Chapter 22
Computation of the Number of Kanbans

Seoul National University

Professor ILKYEONG MOON

CONTENTS

22.1 NUMBER OF KANBANS

- The kanban system represents either a constant-quantity withdrawal system or a constant-cycle withdrawal system.

- *Constant order-quantity system*
- *Constant order-cycle system*

Inventory control

- *Constant-quantity production system*
- *Constant-cycle production system*

Seen from the preceding process

22.1 NUMBER OF KANBANS

❖ Main four numbers of kanbans.

	Constant-cycle	Constant-quantity
Withdrawal kanban		
Production-ordering kanban		

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

- The constant-cycle withdrawal system of inventory control needs to determine the quantity of parts required during the total time period of order interval and production lead time.

Necessary quantity of parts	=	Demand per day × (order interval + production lead time) + safety inventory

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

- The order interval implies the time interval between one ordering time and the next.

- The production lead time stands for the time interval between ordering time and receiving time.

order interval + production lead time = replenishment period

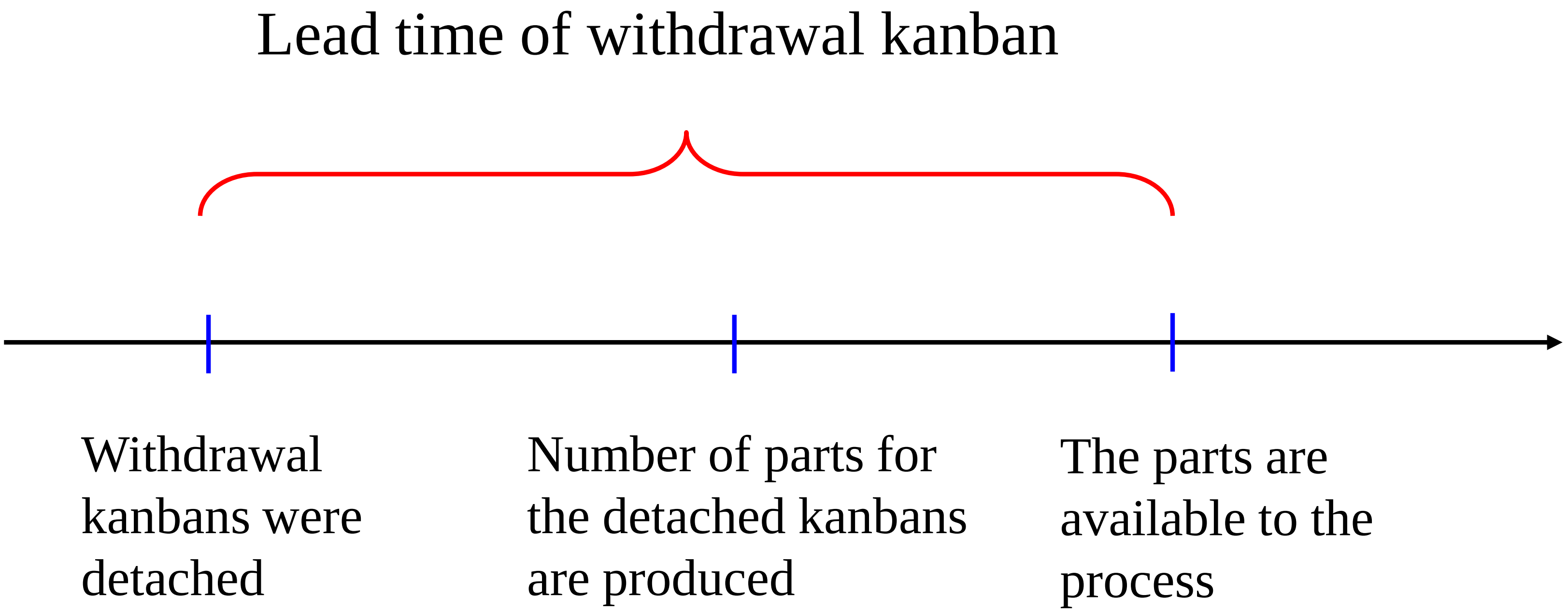
22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

- Withdrawal interval is the time interval between a withdrawal at time t and the next withdrawal at time $t+1$ in a constant-cycle withdrawal system.

- Production lead time is the time interval between the time the withdrawal kanbans were detached and the time when the process has the same parts ready for use.

Lead time of withdrawal kanban	=	Withdrawal interval + production lead time

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM



22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

- Necessary number of parts during the lead time of withdrawal kanban

  = lead time of withdrawal kanban

  × average quantity of parts needed per time unit

$$\text{Necessary number of withdrawal kanbans} = \frac{\text{Necessary number of parts} + \text{safety inventory}}{\text{Capacity of one box}}$$

$$\text{Safety inventory} = \text{Necessary number of parts} \times 0.1$$

- Numerical example

FIGURE 22.1
Order of transmission manufacturing processes.

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

Step 1

- In the entrance area of the machining line, the withdrawal kanban for painted parts is detached.

- At a designated time point, the tractor driver comes to the painted parts storage of the painting process to withdraw the painted parts.

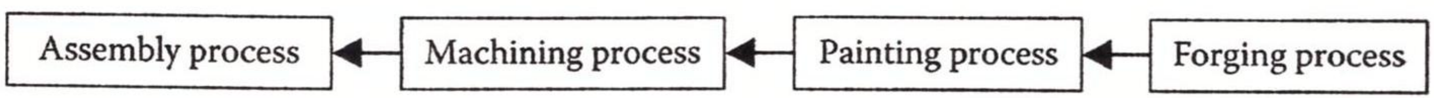


FIGURE 22.1
Order of transmission manufacturing processes.

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

Step 1 (continued)

- The driver exchanges his withdrawal kanban with the painting-ordering kanban attached to the parts box at the painted parts storage of the painting process, and drags the painted parts boxes loaded on the tractor.

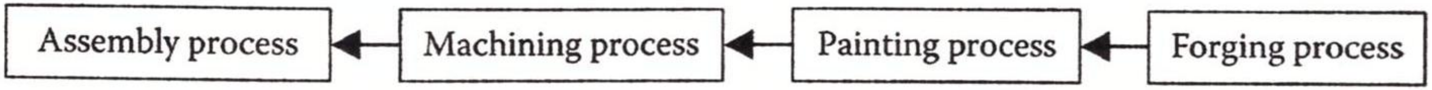


FIGURE 22.1
Order of transmission manufacturing processes.

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

Step 2

- The painting-ordering kanban that was exchanged is brought to the forged parts storage at the end of the forging process by the tractor driver of the painting process.

- This driver detaches the forging-ordering kanbans attached to the forged parts boxes and exchanges them with this painting-ordering kanbans.

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

Step 2 (continued)

- The driver drags the forged parts boxes o the input spot of the painting furnace.

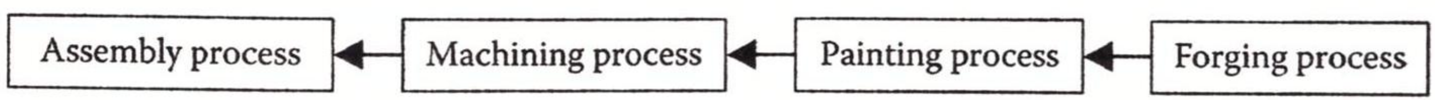


FIGURE 22.1
Order of transmission manufacturing processes.

Step 3

- The painting-ordering kanbans attached to the forged parts boxes will be hung on the production kanban hanger on the wall of the furnace.

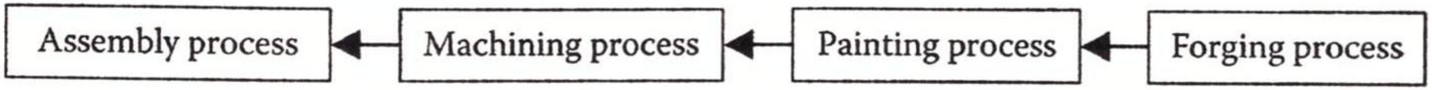


FIGURE 22.1
Order of transmission manufacturing processes.

Step 4

- The painting lead time in the painting furnace (the production lead time) is 3.5 hours.

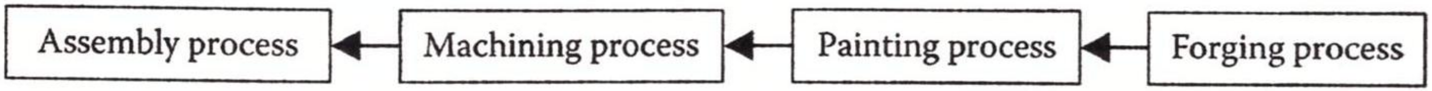


FIGURE 22.1
Order of transmission manufacturing processes.

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

Step 5

- When the painting process is finished, the painted parts are sorted in the painted parts storage area.

FIGURE 22.1
Order of transmission manufacturing processes.

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

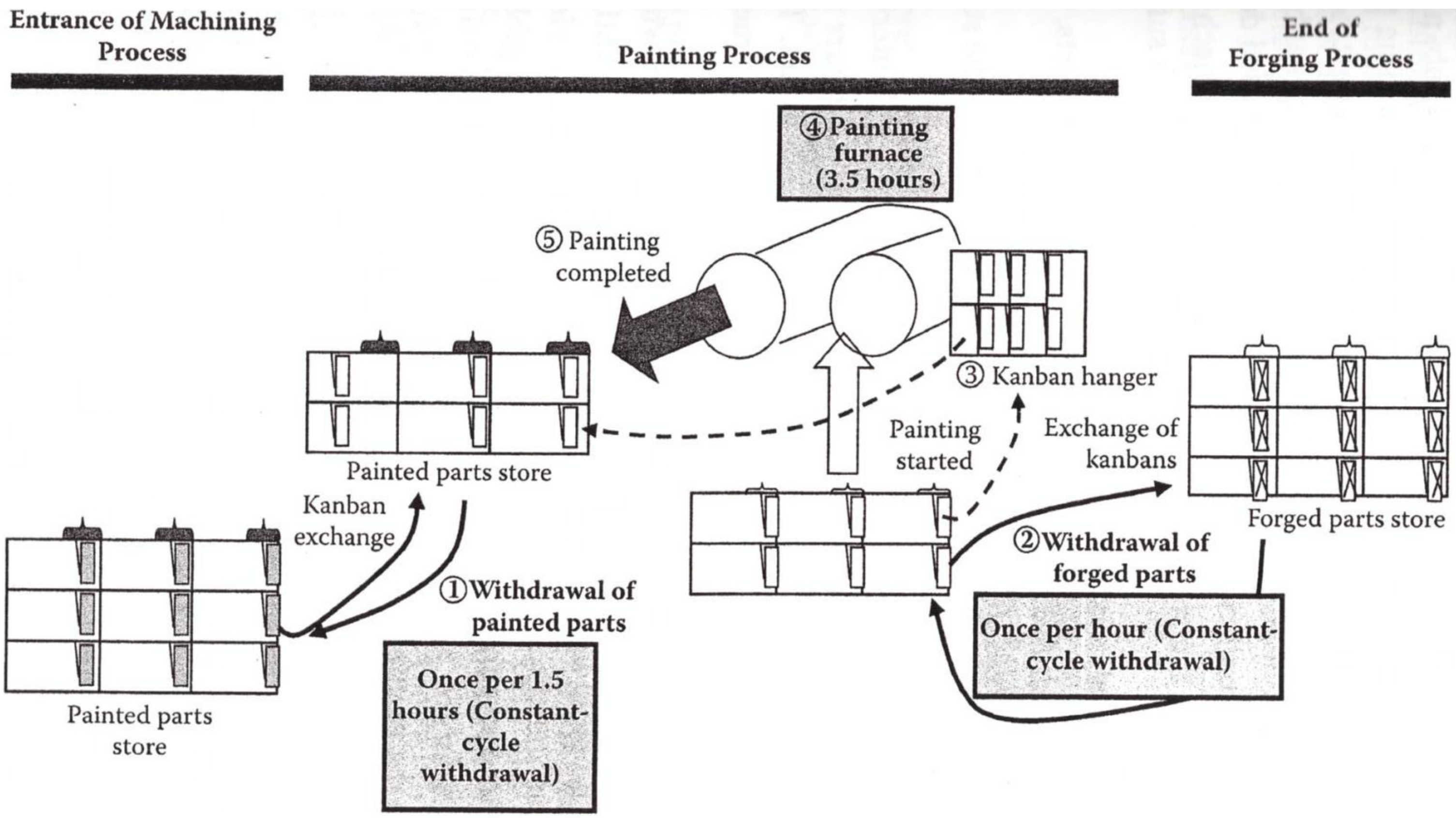


FIGURE 22.2
Movement of various kanban surrounding the painting process. (Adapted from Aoki, M. 2007. *Full Illustration of the Systems of Toyota Production Plants,* Nihon-Jitsugyou Shuppansha, pp. 19–20 with revisions.)

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

- The withdrawal interval from the machining process is 1.5 hours.
- The production lead time is 4.5 hours.
  - one hour for the withdrawal interval of dragging the forged parts from the forging process
  - 3.5 hours for the painting time in the painting process

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT-CYCLE WITHDRAWAL SYSTEM

- During this 6-hour period, the quantity of painted parts used in the machining process is equal to the necessary number of the parts that should be stored at the painted parts storage of the machining process.

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT0CYCLE WITHDRAWAL SYSTEM

- We can obtain the number of withdrawal kanbans for the painted parts.

$$\text{Necessary number of withdrawal kanbans} = \frac{(\text{Withdrawal interval} + \text{production lead time}) \times \text{number of used parts per time unit}}{\text{Capacity of one box}}$$

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT0CYCLE WITHDRAWAL SYSTEM

Assume that

- necessary number of painted parts per hour = 500
- capacity of a parts box = 250
- withdrawal interval of machining process = 1.5 hours
- painting time = 3.5 hours
- withdrawal interval of painting process = 1 hour

$$\text{Necessary number of withdrawal kanbans} = \frac{[1.5 \text{ hours} + (3.5 \text{ hours} + 1 \text{ hour})] \times 500 \text{ units per hour}}{250 \text{ units per kanban}} = 12 \text{ kanbans}$$

22.2 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER THE CONSTANT0CYCLE WITHDRAWAL SYSTEM

- The number of kanbans for the safety inventory should be added.
- The safety inventory is usually set at 10% of the necessary number of parts.
- Toyota tries to reduce the safety inventory through kaizen.

22.3 THE NUMBER OF SUPPLIER KANBANS

- Suppliers are distant from the final product manufacturers.
- The lead time will be longer.
- The manufacturer may have parts shortage under the constant-quantity withdrawal system.

The supplier kanban system is used only under the **constant-cycle withdrawal** system.

22.3 THE NUMBER OF SUPPLIER KANBANS

- Total number of supplier kanbans can be obtained from the following equation.

Total number of supplier kanban = {Daily demand × (*Order interval* to the supplier + *production lead time* of the supplier) + safety inventory} / capacity of units per parts box (22.4)

22.3 THE NUMBER OF SUPPLIER KANBANS

- The order cycle is expressed as

$$a\text{-}b\text{-}c$$

- *a* and *b*: *b* times of deliveries will be made during *a* days.
- *c*: the actual delivery of the parts for the kanbans will be deferred by *c* times of kanban conveyance.
- *c* is also called the transportation interval or the delay coefficient of kanban.

22.3 THE NUMBER OF SUPPLIER KANBANS

- For example

$$a\text{-}b\text{-}c \rightarrow 1\text{-}6\text{-}2$$

- The parts are delivered 6 times a day.
- The actual delivery of the parts for the kanbans will be deferred by 2 times of kanban conveyance.

Toyota wants to **increase *b*** and **decrease *c*** as much as possible.

22.3 THE NUMBER OF SUPPLIER KANBANS

- Order interval or withdrawal interval to the suppliers

$$\text{Order interval} = \frac{a \text{ (usually equivalent to 1 day)}}{b \text{ (transportation times per day)}}$$

- If the order cycle is 1-6-2,

$$\boxed{\text{order interval} = 1 / 6 = 0.166 \text{ days.}}$$

22.3 THE NUMBER OF SUPPLIER KANBANS

- Production lead time of the suppliers

$$\text{Production lead time} = \frac{a}{b} \times c$$

- If the order cycle is 1-6-2,

$$\boxed{\text{Production lead time} = 1 \times 2 / 6 = 0.333 \text{ days.}}$$

22.3 THE NUMBER OF SUPPLIER KANBANS

- The total lead time of the suppliers

$$\text{Total lead time} = (a/b) + (a/b)c = \frac{a(c+1)}{b}$$

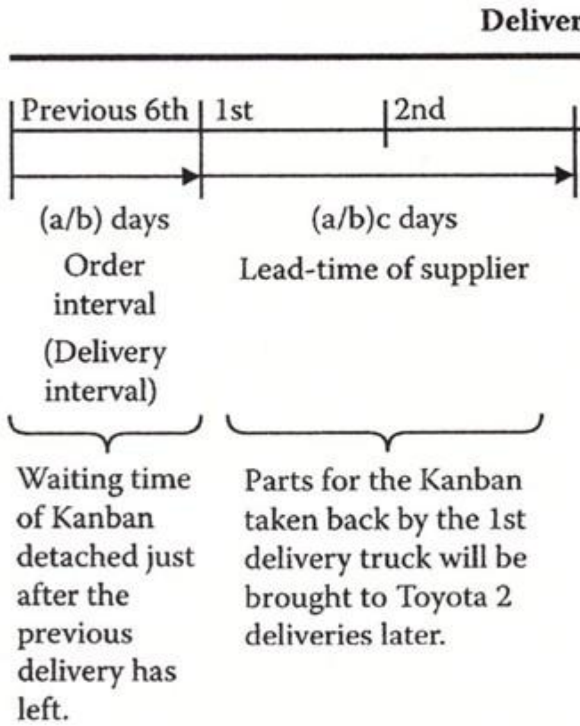


FIGURE 22.3
Supplier kanban lead time for the kanban cycle of "1-6-2."

22.3 THE NUMBER OF SUPPLIER KANBANS

- Necessary number of parts during the lead time of supplier kanban
  = lead time of supplier kanban
  × demand rate

$$\text{Necessary number of supplier kanbans} = \frac{\text{Necessary number of parts + safety inventory}}{\text{Capacity of one box}}$$

$$= \frac{(a/b) \times (c+1) \times \text{demand rate + safety inventory}}{\text{Capacity of one box}}$$

22.3 THE NUMBER OF SUPPLIER KANBANS

Assume that

- a = 1 day b = 6 times c= 2 times
- averaged demand per day = 100 units
- capacity of one box = 5 units/box
- safety coefficient =0.2

Total number of supplier kanbans
= (100/5) ×[(1/6) ×(1+2)+0.2]=20×(0.5+0.2)=14 kanbans

22.4 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER CONSTANT-QUANTITY WITHDRAWAL SYSTEM

- The constant-quantity withdrawal system is not used to withdrawal out-sourced parts.

- It can be used for in-sourced parts.

- The hourly production quantity vary on the assembly line under autonomation.

- Workers at the subsequent line withdrawal a fixed quantity of parts from the preceding process irregularly.

22.4 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER CONSTANT-QUANTITY WITHDRAWAL SYSTEM

- Lead time of withdrawal kanban is the time interval between the time the withdrawal kanbans were detached and the time when the process has the same parts ready for use.

- Withdrawal interval is not considered here.

22.4 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER CONSTANT-QUANTITY WITHDRAWAL SYSTEM

- Necessary number of parts during the lead time of withdrawal kanban

  = lead time of withdrawal kanban

  × average quantity of parts needed per time unit

$$\text{Necessary number of withdrawal kanbans} = \frac{\text{Necessary number of parts + safety inventory}}{\text{Capacity of one box}}$$

22.4 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER CONSTANT-QUANTITY WITHDRAWAL SYSTEM

Assume that

- lead time of withdrawal kanban = 20 minutes
- operation time per day = 480 minutes
- average usage quantity of parts per day = 300 units
- capacity of one box =5 units

22.4 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER CONSTANT-QUANTITY WITHDRAWAL SYSTEM

- Necessary number of parts during the lead time of withdrawal kanban

  = (300 units / 480 minutes) × 20 minutes = 12.5 units

- Safety stock =1.25 × 0.1 = 1.25 units

- Number of withdrawal kanbans

  = (12.5 + 1.25) / 5 = 2.75 ≈ 3

22.4 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER CONSTANT-QUANTITY WITHDRAWAL SYSTEM

If we reduce the lead time to 10 minutes

- Necessary number of parts during the lead time of withdrawal kanban

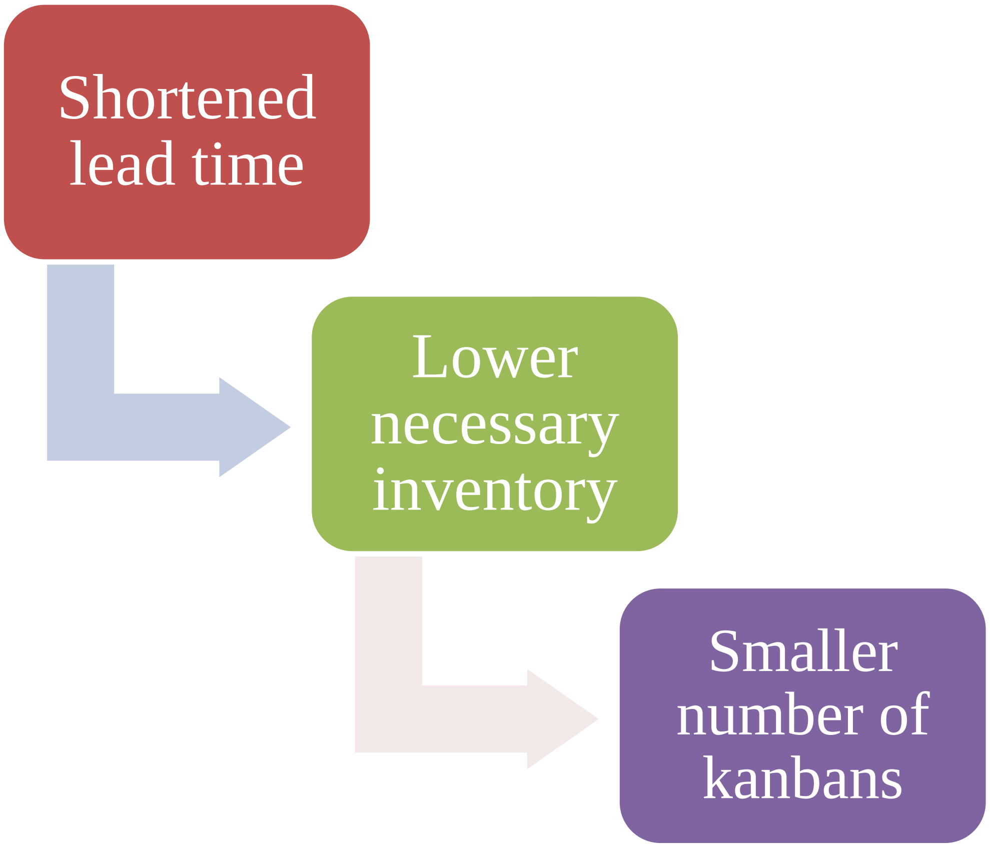
  $= (300 \text{ units} / 480 \text{ minutes}) \times 10 \text{ minutes} = 6.25 \text{ units}$

- Safety stock $= 12.5 \times 0.1 = 0.625$ units

- Number of withdrawal kanbans

  $= (6.25 + 0.625) / 5 = 1.375 \approx 2$

22.4 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER CONSTANT-QUANTITY WITHDRAWAL SYSTEM



22.4 THE NUMBER OF INTER-PROCESS WITHDRAWAL KANBANS UNDER CONSTANT-QUANTITY WITHDRAWAL SYSTEM

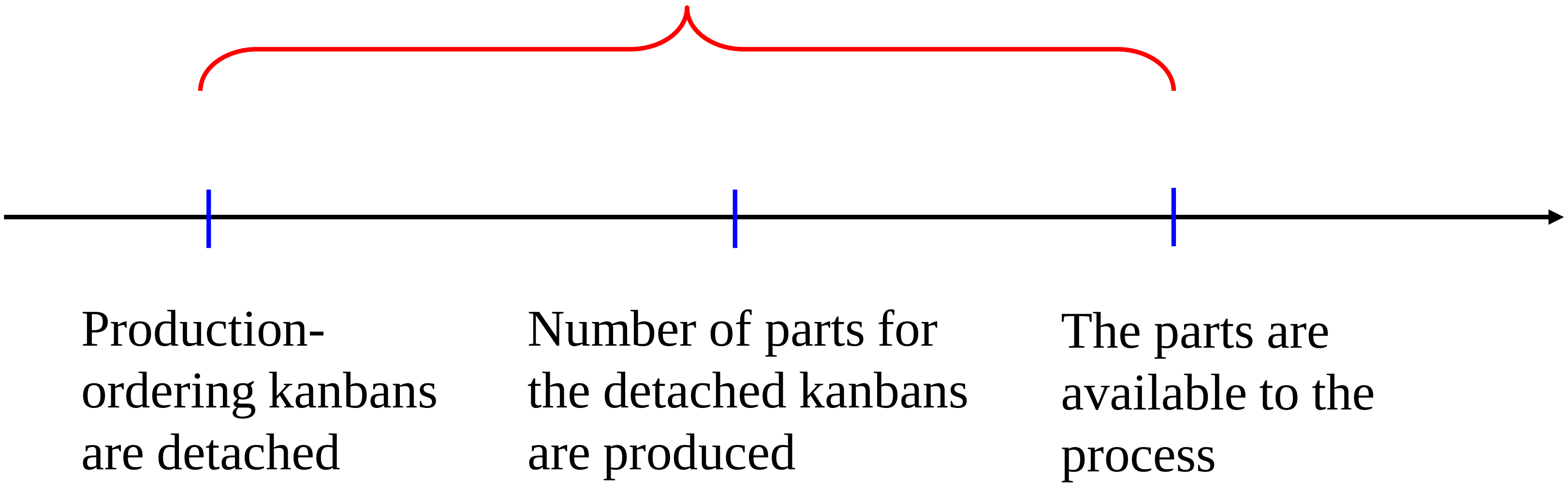
If we increase the capacity of boxes to 10 units

- Number of withdrawal kanbans

  $= (12.5 + 1.25) / 10 = 1.375 \approx 2$

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

- The lead time of production-ordering kanban is defined as



22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

- Necessary number of parts during the lead time of production-ordering kanban

  = lead time of production-ordering kanban

  × average quantity of parts needed per time unit

$$\text{Necessary number of withdrawal kanbans} = \frac{\text{Necessary number of parts + safety inventory}}{\text{Capacity of one box}}$$

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

Assume that

- necessary number of painted parts per hour = 500
- capacity of a parts box = 250
- painting time = 3.5 hours
- withdrawal interval of painting process = 1 hour

$$\text{Necessary number of withdrawal kanbans} = \frac{(3.5 \text{ hours} + 1 \text{ hour}) \times 500 \text{ units per hour}}{250 \text{ units per kanban}}$$

$$= 9 \text{ kanbans}$$

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

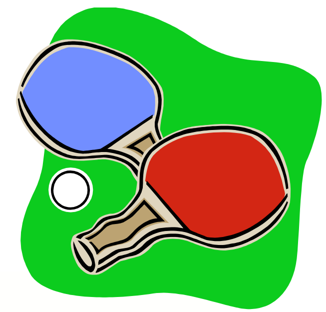
- Suppose that the final assembly line produced one car every 2 minutes.

- All of the preceding processes have the takt time of 2 minutes (one-piece production).

- These processes also use the constant-quantity system.

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

- A ping-pong ball is often used as a production-ordering kanban if the line is set up for one-piece production.



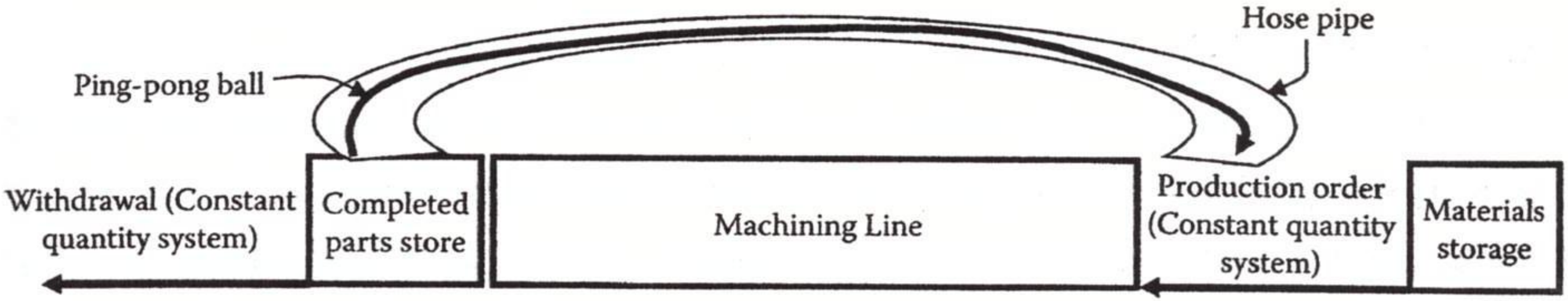


FIGURE 22.4
Ping-pong ball as production-ordering kanban. (Adapted from Aoki, 2007, p. 22, with modification.)

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

- 1-2: The carrier of the assembly line picks up one unit of a part and pick up the ping-pong ball attached to the part that will be hit to the starting point of the machining line through the hose-pipe by compressed air.

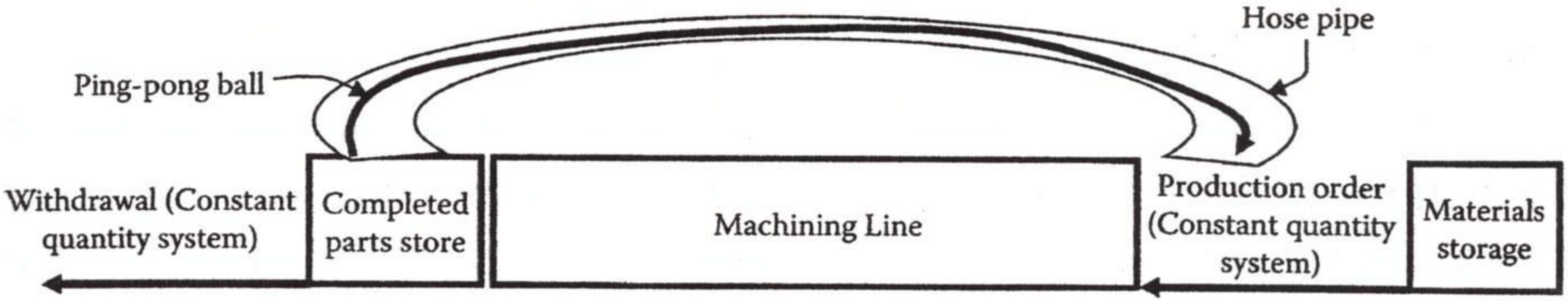


FIGURE 22.4
Ping-pong ball as production-ordering kanban. (Adapted from Aoki, 2007, p. 22, with modification.)

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

- 3: The worker at the starting point of the machining line takes the ball and start the production.

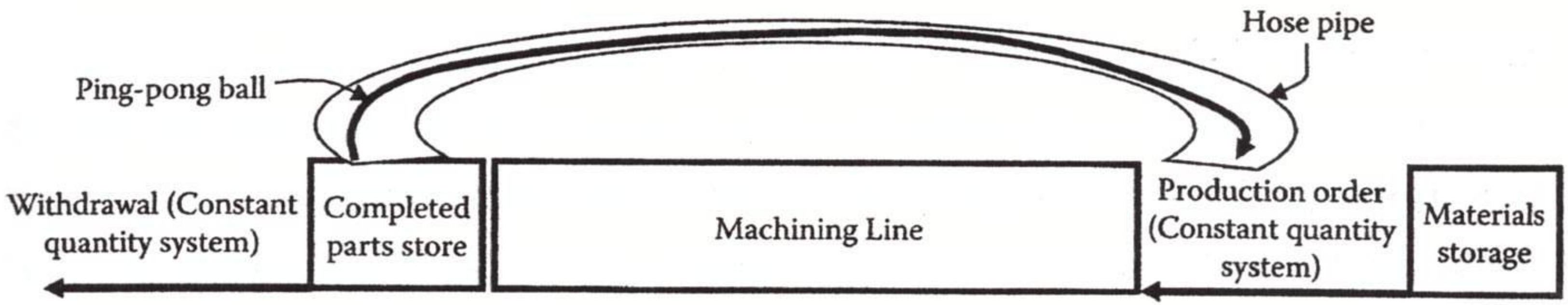


FIGURE 22.4
Ping-pong ball as production-ordering kanban. (Adapted from Aoki, 2007, p. 22, with modification.)

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

- 4: The ball placed on the corner of the worker's instrument box moves with the work along the line.

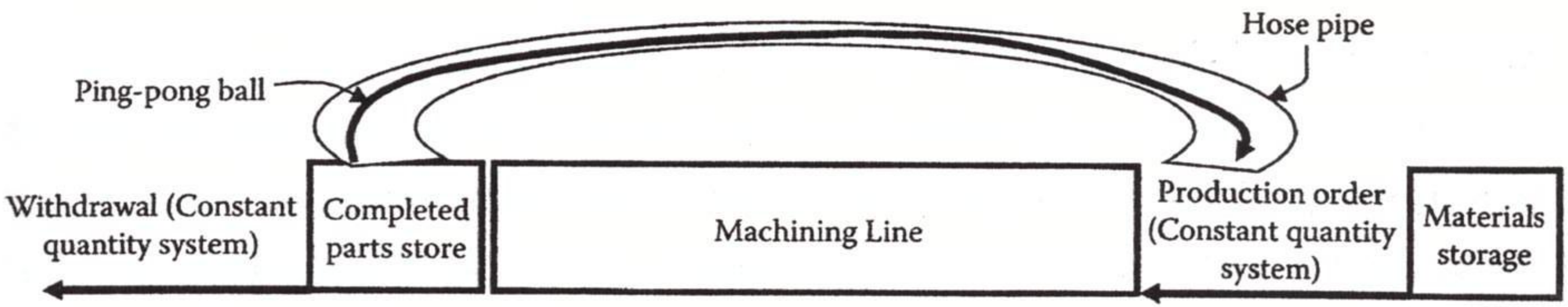


FIGURE 22.4
Ping-pong ball as production-ordering kanban. (Adapted from Aoki, 2007, p. 22, with modification.)

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

- In a two-bin system, two large boxes of inventory are used.
- When one box of inventory goes out of stock, the inventory of the other box will be used.
- The empty box will trigger an order for one box.

22.5 THE NUMBER OF PRODUCTION-ORDERING KANBANS

- Capacity of one box
  = number of units to be used in the subsequent process during the production lead time
  + safety inventory

- Capacity of one box
  = inventory quantity of re-order point
  + safety inventory

22.6 THE RE-ORDER POINT

- For lot production, a signal Kanban is used.

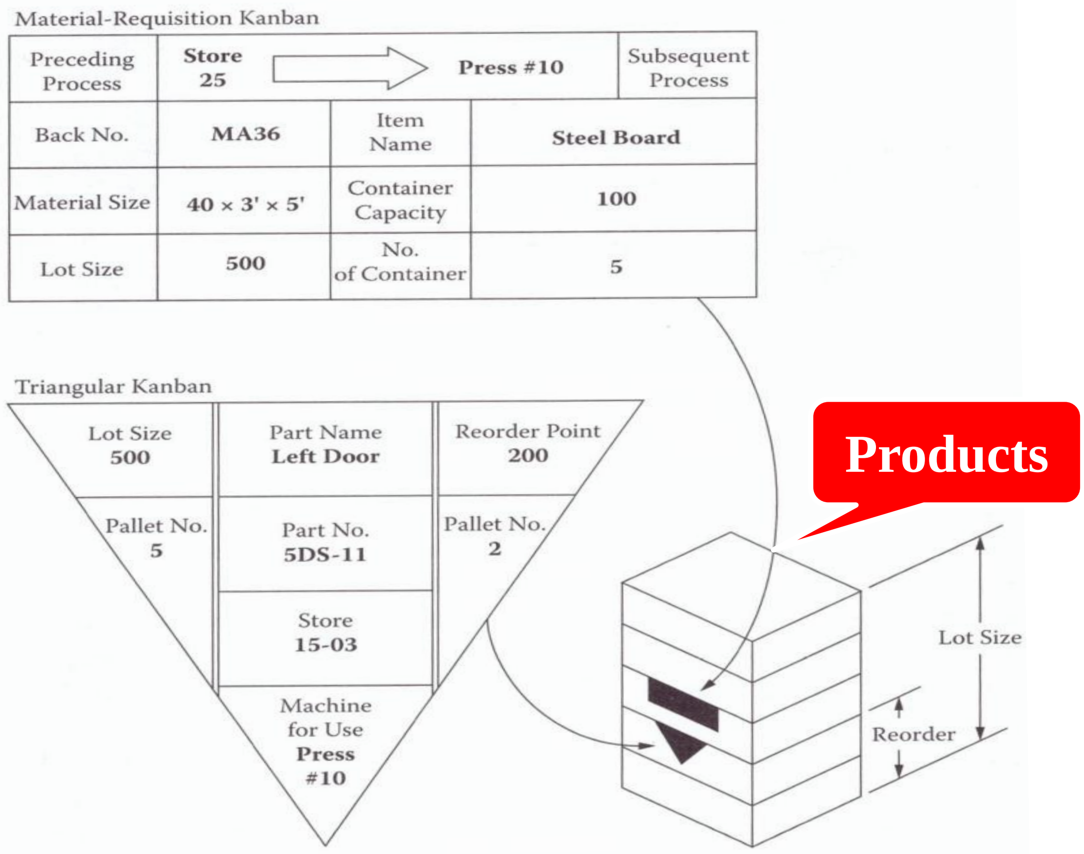
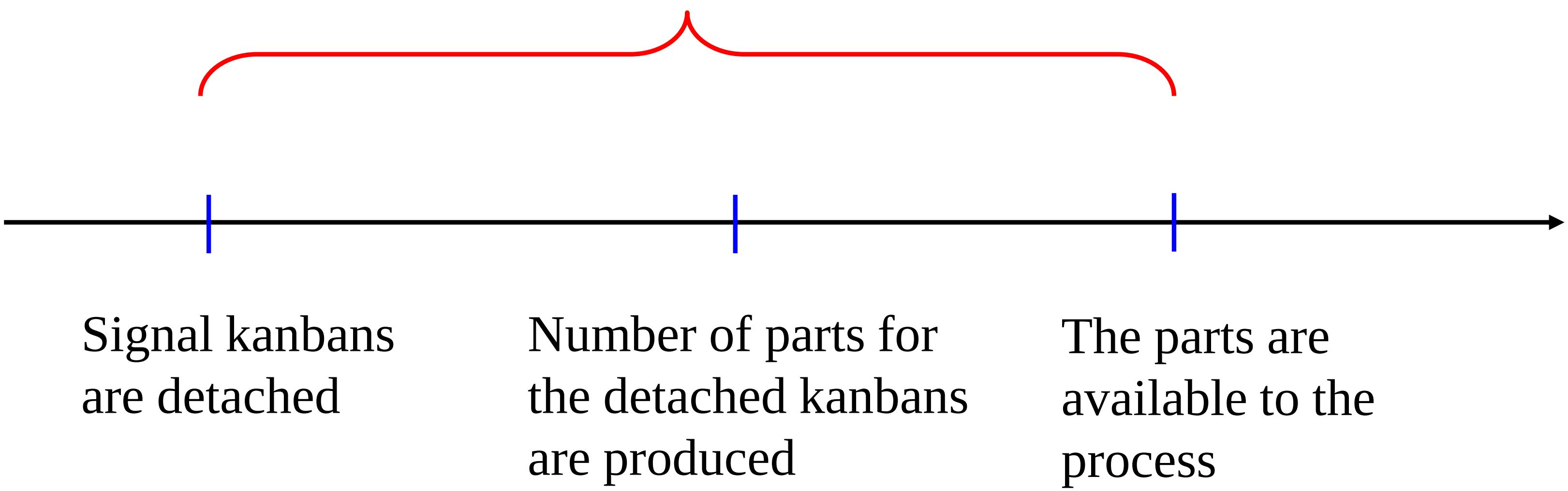


FIGURE 3.6
Signal kanban.

22.6 THE RE-ORDER POINT

- The lead time of signal kanban is the time span from the time when the signal kanban is detached to when the required parts are ready in the same process.



22.6 THE RE-ORDER POINT

- Necessary number of parts during the lead time of signal kanban
  = lead time of signal kanban
  × average quantity of parts needed per time unit

$$\text{Re-order point} = \frac{\text{Necessary number of parts} + \text{safety inventory}}{\text{Capacity of one box}}$$

22.7 THE LOT-SIZE

- Lot-size is the constant-quantity order in the constant-quantity order system.

- At Toyota, the lot-size is determined as follows.

$$\text{Lot-size} = \frac{\text{Daily usage of parts}}{\text{Times of setup per day}} + \text{safety inventory}$$

22.8 CHANGES IN THE NUMBER OF KANBANS

- Changes in the number of kanbans are made in accordance with changes in the estimated volume of production each month.

- The need for changing the number of kanbans is increasing the kanban lead time.

22.8 CHANGES IN THE NUMBER OF KANBANS

- Many supplier kanbans must change their numbers because outsourced parts are delivered from distant suppliers.

  - Toyota needs to change about 10,000 supplier kanbans.

- The changes in the number of inter-process withdrawal kanbans is not frequent.

22.8 CHANGES IN THE NUMBER OF KANBANS

- If the number of supplier kanbans should be decreased, the necessary number of kanbans will be automatically subtracted by the kanban sorter.

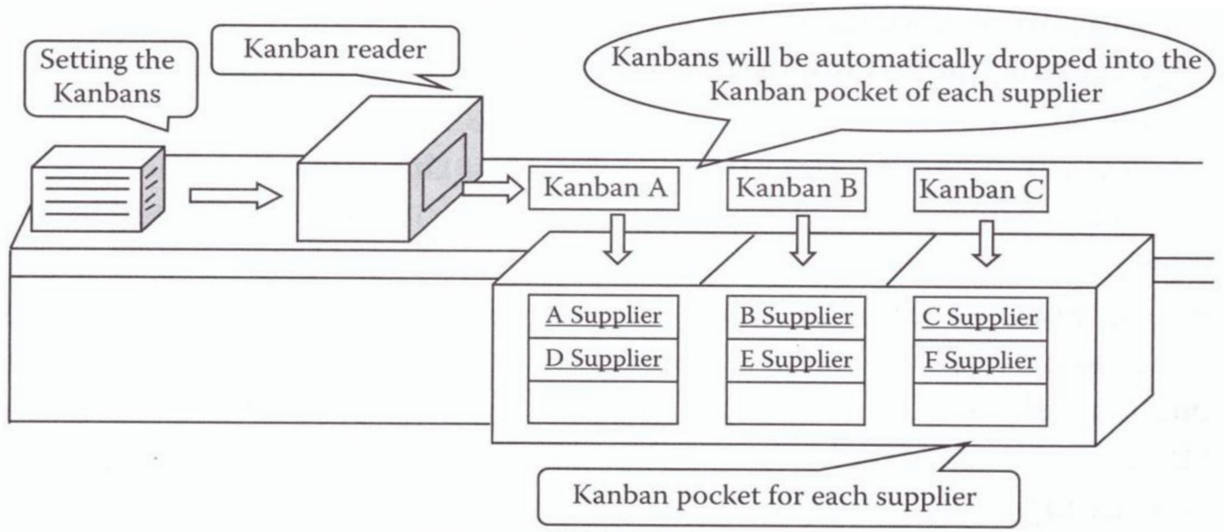


FIGURE 4.11
Post office for supplier kanban. (Adapted from Aoki, M. 2007. *Full Illustration of the Systems of Toyota Production Plants*, Nihon-Jitsugyou Shuppansha, p. 66.)

22.8 CHANGES IN THE NUMBER OF KANBANS

- If the number of supplier kanbans should be increased, it must be handled manually.

- The increased number of kanbans should be added gradually over (c+1) delivery times.

22.8 CHANGES IN THE NUMBER OF KANBANS

- For example, suppose the additional number of kanbans is 15 and the transportation interval, c, is 4.

$$15/(c+1)=15/5=3$$

- You can add 3 kanbans at each time of delivery from the first time to the fifth time.

22.9 MAINTAINING THE NECESSARY NUMBER OF KANBANS

- Some troubles occurs if some of the circulating kanbans are lost in the middle of the month.
- There maybe shortages of kanbans and parts.

22.9 MAINTAINING THE NECESSARY NUMBER OF KANBANS

- To check whether the necessary number of kanbans is maintained, maximum and minimum stock quantities are used at the line-side parts shelves.

- The maximum and minimum numbers of parts boxes are shown on indicator plates at each parts shelf in the production line.

22.9 MAINTAINING THE NECESSARY NUMBER OF KANBANS

- The maximum number of parts boxes
  - The stock of parts at the production site reaches the maximum level when the parts are replenished by the arrival of the delivery truck.
  - Equal to the lot-size
- The minimum numbers of parts boxes
  - Safety stock

22.9 MAINTAINING THE NECESSARY NUMBER OF KANBANS

- If the inventory level exceed the maximum level, it means that some unnecessary kanbans were added.

- If the inventory level falls below the minimum level, it means that the number of kanbans was reduced on account of being lost.

22.9 MAINTAINING THE NECESSARY NUMBER OF KANBANS

- The indicator plate is useful for checking the number of kanbans.
- However, it can be very laborious for team leaders to monitor the differences thousands of parts boxes.
- The automatic pushing-aside system of the inflated kanbans was developed as a personal computer system.

22.9 MAINTAINING THE NECESSARY NUMBER OF KANBANS

Step 1

- The necessary number of supplier kanbans for each supplier in a given month must be registered in the kanban sorter at Toyota.

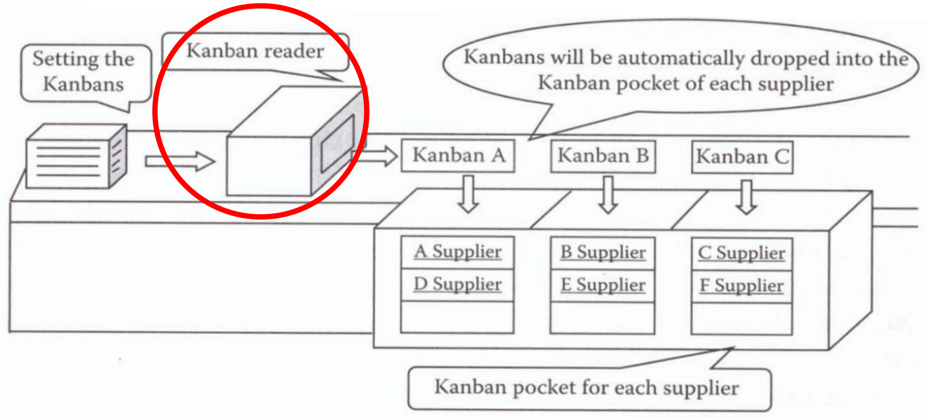


FIGURE 4.11
Post office for supplier kanban. (Adapted from Aoki, M. 2007. *Full Illustration of the Systems of Toyota Production Plants*, Nihon-Jitsugyou Shuppansha, p. 66.)

22.9 MAINTAINING THE NECESSARY NUMBER OF KANBANS

Step 2

- When the supplier kanban goes through the kanban sorter, the series number must be attached and stored with the kanban, and also stored in the kanban sorter.

22.9 MAINTAINING THE NECESSARY NUMBER OF KANBANS

Step 3

- Under the FIFO policy, when the detached kanbans go through the sorter, the kanban whose serial number is stored will pass until the series number reaches the necessary of kanbans.

- Any kanban exceeding the required number will be automatically pushed aside.