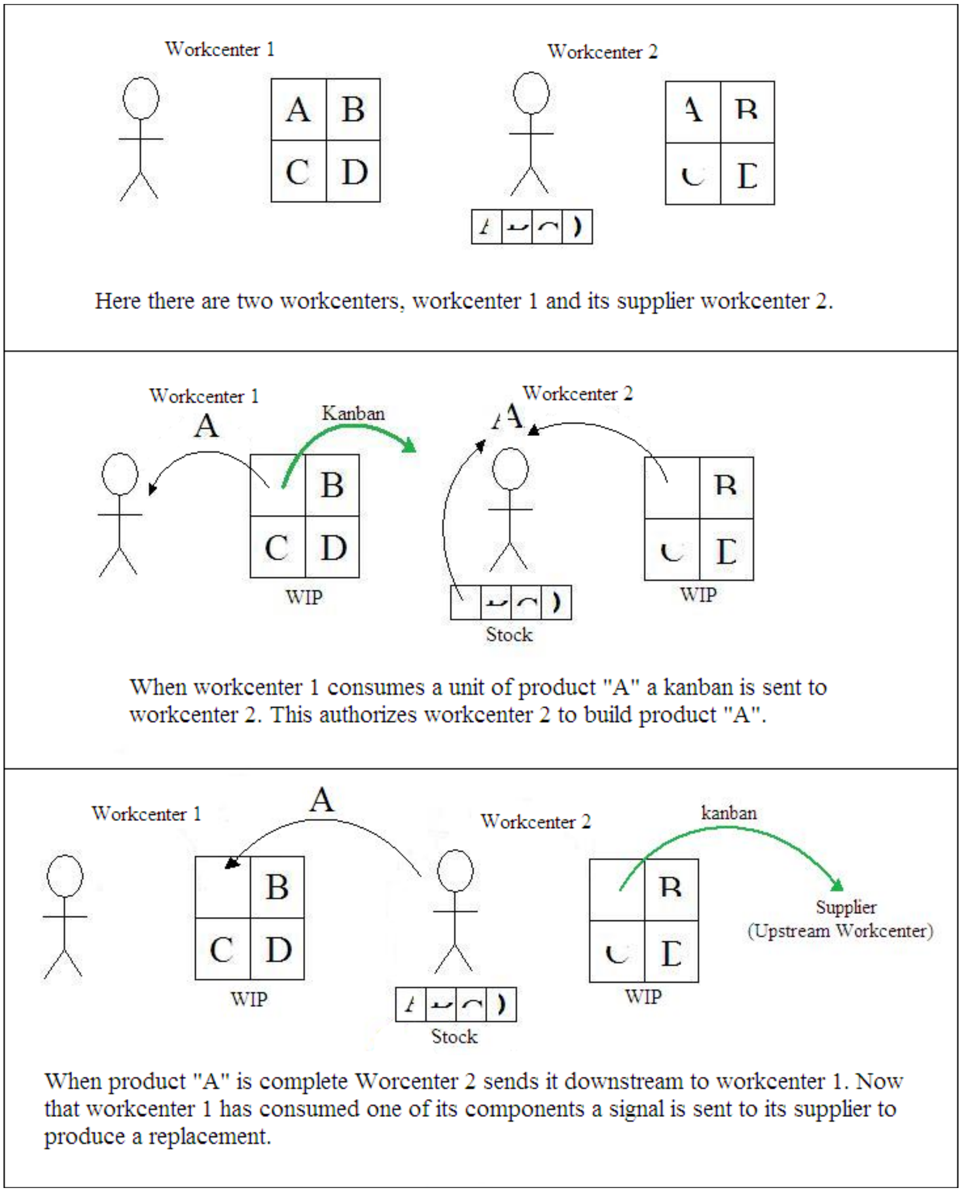



Figure 4, Brand Kanban

## How does it work

- If a workcenter produces 4 different products then it would have 4 different kanban.
- When its customer uses one of its products a kanban is sent.
- When the workcenter receives the kanban it immediately produces a replacement for that product.
- Remember that receiving a single kanban does not necessarily signal the production of a single unit. The workcenter might wait until it has 15 kanban before producing all 15.

## When to use Brand kanban

- Brand kanban are the easiest to understand and control, so they are the first that an organization should implement.
- Brand kanban perform best in an environment with low product mix and high volume

## Generic Kanban

- A generic kanban gives a workcenter permission to build but doesn't say what to build.
- Some other method is used to determine what to build, this can be from the master schedule, a local schedule or some other convenient method.

### How does it work

- When the workcenter receives the kanban it is authorized to produce but the kanban does not tell it what to produce.
- The workcenter would consult a schedule or production list to determine the specific product that should be produced next

### When to use generic kanban

- Generic kanban are most useful in an environment with high product mix and low volume.
- Generic kanban are also useful when a workcenter build several very similar products that can be classified under a single kanban, for example the same product in different colors.

### Moving from brand kanban to generic kanban

- At a certain stage of waste reduction it is useful to switch from brand kanban to generic kanban
- In a brand kanban system each product must have its own unique kanban, so at any time each product would be in inventory
- By switching to generic kanban less kanban could be used, maybe a single kanban for every 2 products. This would reduce inventory by half.

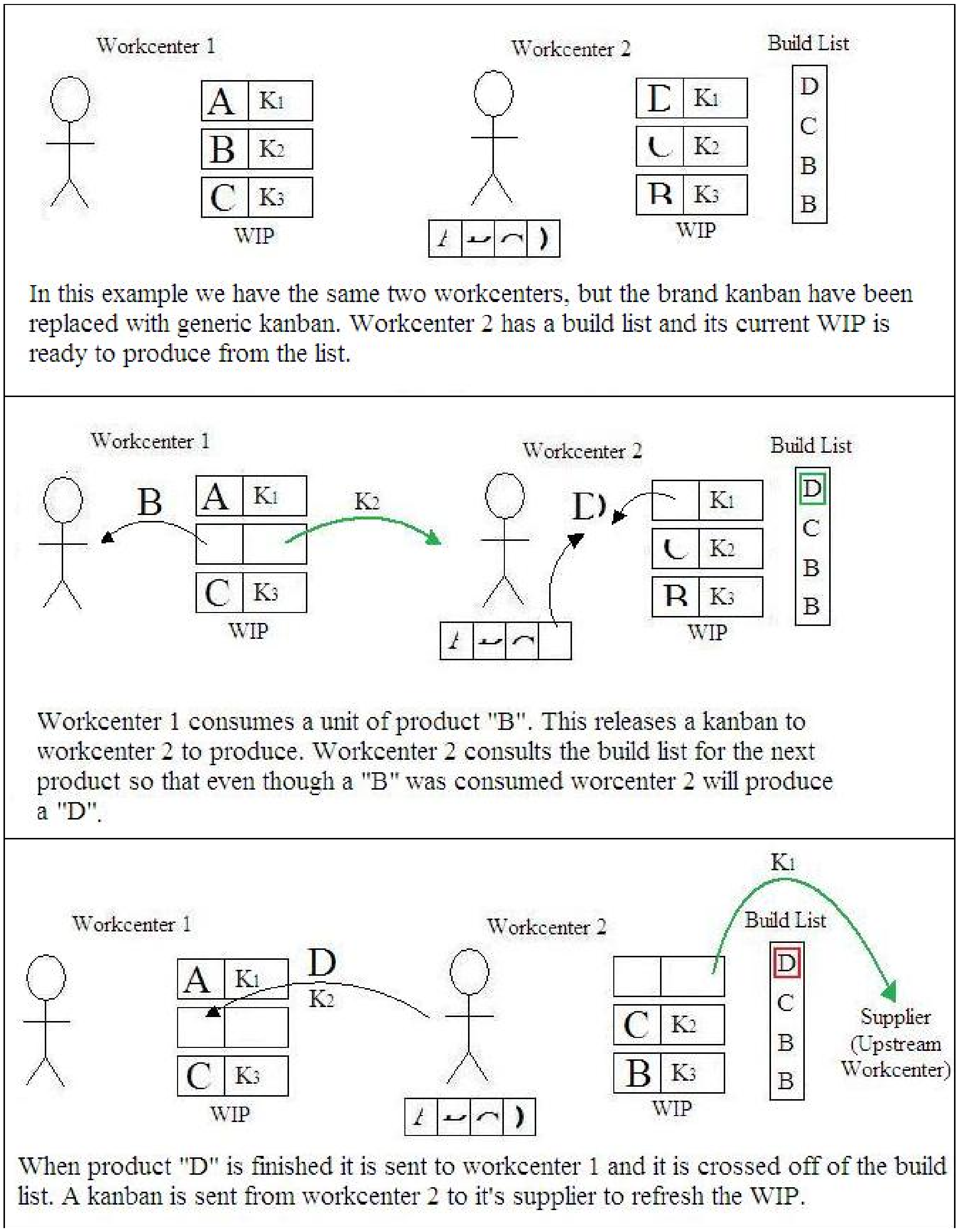



Figure 5, Generic Kanban

## Duel Card Kanban

A duel card kanban system is a two step signal

- The first signals for the production of material
- The second signals for that material to be moved to the customer.

How does it work

- When a workcenter consumes material it sends the normal production kanban to its supplier
- When its supply reaches a low enough level it sends the move kanban to receive the material that has been produced

When to use duel card kanban

- A duel card kanban system is used when there is a large distance between two workcenters, especially when the transport time is much longer then the production time
- A duel card system helps to maintain the visual aspect of kanban between two distant workcenters

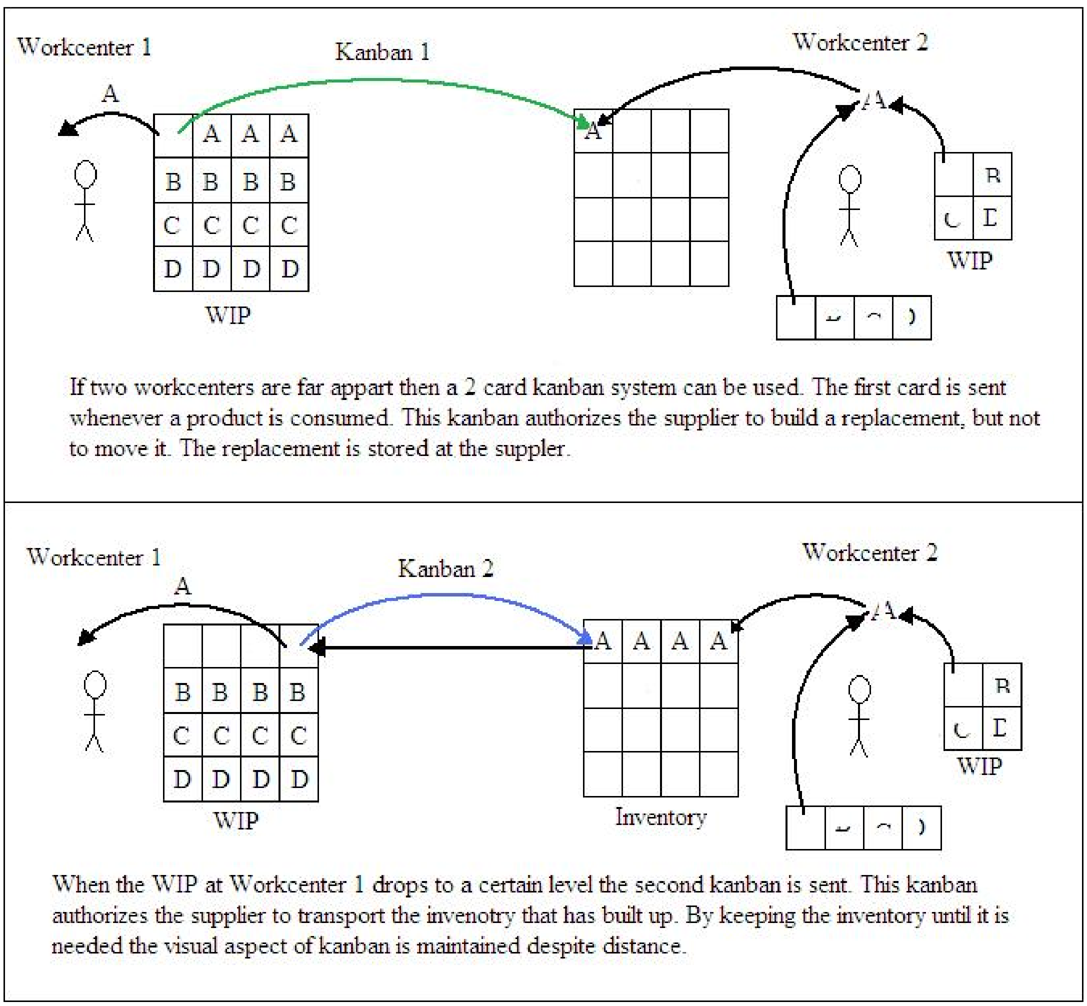


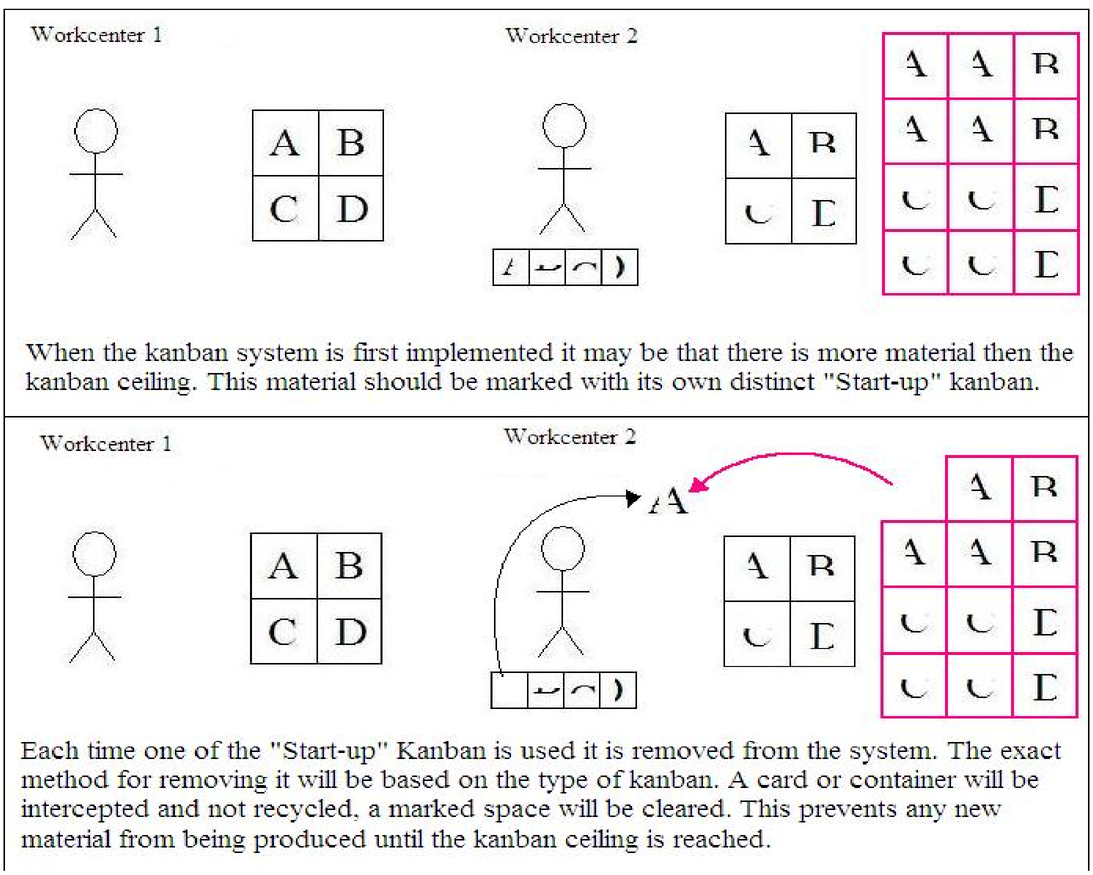

Figure 6, duel Card Kanban

Specialty kanban

There are of course other activities that a workcenter will perform, along with normal production and many of these activities result in some form of inventory. These activities should also be kanban regulated both to show that any inventory is not in violation of the kanban system but also to help control these activities in relation to normal production. All specialty kanban should have their own distinguishing features to keep them separated. The easiest is for each kanban to have its own unique color, this way every kanban can be identical in shape and form while being instantly recognizable. Each specialty kanban below has a suggested color, you are of course free to chose your own.

Start-up kanban (pink)

- When the kanban system is first implemented there is likely to be excess inventory that is above the kanban ceiling
- This inventory can be marked with a start-up kanban that shows its status as temporarily permitted excess.
- When a unit of excess inventory is consumed the start-up kanban is not re-circulated
- Without the kanban production is not stimulated and excess material is purged from the system
- As each start-up kanban is removed it can be displayed to give a good visual indicator of inventory reduction.




When the kanban system is first implemented it may be that there is more material then the kanban ceiling. This material should be marked with its own distinct "Start-up" kanban.

Each time one of the "Start-up" Kanban is used it is removed from the system. The exact method for removing it will be based on the type of kanban. A card or container will be intercepted and not recycled, a marked space will be cleared. This prevents any new material from being produced until the kanban ceiling is reached.

Figure 7, Start-up kanban

Rework kanban (Orange)

- If material is returned to the workcenter it will need some sort of kanban to show that it is not excess inventory in violation of the kanban ceiling
- It best to mark rework with a production kanban so that more production is not stimulated until the rework is handled.
- If the rework exceeds the available production kanban then it can be marked with a rework kanban.
- Rework kanban also give a good visual representation; if all the rework kanban are available then we know that not much is in rework; if a lot of them are taken then there is a problem.

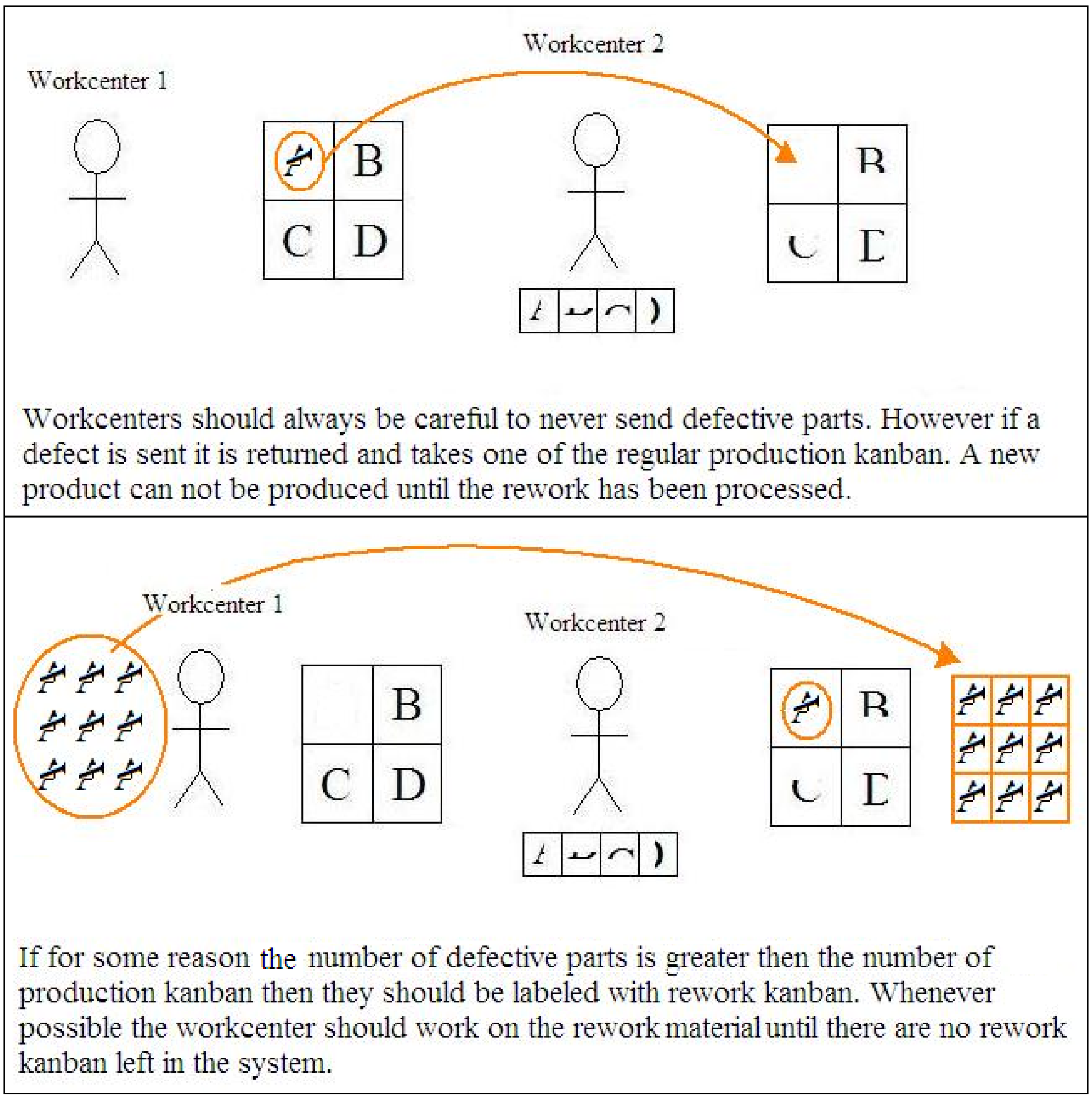



Figure 8, Rework Kanban

Restock Kanban (Yellow)

- Small components such as nails, bolts and other material stored at the point of use can also be kanban controlled.
- When the supply of components reaches a predetermined level a restock kanban is sent to the stock room.
- The stock room replenishes a predetermined amount of components.
- This method does not count the number of components being sent to a workcenter, the backflushing method is used to count the number of components used.
- The backflushing method is simply counting the number of parts produced and then multiplying by the number of components in each part. If 5 parts are produced and each is known to contain 5 screws then the backflushing method would record the use of 25 screws.

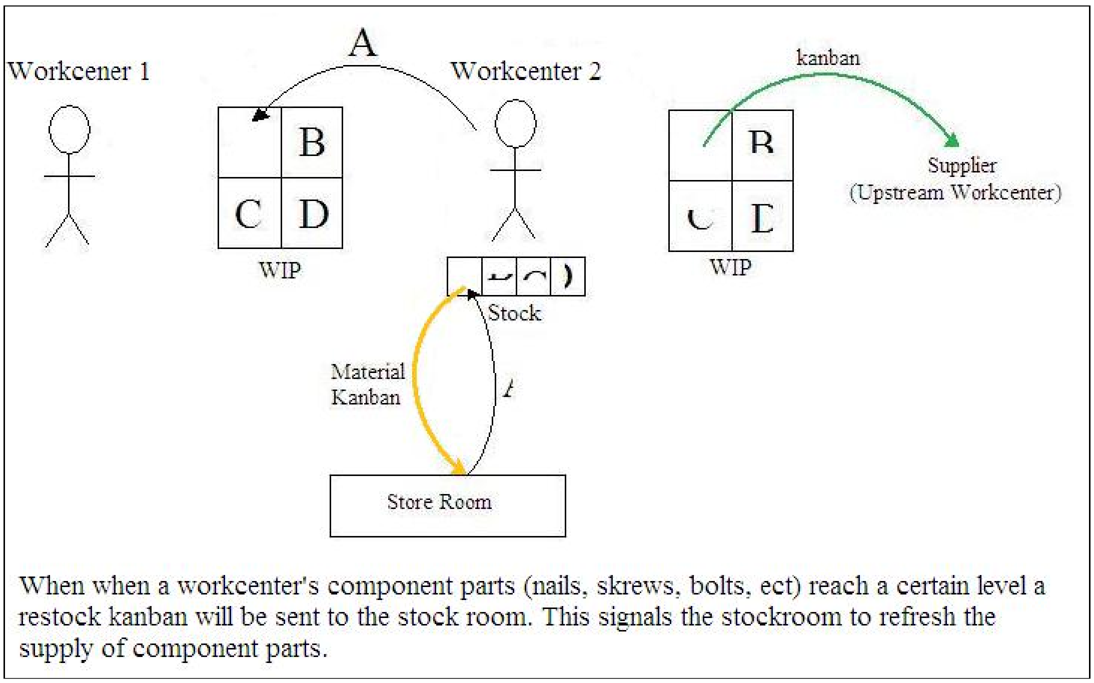



Figure 9, Restock Kanban

Engineering kanban (Blue)

- Occasionally a workcenter will need to supply an uncommon customer, for example producing a new product for engineering.
- A special kanban exists so that these uncommon customers can request production without interrupting the normal operation.
- The customer simply inserts the kanban into the normal pull cycle and waits for the production rotation to respond to the request.
- If necessary the customer can insert their kanban at the front of the line for processing but this can be disruptive for other customers
- It is generally best for the engineering kanban to be inserted like any other kanban.

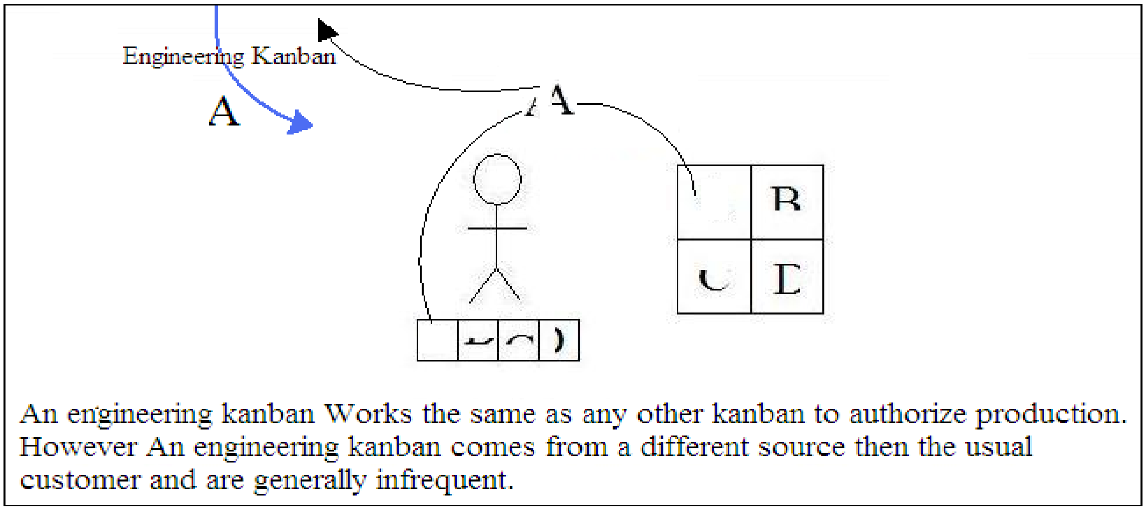
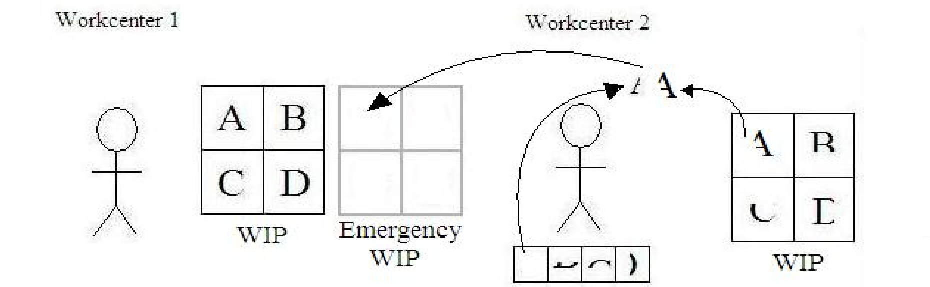


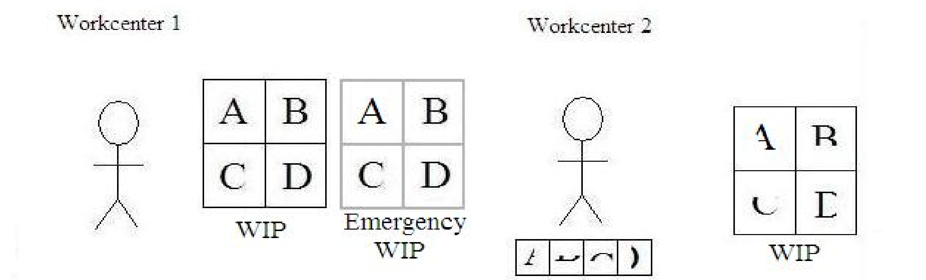

Figure 10, Engineering kanban

Emergency/management kanban (White)

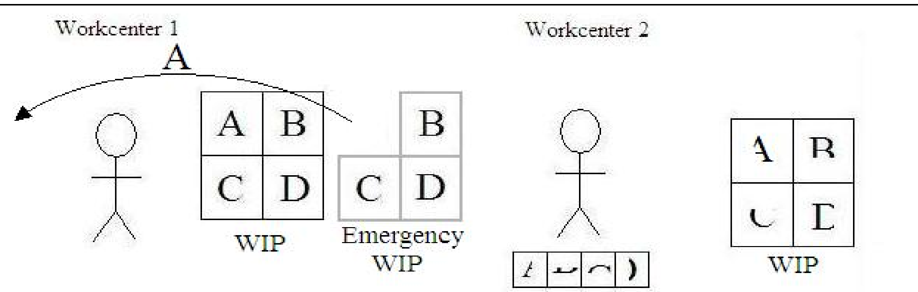
- This kanban exists to work temporarily increase the kanban ceiling in the case of an emergency.
- For example, supply of a vital components may be temporarily disrupted. This might cause a workcenter to be unable to produce, this in turn would cease the normal flow of kanban and all suppliers to that workcenter would also stop production.
- However it may be necessary for the suppliers to continue production regardless.
- Extra kanban are added to the stopped workcenter, these kanban are used to authorize production at the supplier workcenters.
- These emergency kanban still follow all of the rules for kanban, they simply establish a new kanban ceiling.
- When production starts again the excess inventory is consumed, but the emergency kanban are removed from the system to return the kanban ceiling to its original level.
- The danger of emergency kanban is that they may be used t much. If a plant uses emergency kanban to frequently then they are not participating in a pull system.
- Emergency kanban should not be used more than 6 times in a 12 month period, and should not exist in the system for any longer than necessary. (1)




Workcenter 1 is unable to produce, but it is necessary that workcenter 2 continue production. Emergency kanban are added to workcenter 1 so that workcenter 2 can continue to produce.




Workcenter 1 builds to the new kanban limit but continues to follow all the kanban rules. Once the new limit is reached production stops.




Once workcenter 2 begins production again it will use the excess inventory that was created with the emergency kanban. When each emergency product is consumed the kanban is not recycled. The kanban limit decreases back to its original value.

Figure 11, Emergency Kanban

## 5. Kanban Calculations, How Many Kanban Do We Need?

It is important to establish the proper number of kanban in the system, there must be enough to keep the supplier busy and the customer fed, but limited so that inventory is controlled. It is also important to establish a balance between kanban, containers and movement amounts.

Establish a reasonable number of kanban

- A single kanban should not represent a large quantity of product
- The amount that would be considered large will vary from product to product, but a single kanban should not represent more than half a day's work and should preferable represent less.
- If each kanban represented 1000 units then the workcenter would have uneven workloads.
- Instead each kanban could represent 10 units. This would more evenly level demand on the workcenter and make it easier to add and remove kanban.

Consider lot size and movement multiples

- Kanban should be established as a fraction of the transportation amount and the lot size.
- Suppose a product is produced in lots of 100 but transported in groups of 25 for convenience. A kanban should represent some fraction of both these numbers for example 5 units.
- When the workcenter has 5 kanban they can move a group of 25. When 20 kanban are available a lot of 100 can be produced.
- This makes it easier to change the number of kanban or the units each kanban represents if either the movement amount or the lot size were to change.

Avoid matching kanban with daily or weekly production

- This can lead to the mistaken assumption that the kanban equate to the daily or weekly production, and the thought that an increase in daily or weekly output requires an increase in kanban.

Consider downstream unevenness

- If a single workcenter makes several products it may be that one of them requires an especially large amount of resources from an upstream workcenter.
- If this large requirement is the exception rather than the rule then it is valuable to use smaller kanban to level the load on the upstream workcenters.
- For example, if most products required 5 screws, but one required 15, it would be helpful to have a kanban represent 1/3 the amount for the larger requirement to level the demand the demand on the screw supplier.

Kanban calculation

- As we have previously discussed kanban represent the total amount of material that is allowed to exist. Therefore the number of kanban is based on the consumption rate of material and the time it takes to replenish that material.

- The replenishment time is the time between when a product is consumed to the moment a replacement can be produced. The replenishment time includes all of the time that material spends between when it is order and when it can be delivered:

    - Any time it may take for the kanban to reach the supplier
    - The transportation time to get material to the supplier
    - The time it spends waiting to be worked on if the supplier has other orders to fill
    - The processing time it spends with the supplier.
    - The transportation time to move the material to the customer.
    - Additional considerations must be made for rework, machine down time, part storage and any planning time.

| |
|---|
| Replenishment time is a combination of all the tasks that it takes to produce a product. It is a combination of the amount of time the material spends waiting, the time it spends in the queue for the workcenter. The set-up time for the workcenter. The actual run time and the transportation time to the next workcenter, including any time it spends waiting to be transported. |

- It is important to note that all of the factors that add to the replenishment time are forms of waste as discussed in Section 1. Eliminating these wastes and reducing replenishment times are one and the same. In this way kanban act as tool that gauges how effectively waste is being eliminated, the less kanban you can use the less waste you have. By studying the causes of long replenishment times you can study and reduce the amount of waste.

- William Sandras (1) uses the following calculation:

| | |
|---|---|
| | Replenishment Days |
| + | Safety Days |
| = | Total Days |
| X | Rate/Day |
| = | # of Pieces |
| + | Lot Size |
| = | Total Pieces = # Of Kanban |

Note: If the kanban represents more then one unit then:
Total # Pieces / # Pieces Per Kanban = # of kanban

Table 2, Kanban calculation

- While these values are given in days it is entirely possible that they could be measured in weeks, hours or minutes. Whatever is appropriate for a given workcenter.
- Replenishment Days is the number of days it takes for a product to be available to the customer. If it were to take 1 day to produce a unit and 1 day to transport it then the replenishment days would be 2. If the product were produced in lots of 5 then the replenishment days would be 6 (5 days of production, 1 day of transportation). If the lot size changes then the Replenishment Days change as well
- Safety Days Is the amount of material that will be available if there is a delay or an error of some type. If the product is produced in lots then the Safety Days will be the amount of material available between lots.
- Rate/Day is the amount of material consumed per day by the consumers of a product. It is important to include all the customers that use a product so that enough material is produced.
- # of Pieces gives the amount of inventory that would be necessary if the produce were produced in lots of 1.
- Lot Size, Lot size in included in the calculation for two reasons. First, if the lot size were larger than the number kanban production would never be stimulated. Second, extra inventory must be included to cover the extra time to produce the lot size over individual products.

An example kanban calculation:

- Our example workcenter will have a daily consumption rate of 4 units, 2 safety days, and replenishment time of .25 days with a lot size of 1.
- The calculation looks like this:

.25 Day Replenishment
\+ 2 Days Safety
= 2.25 Days Total
X 3 Pieces Per Day
= 6.75 kanban
Round to 7 kanban

Table 3, Kanban Example

- If we change the lot size to 12, the replenishment time increases to 3 days and the calculation looks like this:

3 Days Replenishment
\+ 2 Days Safety
= 5 Days Total
X 3 Pieces Per Day
= 15 Pieces
\+ 12 Lot size
= 27 kanban

Table 4, Kanban Example

- One other change we might make is to produce the product on lots of 12 but ship in groups of 4. This would reduce the replenishment time to 1 day.

1 Day Replenishment
\+ 2 Days Safety
= 3 Days Total
X 3 Pieces Per Day
= 9 Pieces
\+ 12 Lot size
= 21 kanban

Table 5, Kanban Example

Inventory Levels With kanban

This table shows the level of inventory at each workcenter and the number of kanban that the supplier workcenter has available. The “Customer WIP” column records the amount of material that the customer has at the end of the day. The “Kanban” column is the number of kanban that have been sent to the supplying workcenter. The “Supplier Units” column is the number of units that the supplier has completed by the end of the day.

| Day | Customer WIP | Kanban | Supplier units | Notes |
|---|---|---|---|---|
| 0 | 27 | 0 | 0 | |
| 1 | 24 | 3 | 0 | |
| 2 | 21 | 6 | 0 | |
| 3 | 18 | 9 | 0 | |
| 4 | 15 | 12 | 0 | Kanban Collected, Production begins |
| 5 | 12 | 3 | 4 | |
| 6 | 9 | 6 | 8 | |
| 7 | 6+12=18 | 9 | 12 | The product is shipped |
| 8 | 15 | 12 | 0 | Kanban Collected, Production begins |
| 9 | 12 | 3 | 4 | |
| 10 | 9 | 6 | 8 | |
| 11 | 6+12 = 18 | 9 | 12 | The product is shipped |
| 12 | 15 | 12 | 0 | Kanban Collected, Production begins |

Table 6, Inventory Levels

For the first 4 days the supplier does not have enough kanban to authorize a lot of 12. At the end of day 5 the supplier has 12 kanban and production can begin. The supplier finishes the lot of 12 in 3 days and ships the whole lot at once. The Customer receives the 12 units just as it reaches its safety level of 2 days of WIP or 6 units. From day 4 onward the system is in steady state, the customer uses 3 units per day and the supplier works 3 days to supply 12 units every 4 days and the customer never falls below the safety level.

If for some reason the supplier cannot meet demand temporarily then the customer has 2 days of safety material. Once the supplier is ready to supply again the excess capacity allows the supplier to catch up to the customers demand.

| Day | Customer WIP | Kanban | Supplier units | Notes |
|---|---|---|---|---|
| 1 | 18 | 9 | 0 | |
| 2 | 15 | 12 | 0 | Production delayed |
| 3 | 12 | 15 | 0 | Kanban Collected, Production begins |
| 4 | 9 | 6 | 4 | |
| 5 | 6 | 9 | 8 | |
| 6 | 3+12=15 | 12 | 12 | The product is shipped,<br>Kanban Collected, Production begins |
| 7 | 12 | 3 | 4 | |
| 8 | 9 | 6 | 8 | |
| 9 | 6+12=18 | 9 | 12 | The product is shipped |
| 10 | 15 | 12 | 0 | Kanban Collected, Production begins |
| 11 | 12 | 3 | 4 | |
| | 9 | 6 | 8 | |
| | 6+12=18 | 9 | 12 | The product is shipped |
| | 12 | 12 | 0 | Kanban Collected, Production begins |

Table 7, inventory Levels

This table shows what happens if the supplier is down for a day. During the down time extra kanban accumulate. The supplier still collects 12 and supplies a normal lot, however after this lot is complete there are 12 kanban available which immediately authorizes the production of another lot. When this extra lot is sent the system returns to a steady state. This example demonstrates the advantage of extra capacity to make up for lost production time and the importance of proper safety stock levels.

## 6. Being productive without producing

One of the more difficult aspects of pull manufacturing to get used to is the apparent idleness of some of the operators, especially at non-bottleneck workcenters. The core tenet of pull manufacturing is that without a signal no production occurs, but this does not mean that an operator cannot be productive without producing. There are many non-productive tasks that can be performed during workcenter down time.

Total Productive Maintenance

- Total productive maintenance is more than proactive approach to maintenance problems.
- Whenever an operator is starved for kanban (no kanban have arrived to authorize production) then they should spend the time maintaining the workcenter.
- Machines should be lubricated and checked for errors. Tools should be sharpened or otherwise prepared for future use.
- When maintenance issues arise the cause is identified and preventative measures are performed in the future.
- If a workcenter goes down the first step is to identify why, if the issue is a mechanical failure then what caused the mechanical failure. If the machine was not sufficiently lubricated then checking the lubrication level should become a common preventative measure taken whenever the workcenter is not authorized to produce.
- This system can performed retroactively as well; if a machine went down 8 times last quarter then there should be a record of why. When all the records are compiled it may be that 2 of those times a tool broke, 2 times the machine was not properly lubricated and 4 of those times a part was improperly installed.
- In this case the installation procedure and training can be addressed. These study and training activities can take place during workcenter down time.

5-S Activities

- 5-S is a system for improving workstations through organization and cleanliness. It stands for **S**ort, **S**et in order, **S**hine, **S**tandardize and **S**ustain.
- During downtime an operator can engage in 5-S activities to improve and maintain the efficiency of the workcenter.
- The Sort activity is the step where unnecessary materials are removed from the workcenter. This includes tools that are only used at the workcenter occasionally, any tools that are not likely to be needed in the near future should be removed from the workcenter, but stored somewhere nearby.

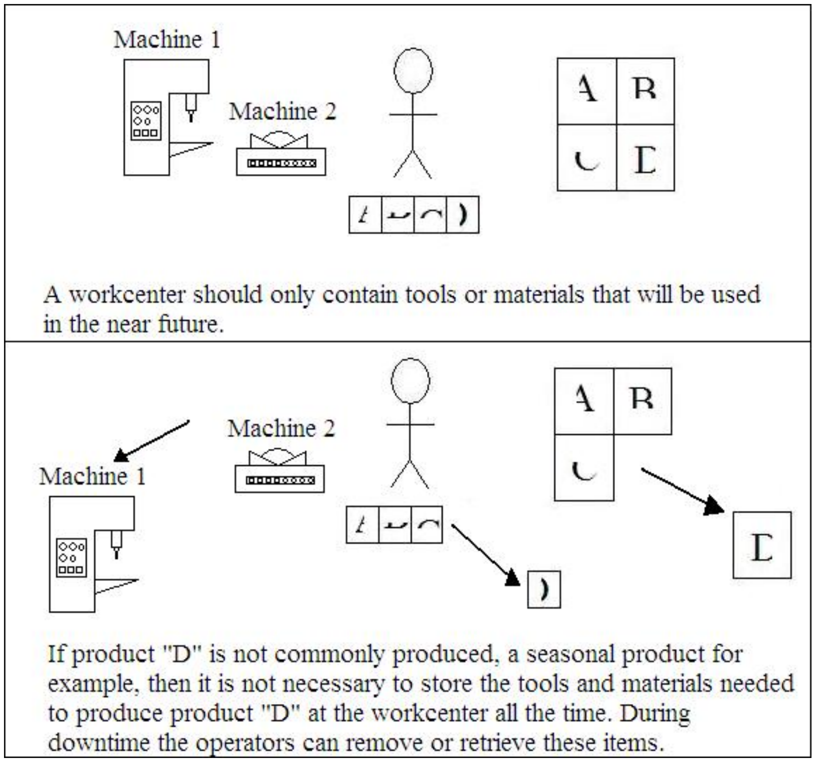



Figure 12, Sort

- Set in order is the process of organizing tools within the workcenter. Every tool should have its own specified location. During downtime the operator should check to make sure that every tool is returned to its proper place.

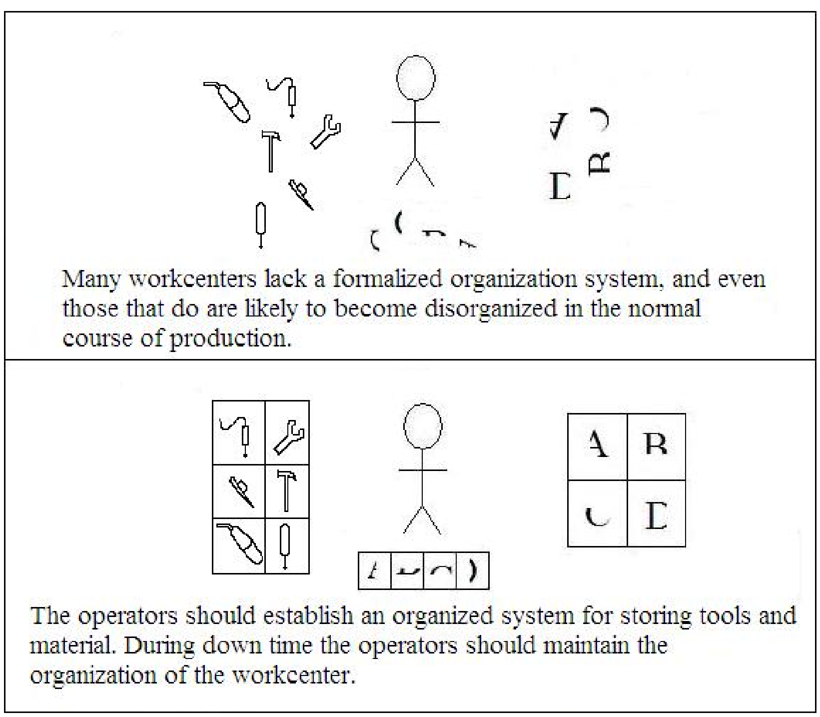



Figure 13, Set in Order

- Shine is basic cleanliness, the workstation should be free of trash and other waste. If a process results in waste such as metal shavings then during downtime the machines and floors should be cleaned.
- Standardize is an effort to make sure that all tasks are performed in the same way. The Sorting methods, Set in Order approach and Shine process all need to be the same in every similar workcenter. This is accomplished by establishing specific duties for each member of the workcenter and by cross workcenter communication.
- Sustain is about maintaining the previous steps, 5-S is only useful as long as there is active participation. Sustaining 5-S is what should be done during down time at a workcenter.

## SMED

- SMED, or Single Minute Exchange of Die, is a method of waste reduction that focuses on reducing the setup times for a workcenter between different product runs.
- The first phase of SMED is to identify internal and external activities. This activity can be performed by the operators during a regular set-up or by recording a set-up and reviewing it during down time.
    - An internal activity is performed while the workcenter is not active. For example installing a new tool could only be performed while the machine is inactive.
    - An external activity is performed while the work center is active. Gathering the tools together before the set-up can be performed while the machine is running
    - An internal activity is performed while the workcenter is not active. For example installing a new tool could only be performed while the machine is inactive.
    - An external process does not impact the productive time of a workcenter
    - Often this process is can be done during the normal set-up procedure, or by recording the procedure and reviewing it later.
- The second phase of SMED is to move process from internal to external. This step can be performed with brainstorming sessions during downtime.
    - Identify an internal activity that can be performed externally and make it external. Gathering tools for example can easily be done while the work center is still working.
    - Prepare the next product for the workcenter. If parts are processed in batches then batch preparation should be performed externally.
    - Brainstorm how internal activities can be performed externally. If a die is assembled in the machine then in might be possible to assemble parts of it externally
    - It is might be worth changing the process or investing in addition equipment. A machine that needs it tools rearranged might be better with multiple tool heads that have been pre-arranged.

- The final step is to streamline any internal activities that cannot be made external.
    - If a machine requires time consuming adjustments then those adjustments should be made quicker. If a tool must be installed very precisely find a way to have it installed correctly by adding slots or a locating pin so that the tool simply fits in the correct alignment.
    - In some cases tools are different heights and adjustments must be made so the tools fit properly. Standardize the fit so that tools don't require adjustment.
    - If a process can be done incorrectly then make the correct process obvious. If a tool might be installed upside-down then color code it to avoid mistakes.

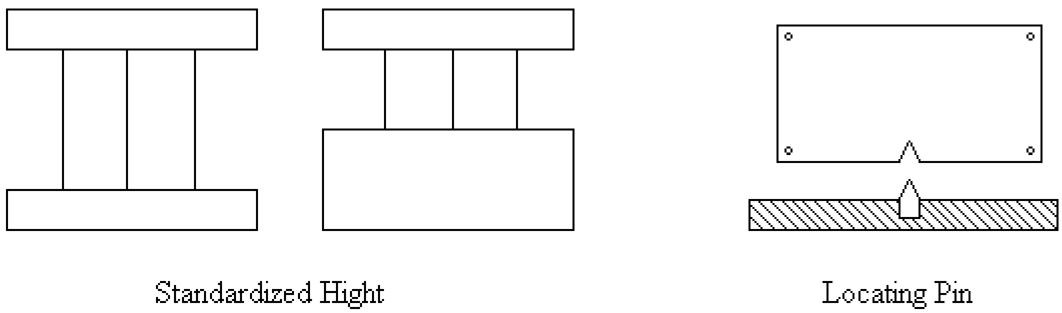



Figure 14, Reduced Adjustment

- Another method for reducing set-ups times is to assign more people to the task.
- This does more then simply divide the workload, operators frequently walk significant distances in the course of a set-up operation, dividing the workload can decrease the walking distance.
- This arrangement can also allow a skilled operator to focus on the tasks that require their expertise.
- The group operations also tend to foster team spirit and teamwork.

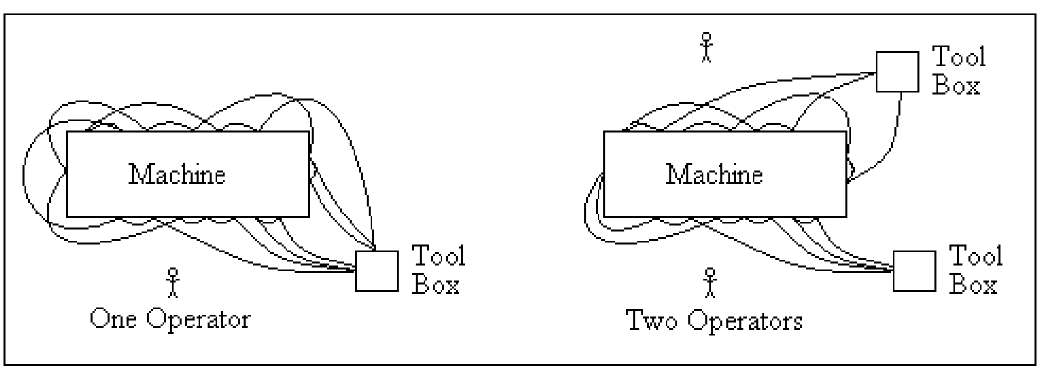



*Figure 15, Parallel Operations*

Once new set-up methods have been established the operators can perform them during down time. Locating and preparing the tools they will need in the set-up, readying any WIP before the production run, assembling die components before installation.

Setup reduction does not happen overnight. No single change will reduce an 8 hour setup to 3 minutes. SMED is a system for identifying and eliminating the waste associated with setup times in small steps, the downtime that a workcenter has enables the operators to see the opportunities to take these small steps.

## Conclusion

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 most costly 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 preemptively 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.

Literature review

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