MIT 2.853/2.854

Introduction to Manufacturing Systems

Toyota Production System

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Toyota Production System

Historic context

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  - ⋆ TPS is low tech, not dependent on computers (when they became available in the 1960s). All required actions had to be easily understood and executed.
- TPS has been highly influential and widely imitated.

Toyota Production System

Framework and Goals

- Profit through cost reduction

Toyota Production System

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- Elimination of waste:

Toyota Production System
Framework and Goals

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Toyota Production System
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  - ⋆ Overproduction
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  - ⋆ Unnecessary capital investment

Toyota Production System
Framework and Goals

- Quantity control

Toyota Production System

Framework and Goals

- Quantity control
- Quality assurance

Toyota Production System

Framework and Goals

- Quantity control
- Quality assurance
- Respect for people

Toyota Production System

Framework and Goals

- Just in time

Toyota Production System

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Toyota Production System

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Toyota Production System

Framework and Goals

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- "Autonomation" — *jidoka*
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- Creative thinking — *seiko*

Toyota Production System

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- People at each process withdraw from the previous process only what they need.
- People at each process produce what is necessary to replenish what has been taken by the next process.

Toyota Production System

Systems and methods

- Kanban
- Production smoothing
- Reduction of setup time
- Standardization of operations to attain line synchronization
- Machine layout
- Visual control
- *... and many more*

Toyota Production System

"DNA"

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1. All work shall be highly specified as to content, sequence, timing, and outcome.

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The Four Rules:

1. All work shall be highly specified as to content, sequence, timing, and outcome.

2. Every customer supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses.

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"DNA"

3. The pathway for every product and service must be simple and direct.

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"DNA"

3. The pathway for every product and service must be simple and direct.

4. Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization.

Toyota Production System

"DNA"

Toyota's notion of the ideal: A common vision

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- can be supplied on demand in the version requested;
- can be delivered immediately;
- can be produced without wasting any materials, labor, energy, or other resources (such as costs associated with inventory);
- can be produced in a work environment that is safe physically, emotionally, and professionally for every employee.

Kanban

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  ... and between factories.

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Non-kanban systems

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- Push systems cannot easily adapt to demand fluctuations, disruptions, etc.
- This leads to excessive inventory.

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- When demand changes occur, it is enough to notify final assembly.
- All preceding stages learn about schedule changes through the kanban system.
- It is not necessary to issue updated detailed schedules to each stage.

Kanban
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- Kanbans allow systems to operate based on local real-time information.
- The number of kanbans at each stage determines the maximum inventory at that stage.

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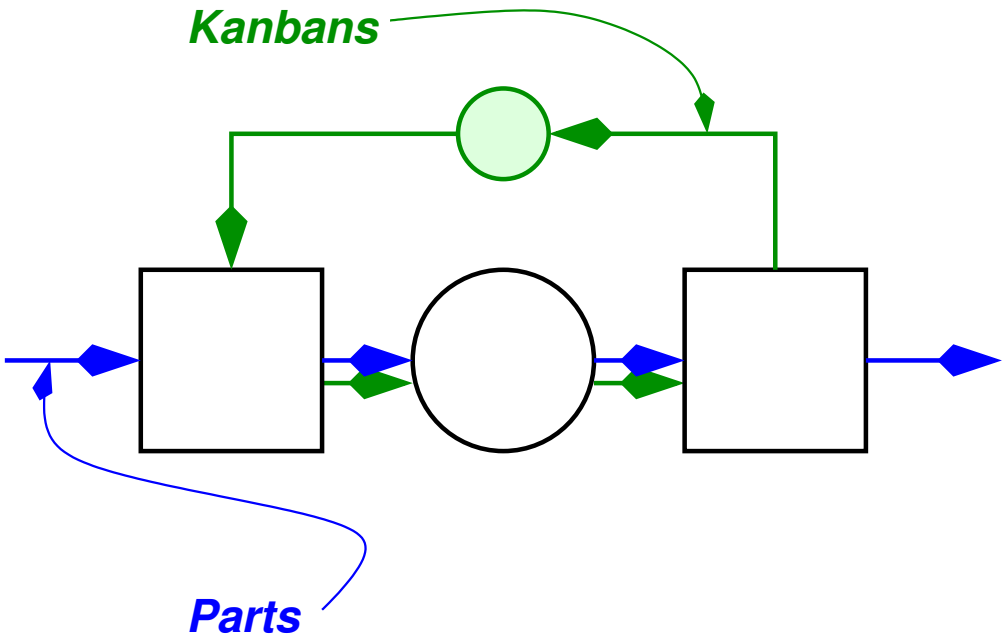
- In the following discussion of kanban systems, each square can represent an individual machine, a multi-machine work cell, or a sub-process, consisting of several cells.
    - ⋆ It could be an entire factory.
- Flow into and out of a square need not be the same as that of any other square at the same time.
- The movement of kanbans can be more complex than described here.

Kanban

Single-Card Kanban



Kanban

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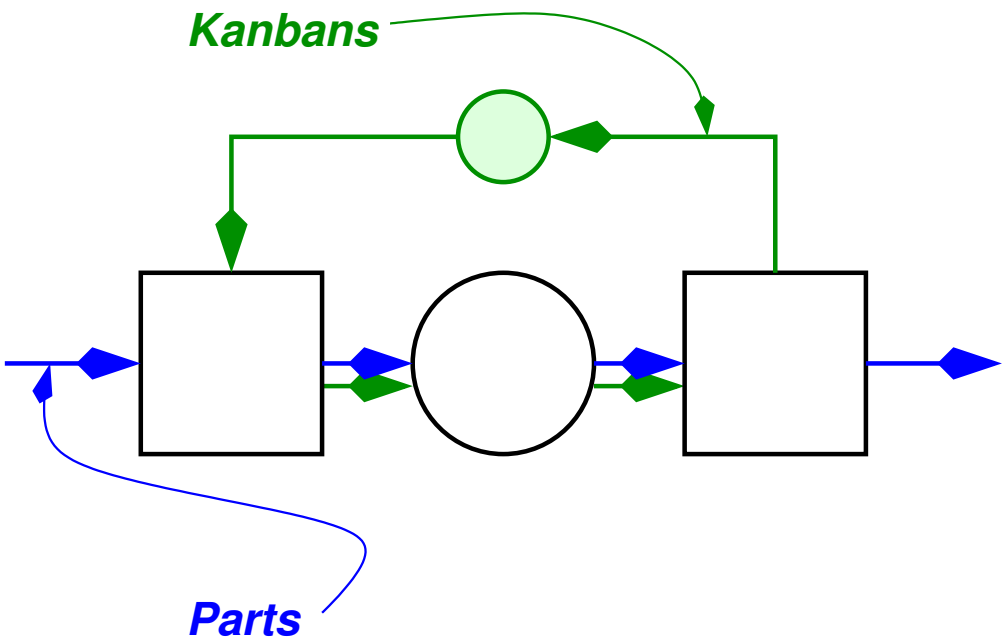

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Kanban

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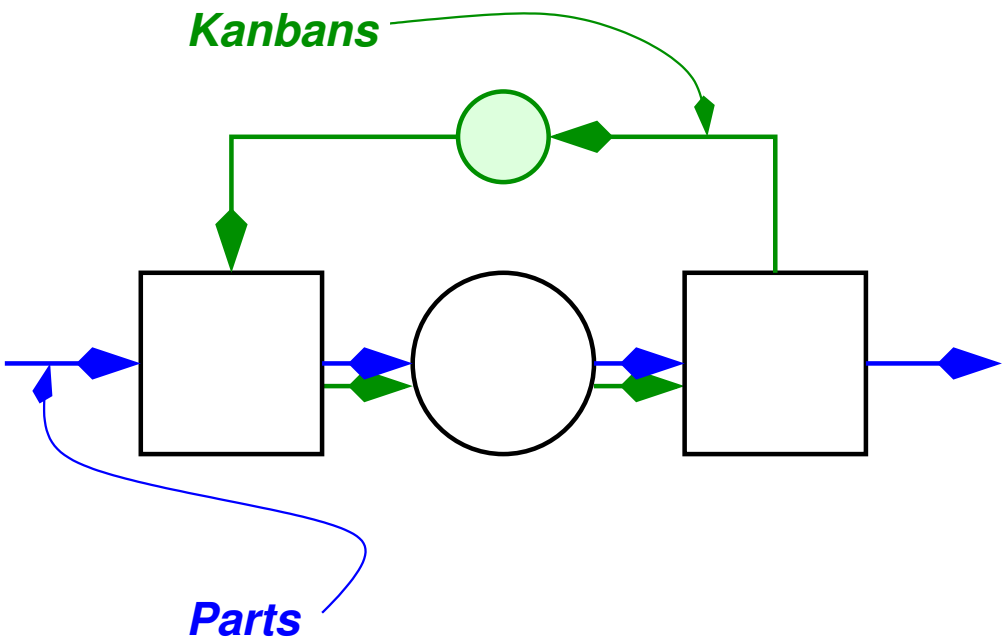

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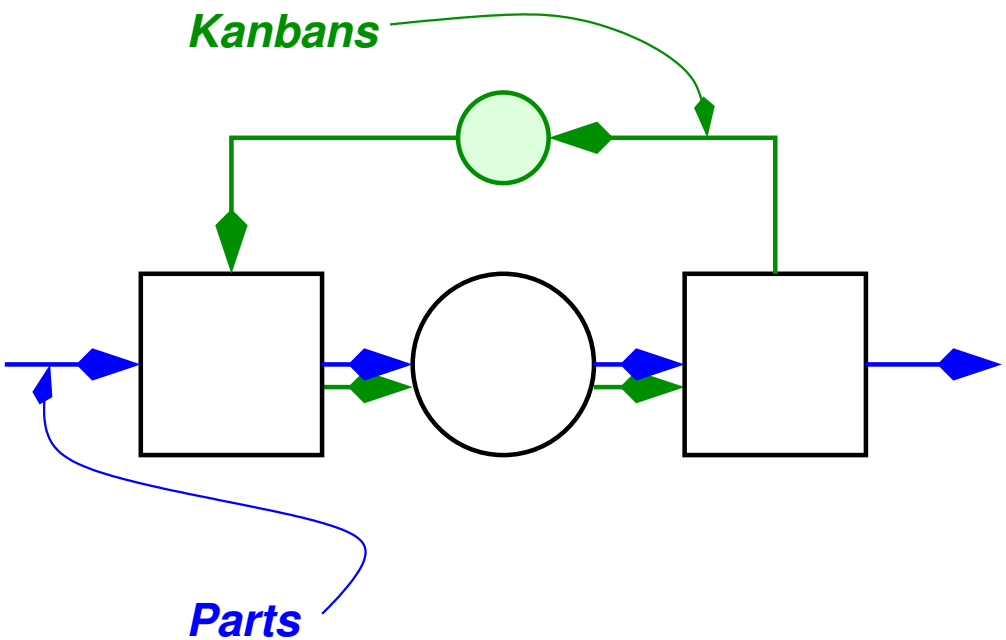

- The upstream machine does an operation when its previous operation or downtime is completed, there is a kanban in the kanban buffer, and a part is available.

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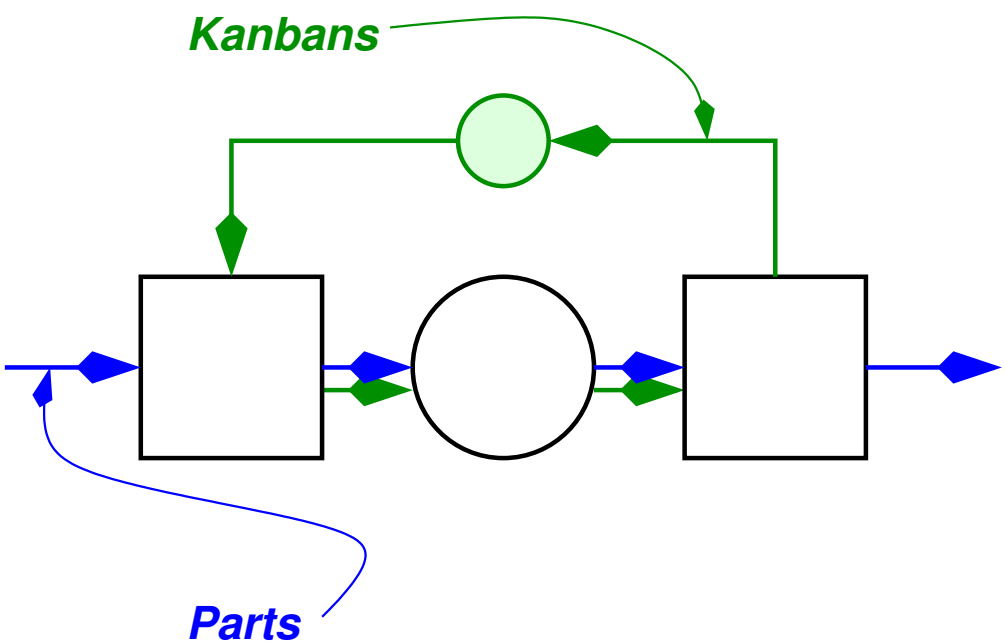

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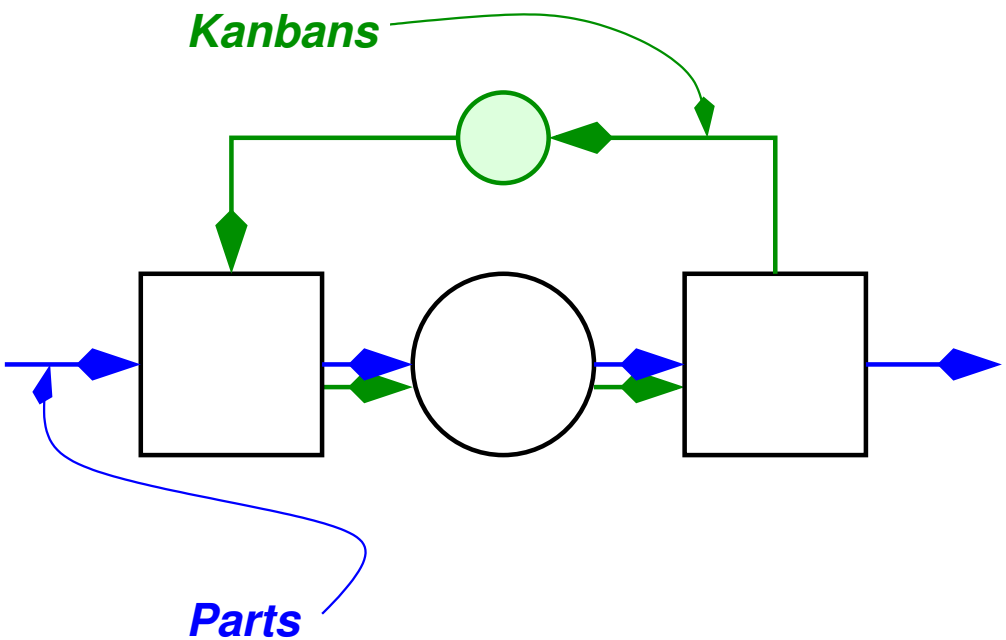

- The upstream machine does an operation when its previous operation or downtime is completed, there is a kanban in the kanban buffer, and a part is available.
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- The upstream cycle repeats.

Kanban

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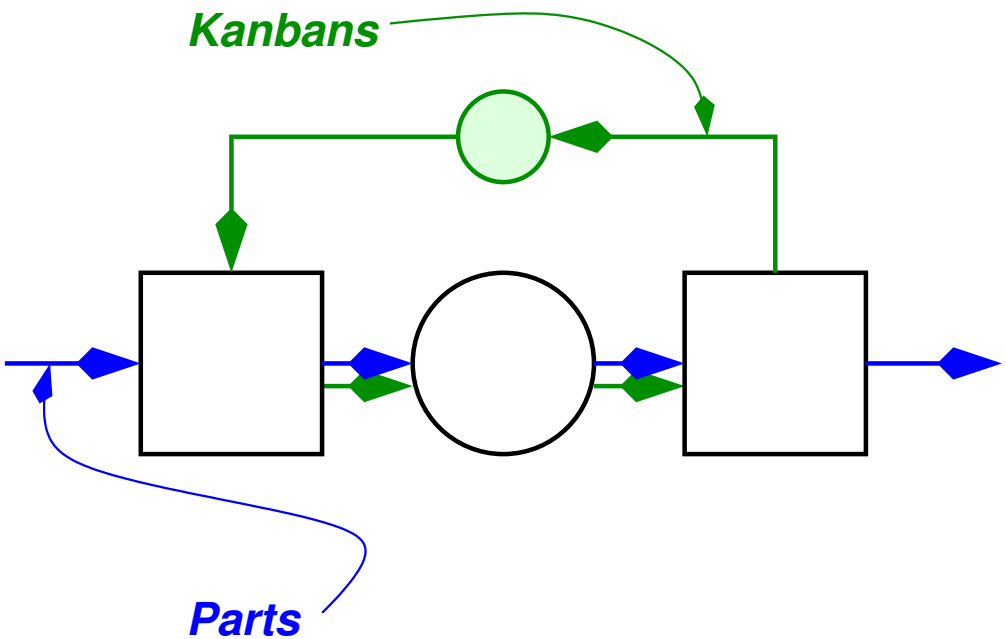

- When the previous operation or downtime of the downstream machine is completed and it is not blocked, the downstream machine takes a part from the WIP buffer.

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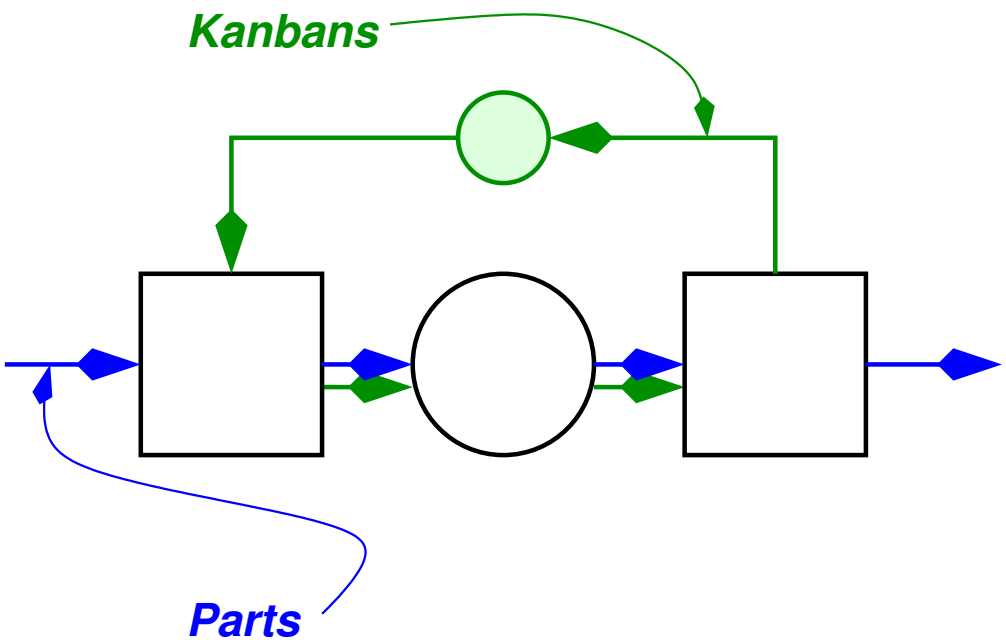

- When the previous operation or downtime of the downstream machine is completed and it is not blocked, the downstream machine takes a part from the WIP buffer.
- It removes the kanban and puts it into the kanban buffer.

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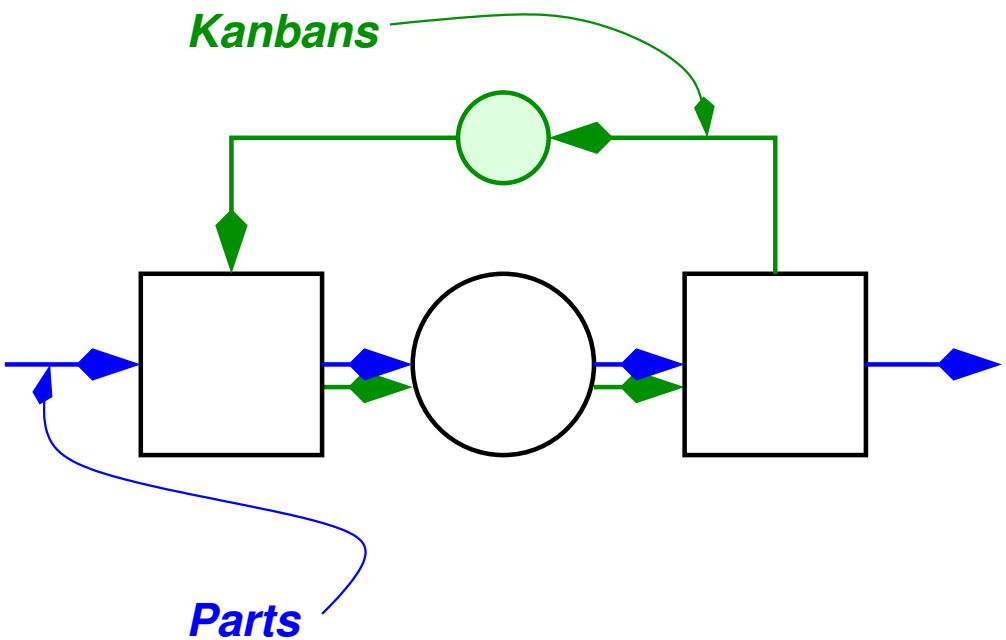

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- It does the operation on the part and the part is sent to its next production step.

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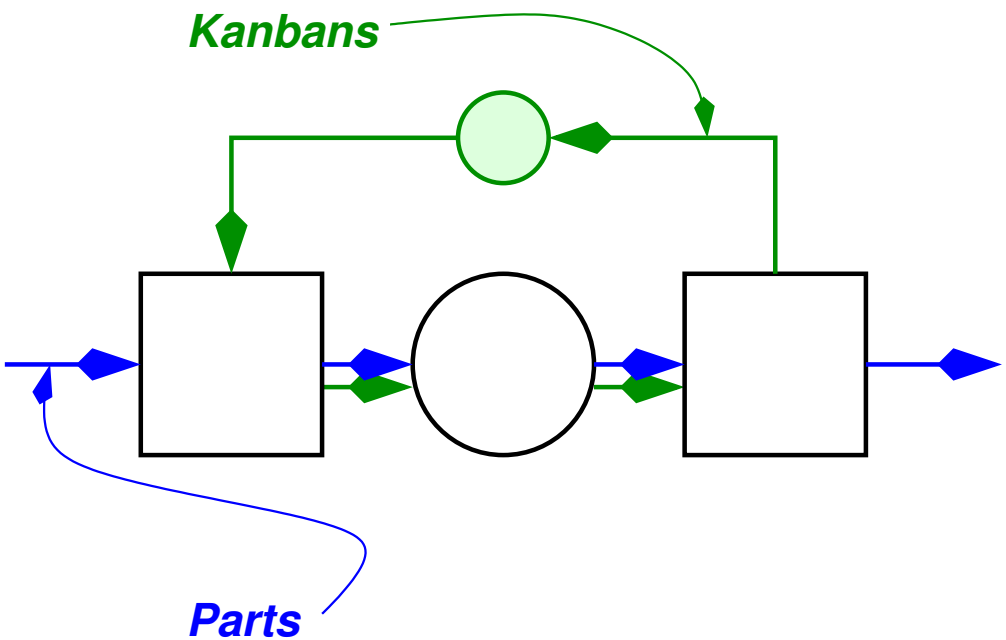

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- It removes the kanban and puts it into the kanban buffer.
- It does the operation on the part and the part is sent to its next production step.
- The downstream cycle repeats.

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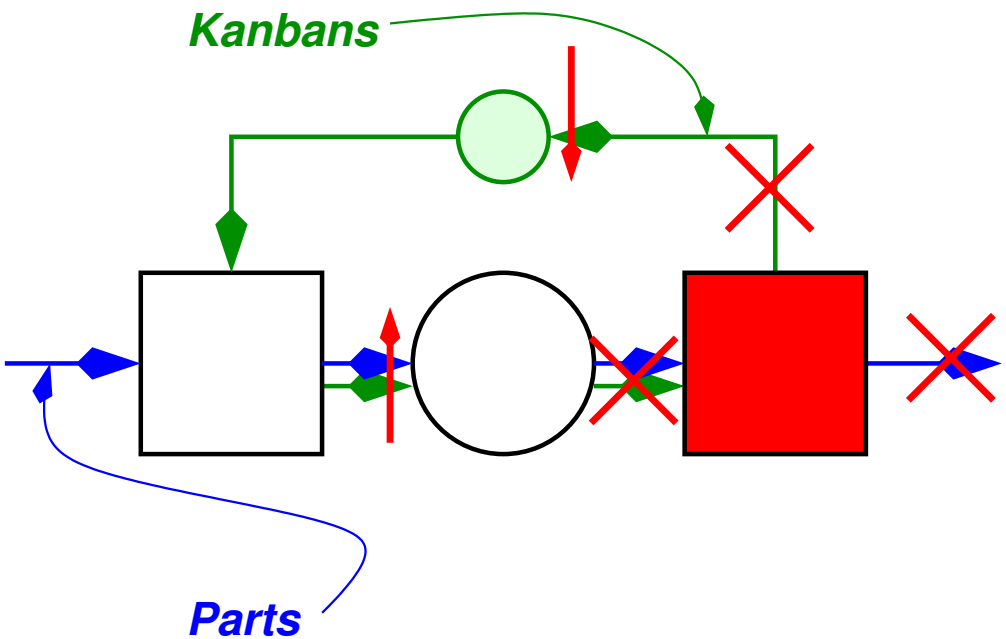

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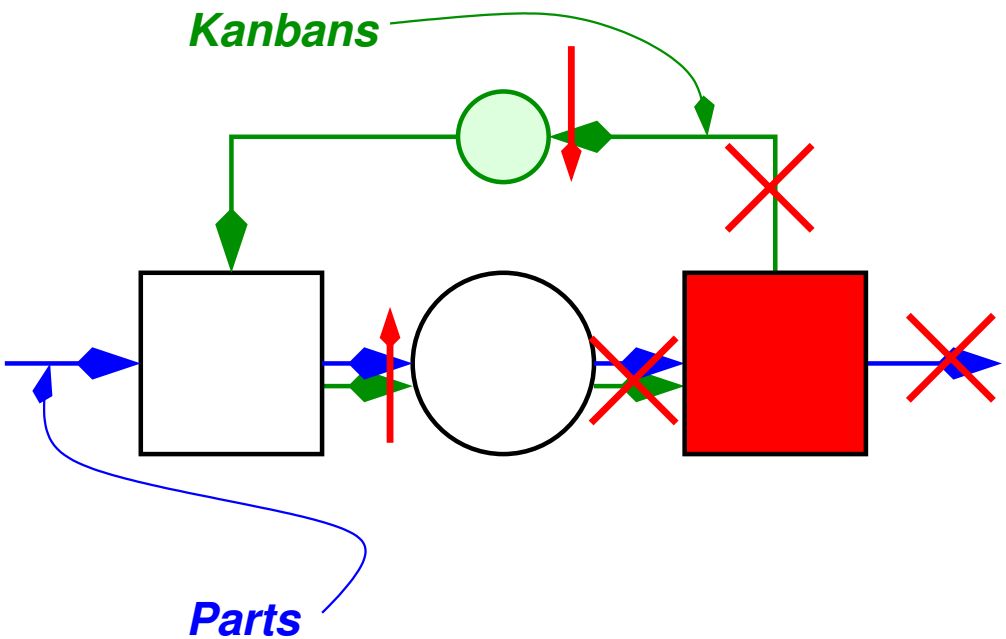

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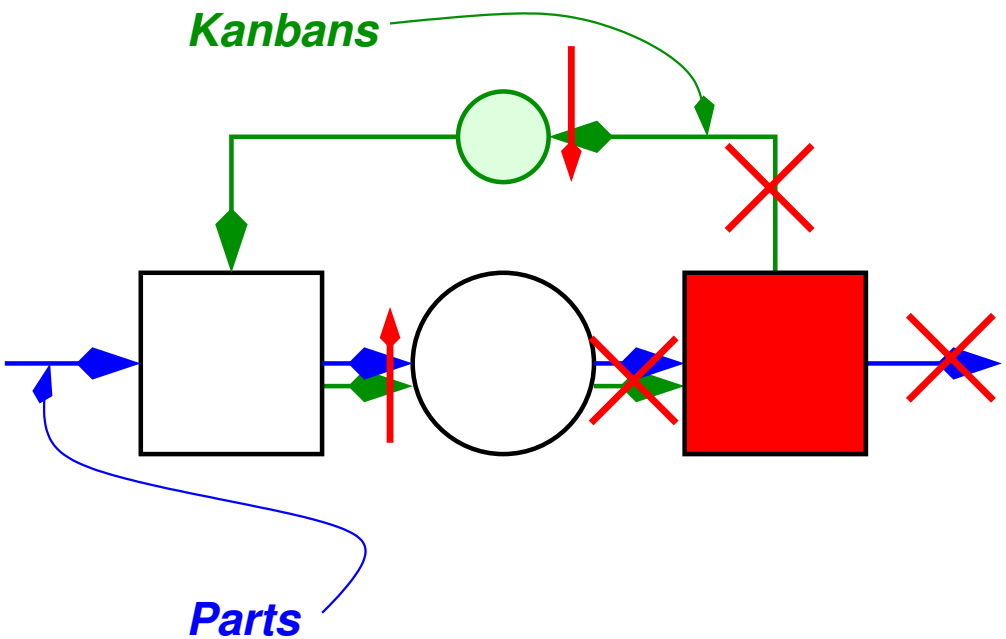
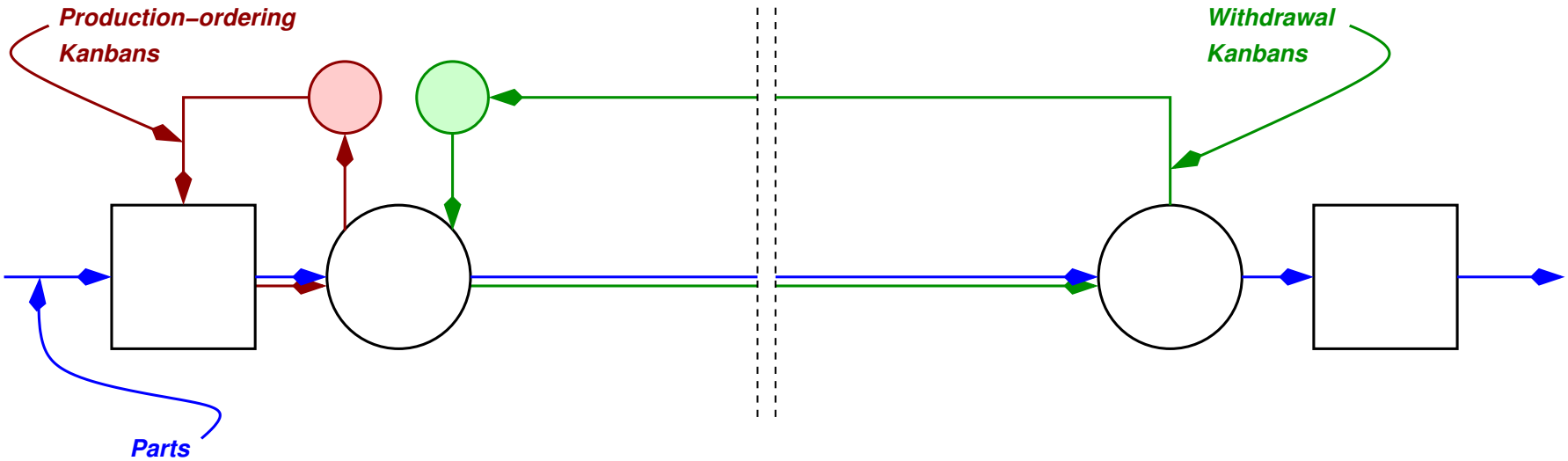


- If the downstream machine goes down, it does not take any parts from the WIP buffer and it does not add any kanbans to the kanban buffer.
- The kanban buffer level goes down and the WIP buffer level goes up.
- The upstream machine can keep operating until there are no more kanbans in the kanban buffer.

Kanban

Two-Card Kanban



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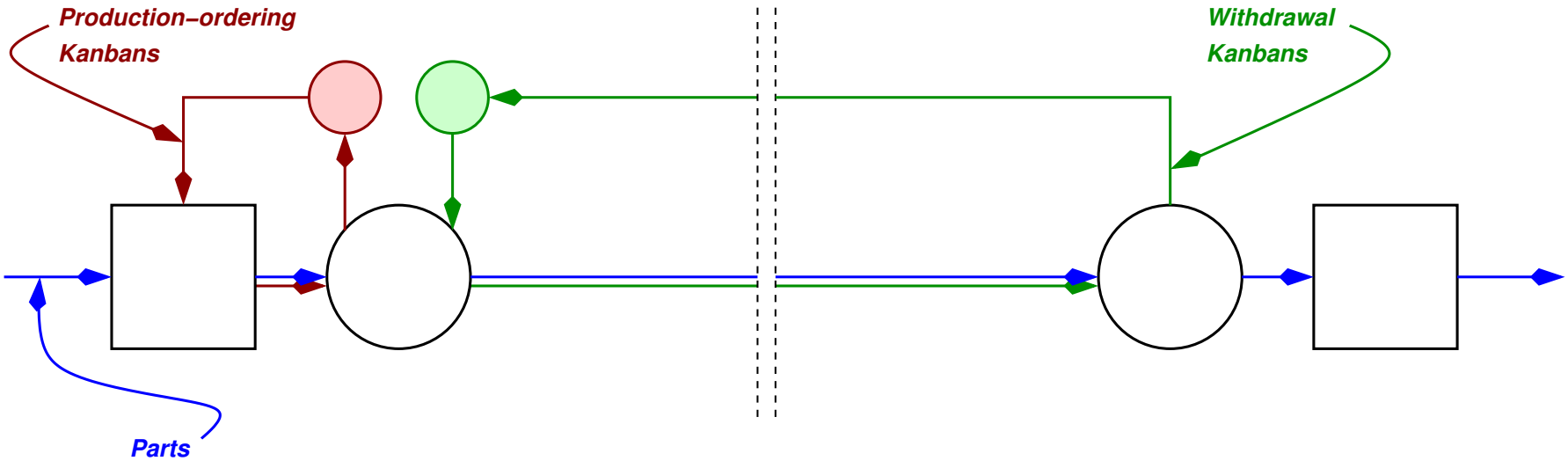

- In a two-card kanban system, there are *production-ordering* kanbans and *withdrawal* kanbans.

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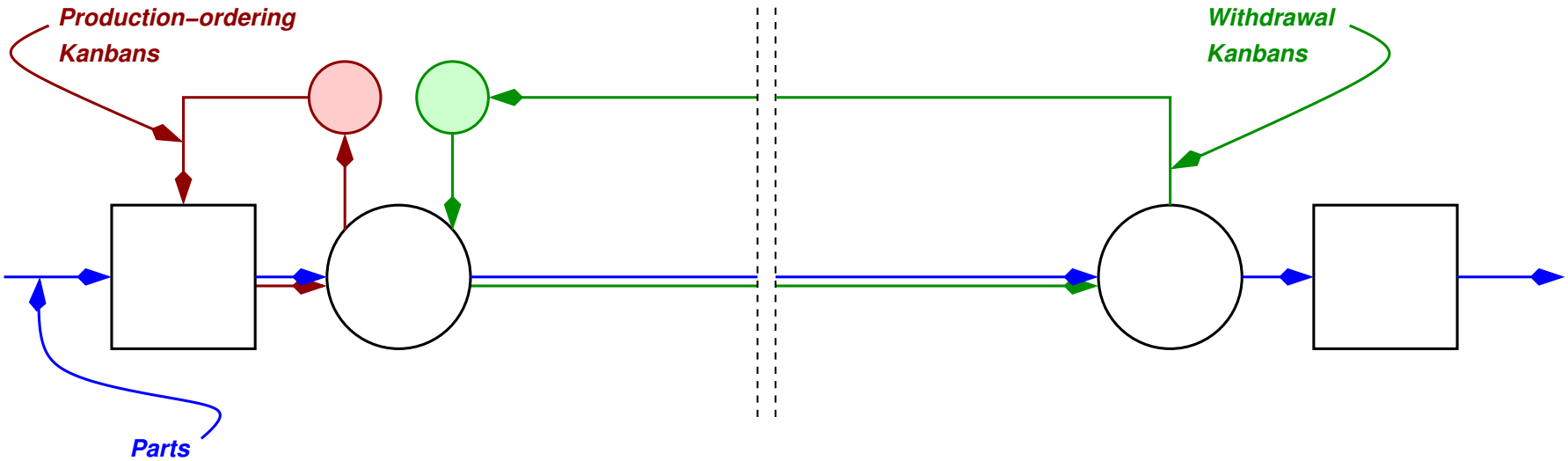

- In a two-card kanban system, there are *production-ordering* kanbans and *withdrawal* kanbans.
- It is often used when there is a long distance between operations or work cells...

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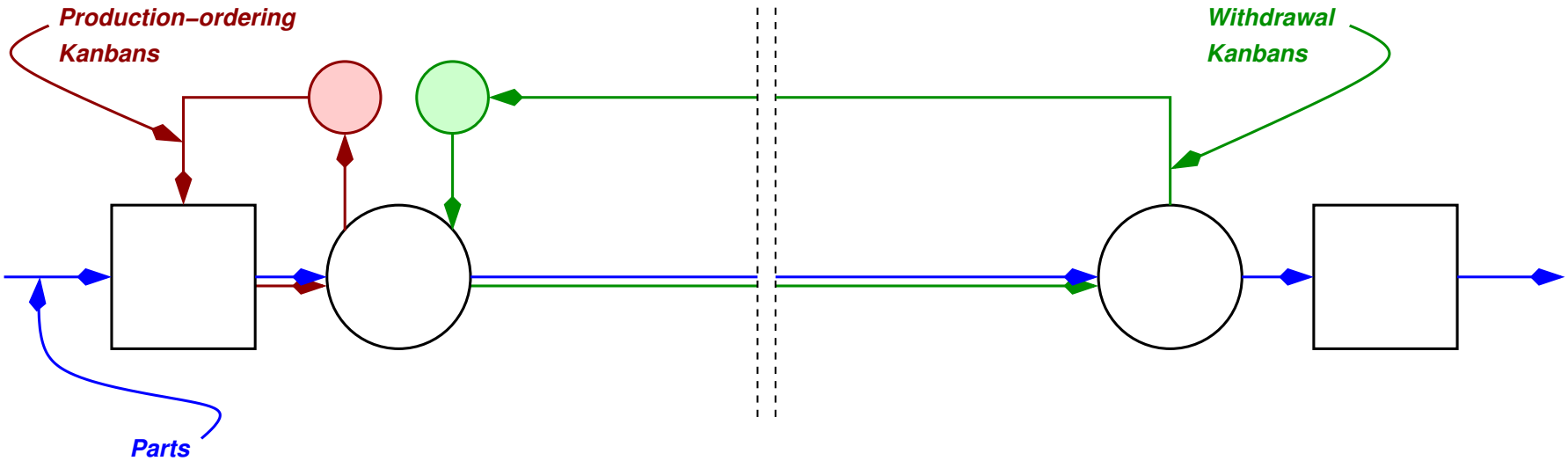

- In a two-card kanban system, there are *production-ordering* kanbans and *withdrawal* kanbans.
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- ... or when parts are delivered to the machines in different-sized batches.

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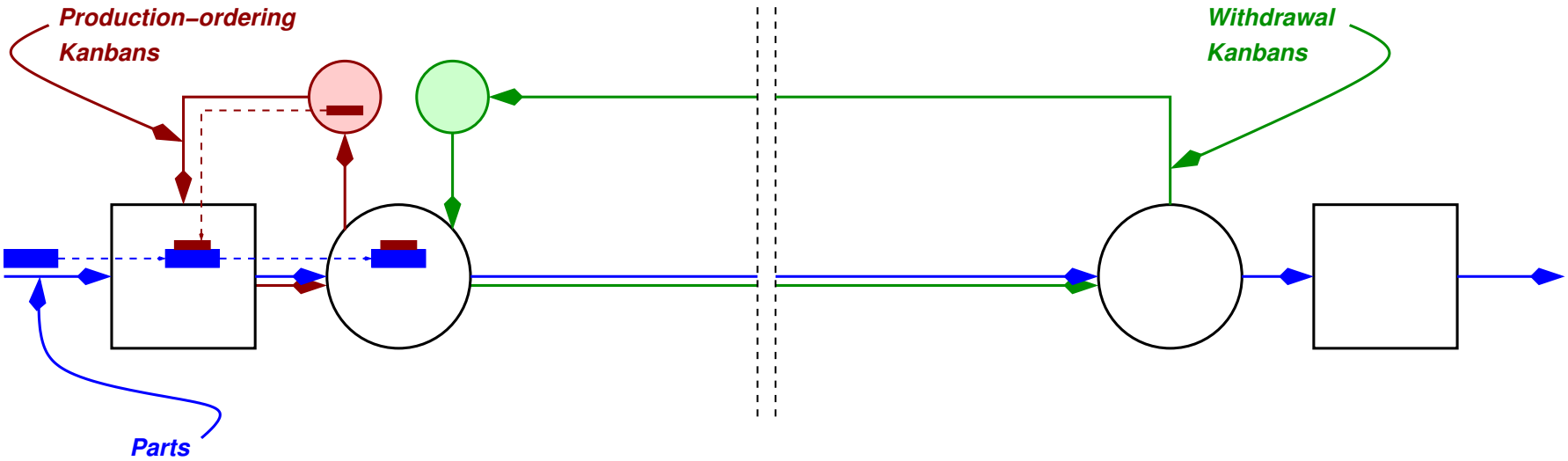

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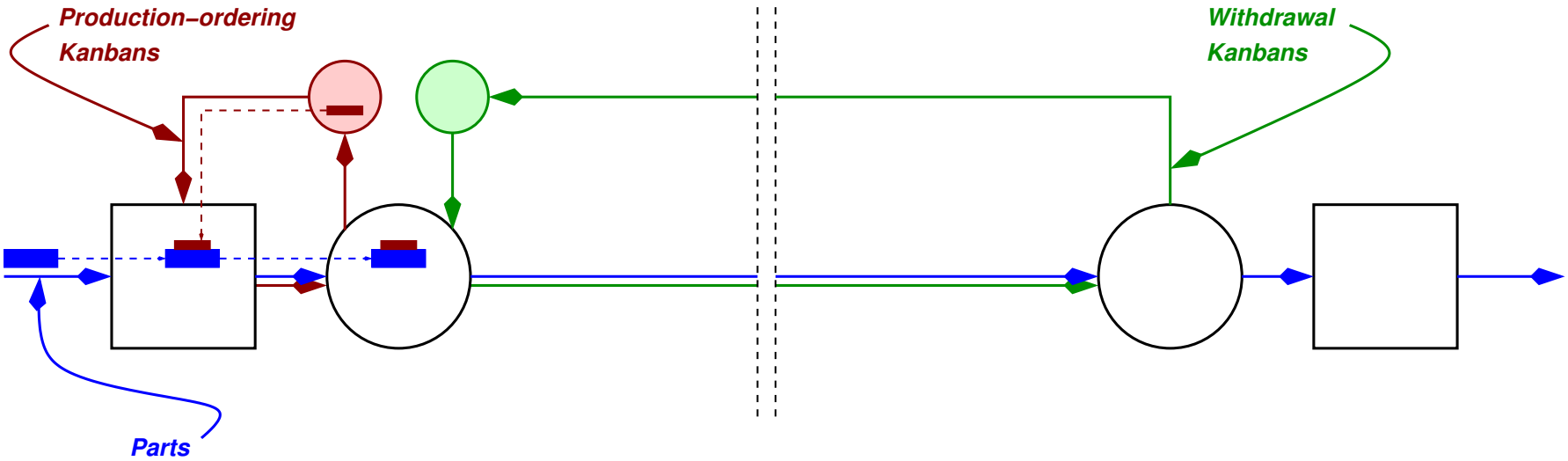

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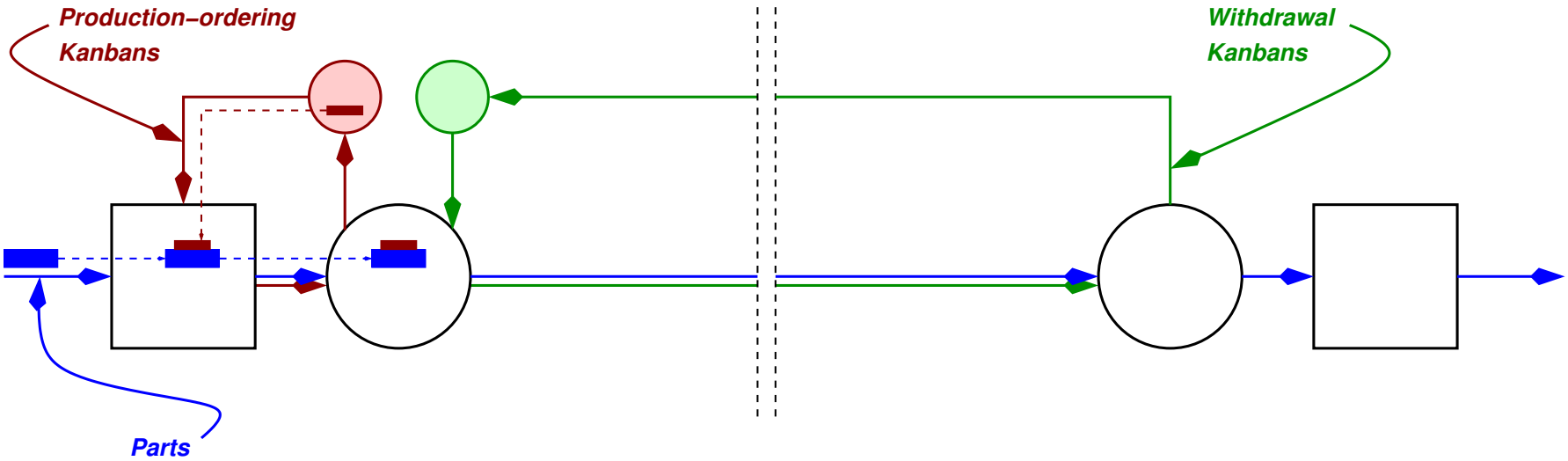

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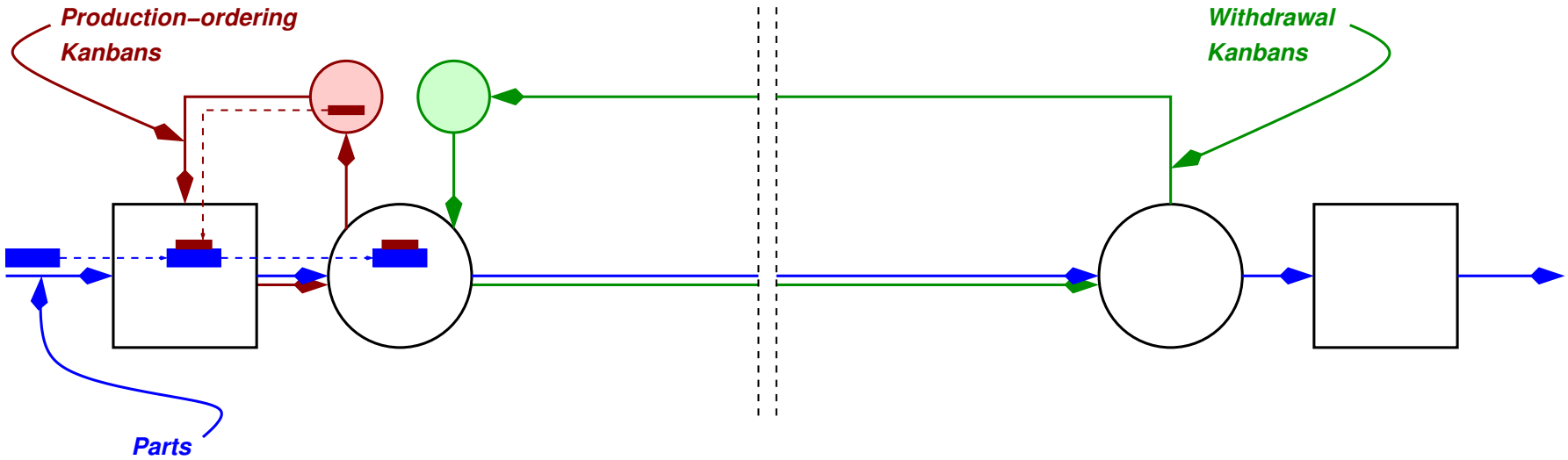

- The upstream machine does an operation when its previous operation or downtime is completed, there is a production-ordering kanban in the production-ordering kanban buffer, and a part is available.
- After the operation, the kanban is attached to the part and they move to the output WIP buffer of the upstream machine together.

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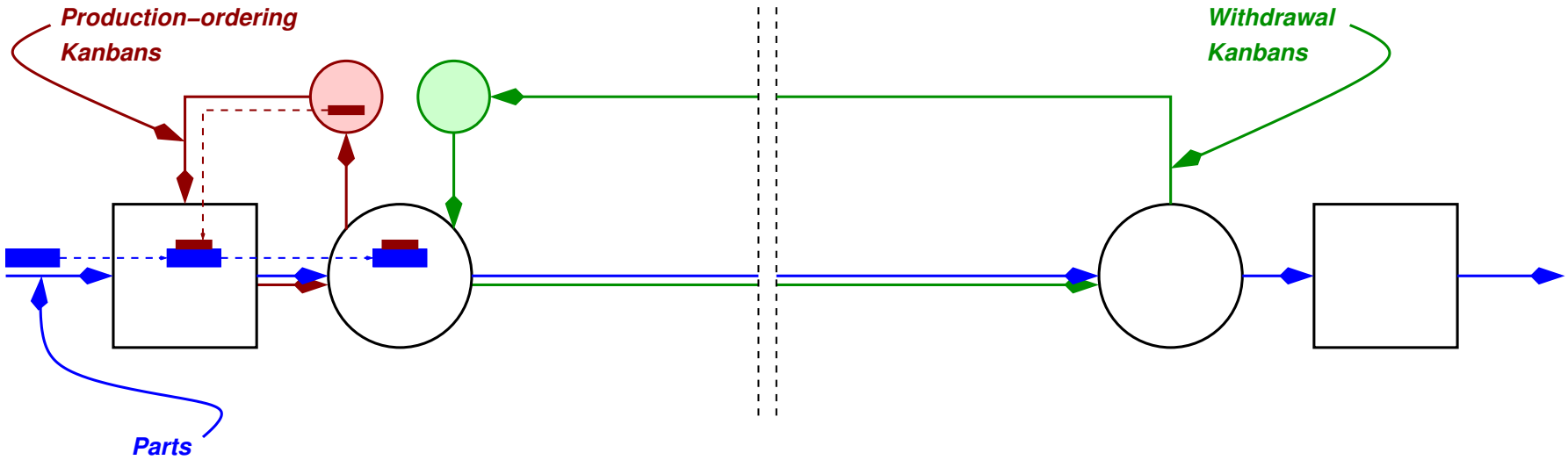

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- The upstream cycle repeats.

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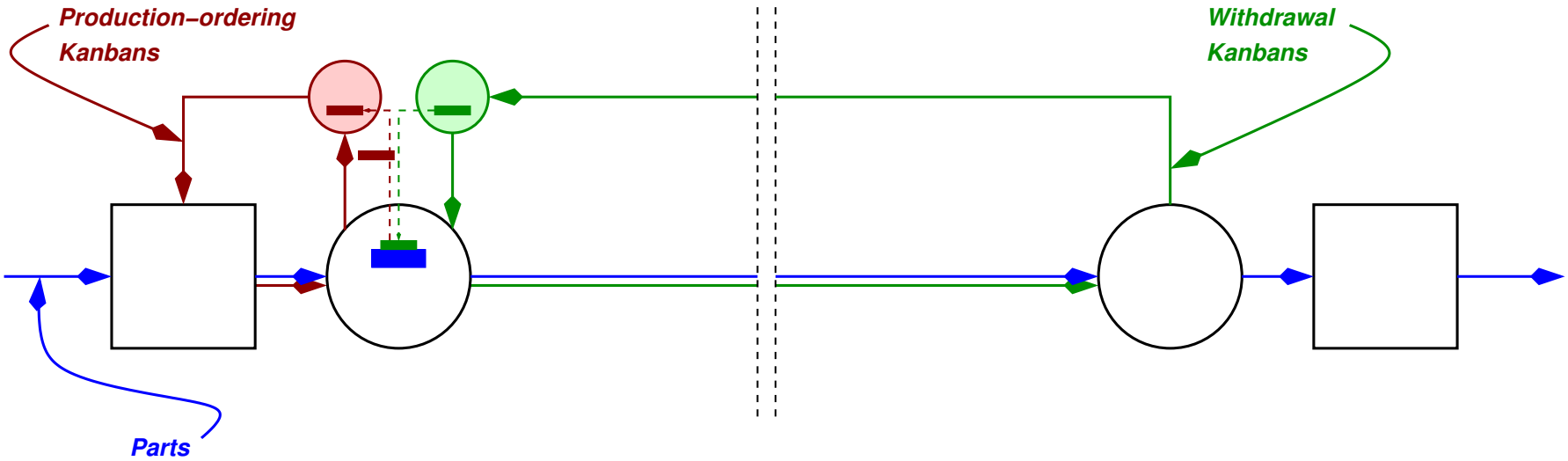

- If the withdrawal kanban buffer is not empty, the production-ordering kanban is removed from a part in the output WIP buffer of the upstream machine and moved to the production-ordering kanban buffer.

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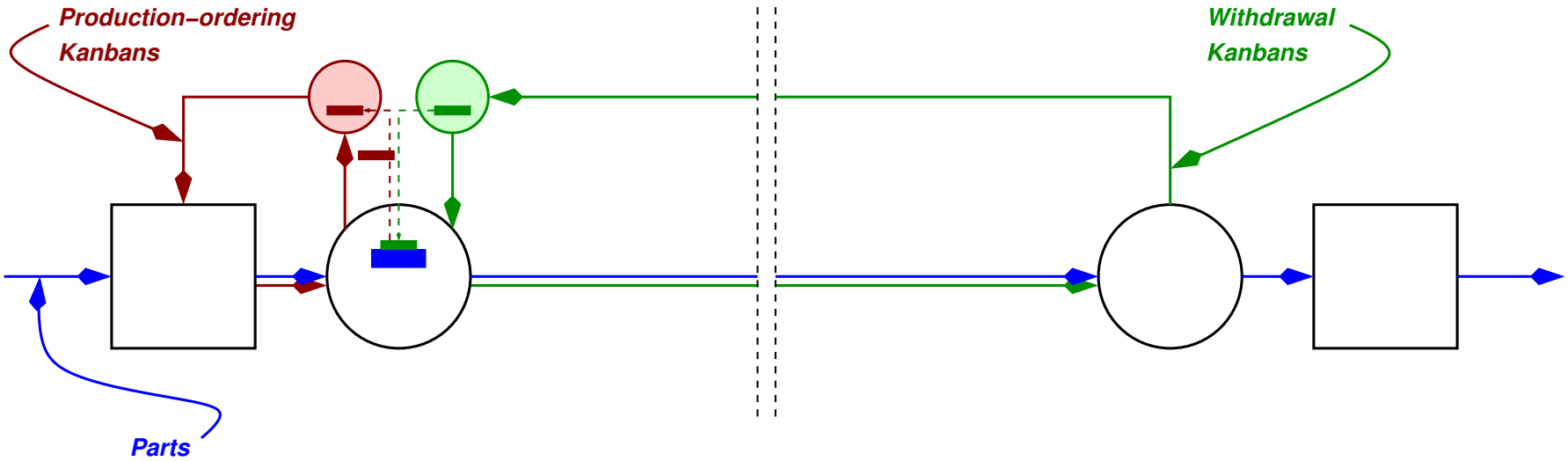
Two-Card Kanban



- If the withdrawal kanban buffer is not empty, the production-ordering kanban is removed from a part in the output WIP buffer of the upstream machine and moved to the production-ordering kanban buffer.
- A withdrawal kanban is attached to that part.

Kanban

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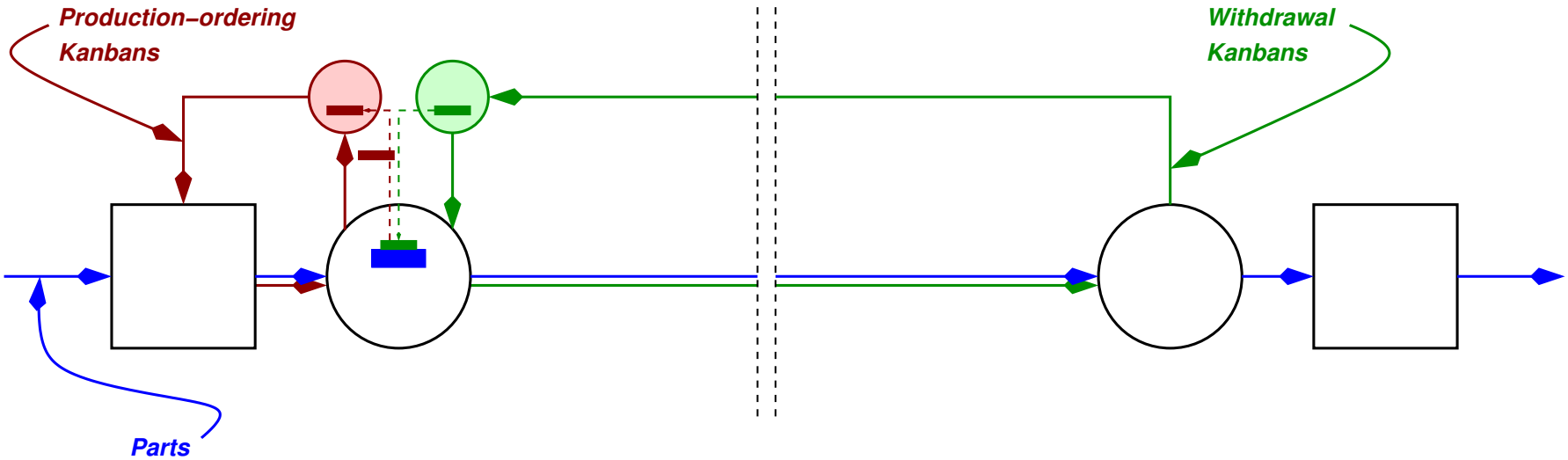

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- The part is made ready for transportation. Transportation occurs according to some specific protocol: there may be a transportation batch size or there may be a transportation schedule.

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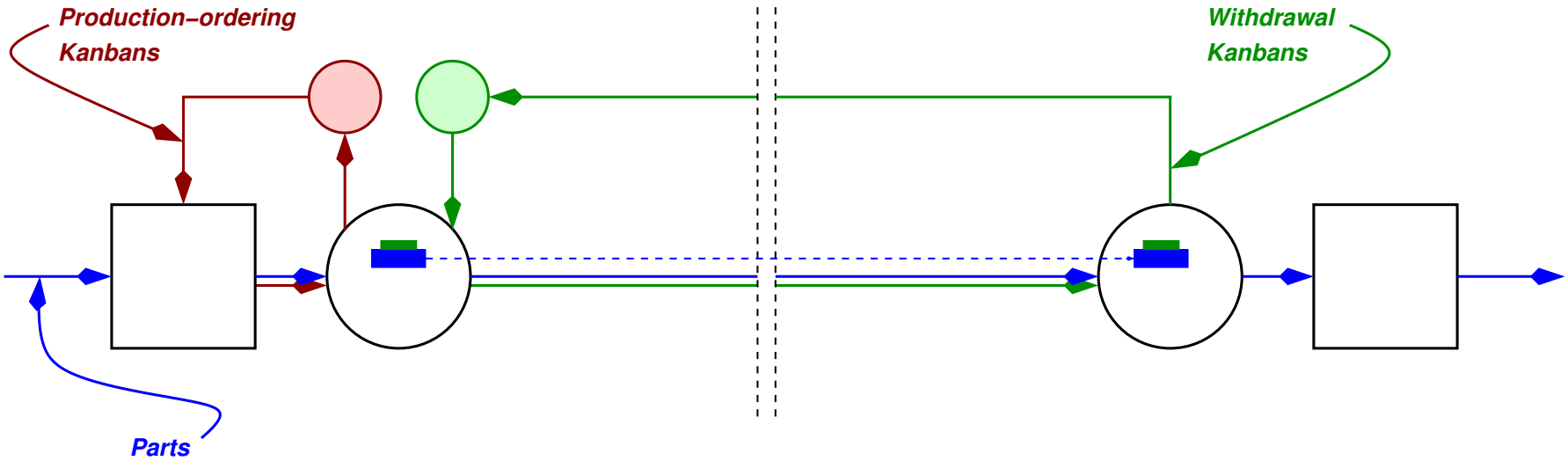

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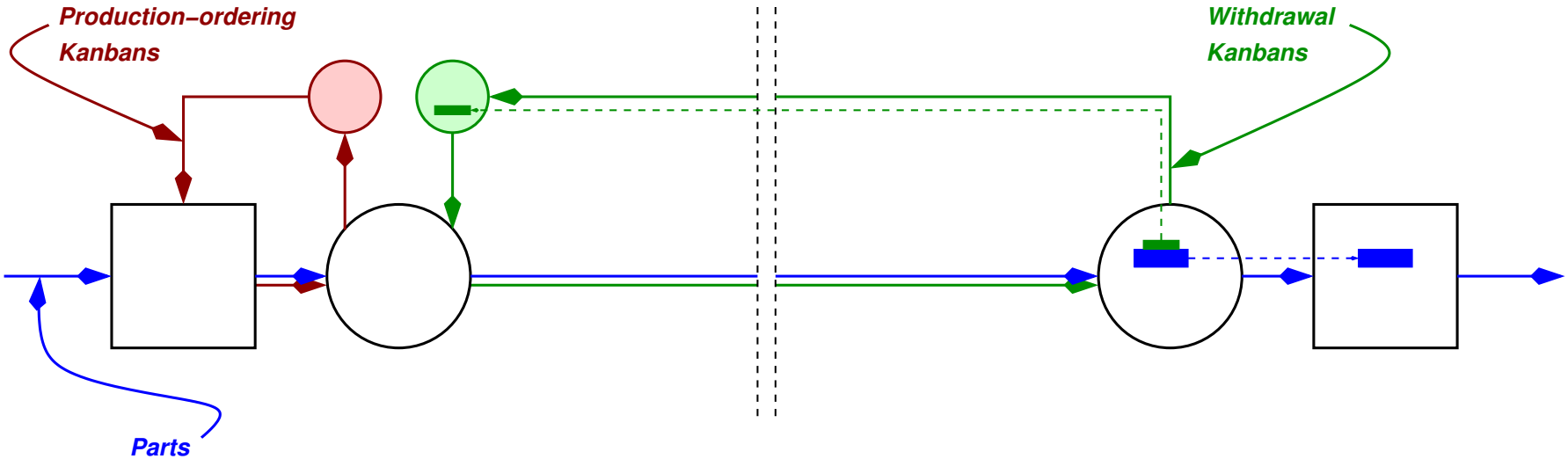

- When the previous operation or downtime of the downstream machine is completed and it is not blocked, the downstream machine takes a part from its input WIP buffer.

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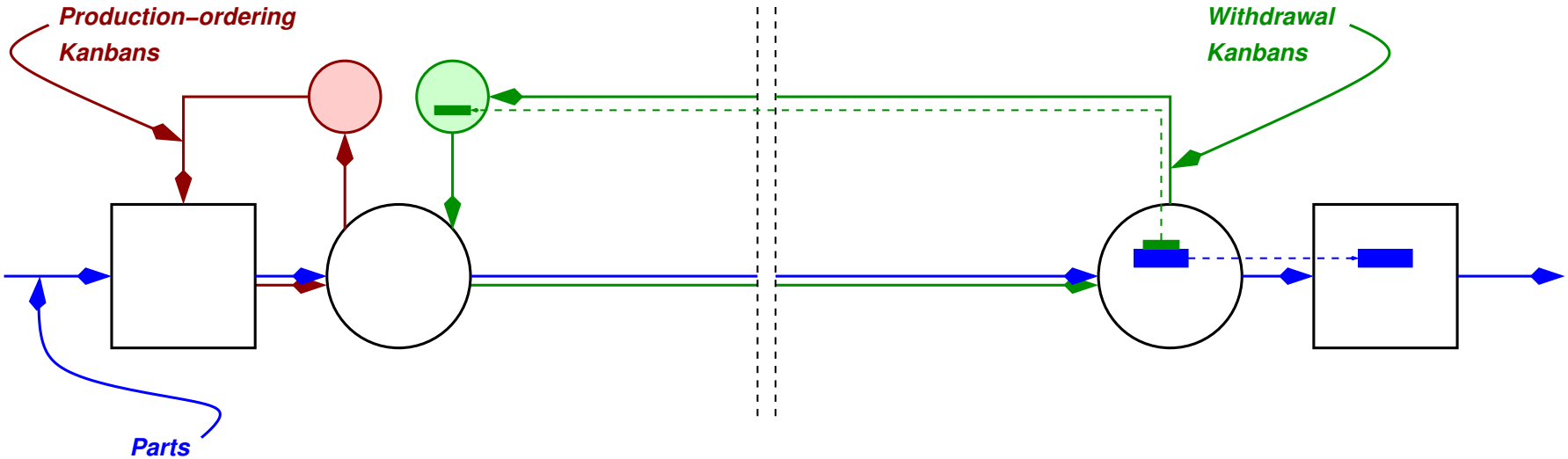

- When the previous operation or downtime of the downstream machine is completed and it is not blocked, the downstream machine takes a part from its input WIP buffer.
- The withdrawal kanban is removed from the part. The withdrawal kanbans are transported to the withdrawal kanban buffer according to a transportation protocol.

Kanban

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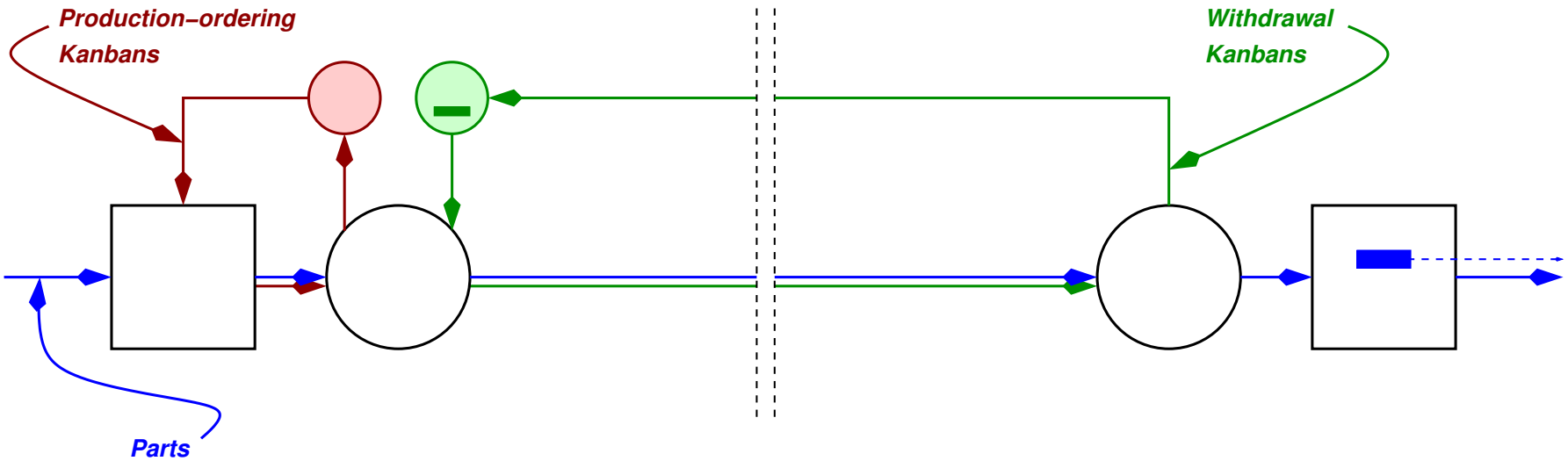

- The downstream machine does an operation on the part and the part is sent to its next step.

Kanban

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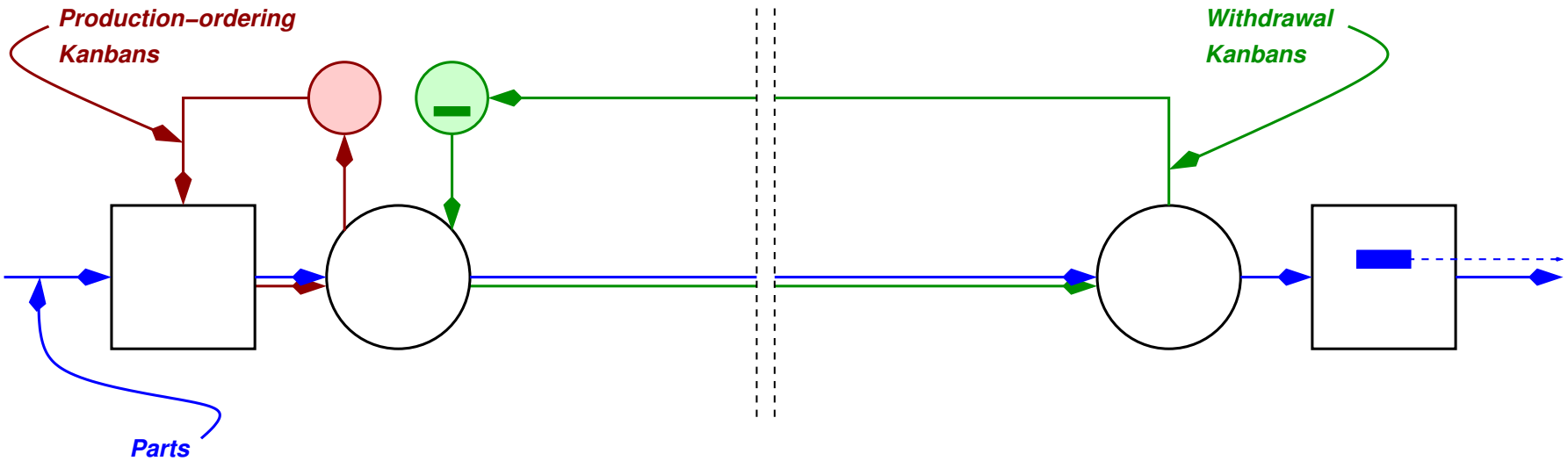
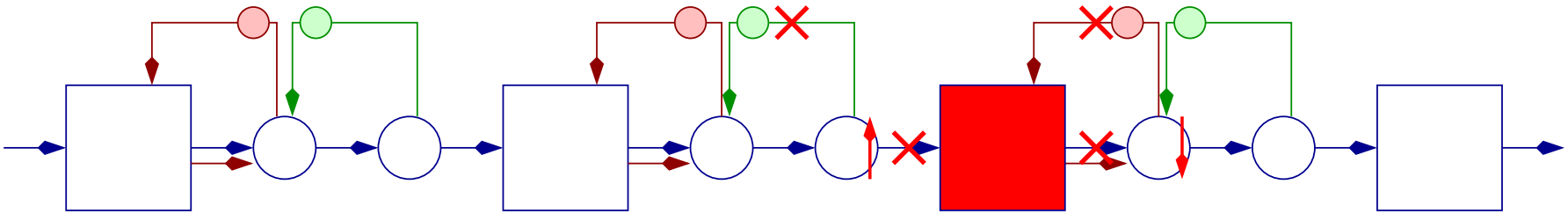


- The downstream machine does an operation on the part and the part is sent to its next step.
- The downstream cycle repeats.

Kanban

Two-Card Kanban



- Effects of a machine failure.

Kanban

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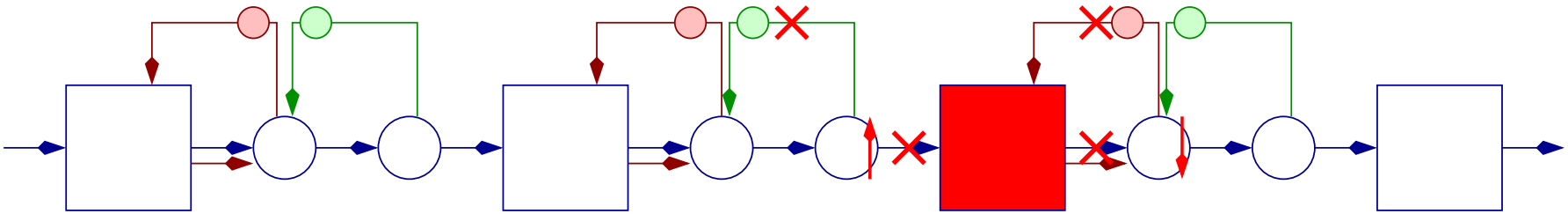

- Effects of a machine failure.
- Withdrawal kanbans are not added to the upstream withdrawal kanban buffer. The ones already there are removed as the upstream machine does operations.

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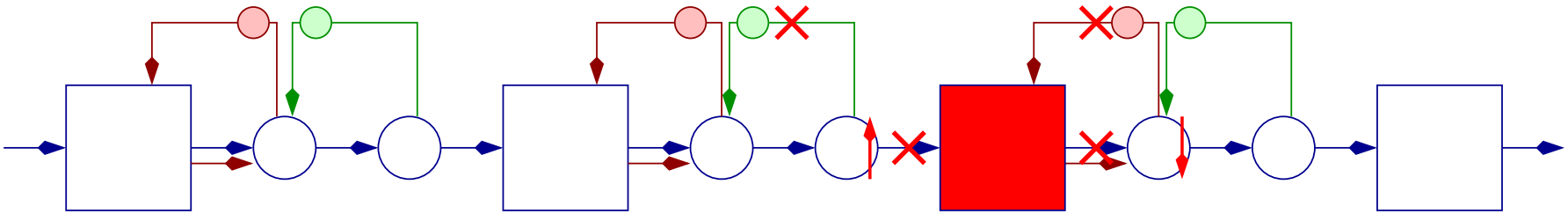

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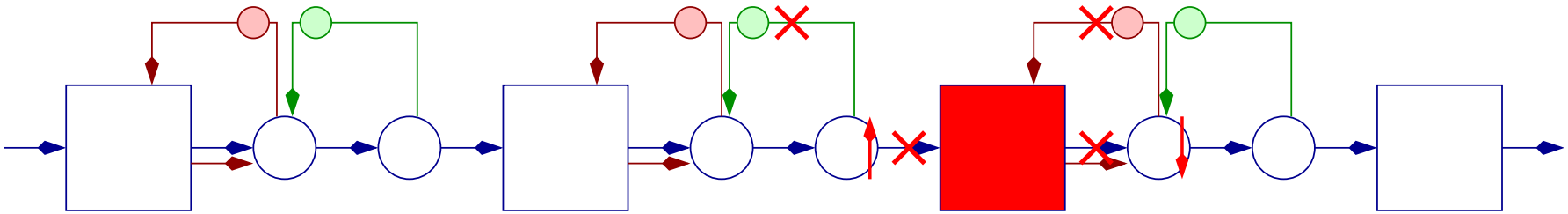

- Effects of a machine failure.
- Withdrawal kanbans are not added to the upstream withdrawal kanban buffer. The ones already there are removed as the upstream machine does operations.
- A part in the output WIP buffer of the upstream machine gains a withdrawal kanban and is transported to the input buffer of the failed machine.
- This continues until the upstream withdrawal kanban buffer is empty.

Kanban

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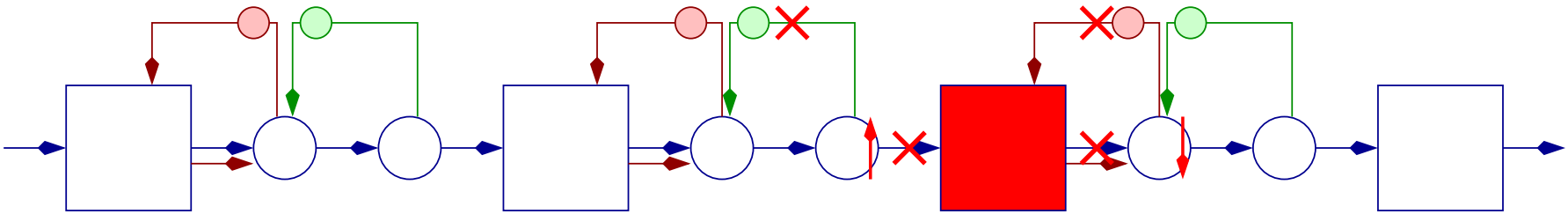

- No parts are added to the output buffer of the failed machine.

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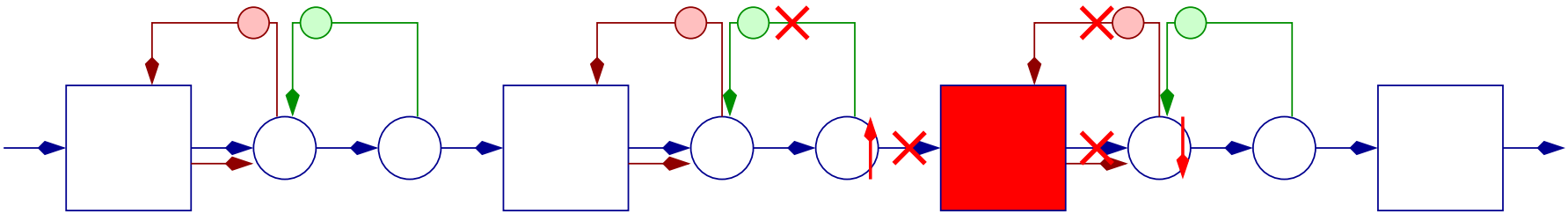

- No parts are added to the output buffer of the failed machine.
- The parts that remain in the output buffer of the failed machine have their production-ordering kanbans replaced by withdrawal kanbans and the parts are moved to the input WIP buffer of the downstream machine.

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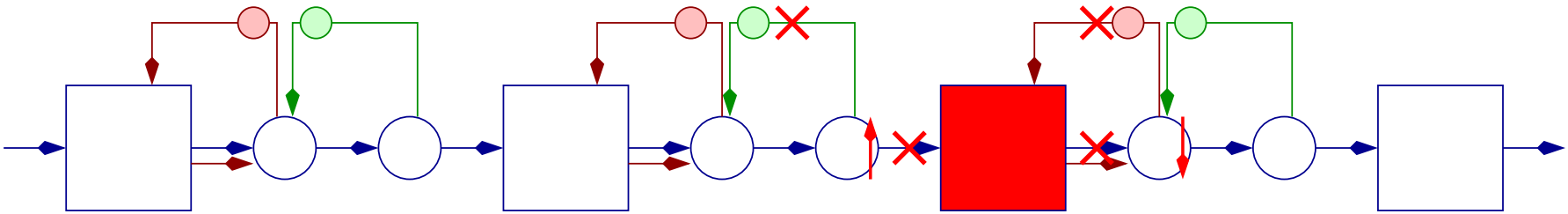

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- This continues until the output buffer of the failed machine is empty.

Kanban

Other kanbans

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- ... and more.

Kanban

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1. Each process withdraws the *necessary* products from the previous in *necessary* quantities at the *necessary* time.

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Kanban

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    - ⋆ To enforce this, workers must first be won over.
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2. Each process produces only what is withdrawn by subsequent process.

3. Defective products are never moved to next process.

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4. The number of kanbans should be minimized.

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4. The number of kanbans should be minimized.

5. The kanban system should be used to adapt to small fluctuations in demand.

Production smoothing

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- It includes
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  - ⋆ smoothing of each model's production quantity
- However, production must respond to variable demand.

Production smoothing

Adaptation to varying demand

- Just-in-time (JIT) in sales: supplying products in salable quantities only.

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Adaptation to varying demand

- Just-in-time (JIT) in sales: supplying products in salable quantities only.
  - ⋆ That means that production must adapt promptly to demand changes.
  - ⋆ This eliminates excess inventories of finished goods.

Production smoothing

Adaptation to varying demand

- If demand increases, hire temporary workers; add shifts, etc.

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Adaptation to varying demand

- If demand increases, hire temporary workers; add shifts, etc.
- If demand decreases,
  - ⋆ dismiss temporary workers,
  - ⋆ transfer workers to lines with increased demand,
  - ⋆ decrease overtime,
  - ⋆ fill up workers' time with quality control meetings, set-up practice, maintenance, etc.

Production smoothing

Waste Reduction

- A system has a maximum production rate, its capacity. When demand is less than that maximum, capacity is wasted.

Production smoothing

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Production smoothing

Waste Reduction

- A system has a maximum production rate, its capacity. When demand is less than that maximum, capacity is wasted.
- Smoothing production can reduce the required maximum.
- However, when demand is greater than capacity, there will have to be inventory or lost sales.

Production smoothing

Total production

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Production smoothing

Total production

- Goal: minimize the variance of total output in a period.
  - ⋆ Produce the same amount every day, if demand is constant.
- Amount produced in a day is the total for a planning period (eg, one month) divided by the number of days in a month.
  - ⋆ The planning period should be as short as possible.

Production smoothing

Example

- Consider an engine line that normally produces 100 engines per day.

Production smoothing

Example

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- An assembly plant requests lots of 5 with withdrawal kanbans.

Production smoothing

Example

- Consider an engine line that normally produces 100 engines per day.
- An assembly plant requests lots of 5 with withdrawal kanbans.
- Withdrawals normally occur 20 times per day.

Production smoothing

Example

- If demand is reduced to 90 per day, withdrawals occur 18 times per day.

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Production smoothing

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- If demand is reduced to 90 per day, withdrawals occur 18 times per day.
  - ⋆ The process is stopped after 90 are produced.
- If demand is increased to 110 per day, withdrawals occur 22 times per day.
  - ⋆ The additional engines are produced in overtime.
- If the engine plant did not alter their work hours, they would either build inventory or starve the assembly plant.

Production smoothing

Mixing models

Mix models to:

Production smoothing

Mixing models

Mix models to:

- minimize inventory

Production smoothing

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- maximize utilization.

Production smoothing

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Production smoothing

Mixing models

Example:

Production smoothing

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Example:

- Over a period of 168 working hours (8 hours/day for 21 days), there is a constant demand for 56 A items, 56 B items, 56 C items.

Production smoothing

Mixing models

Example:

- Over a period of 168 working hours (8 hours/day for 21 days), there is a constant demand for 56 A items, 56 B items, 56 C items.
- A items have a 50-minute operation time; B items require 60 minutes; C items require 70 minutes.

Production smoothing

Mixing models

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- Over a period of 168 working hours (8 hours/day for 21 days), there is a constant demand for 56 A items, 56 B items, 56 C items.
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  - ⋆ 46 hours, 40 minutes for A items at a rate of 1.2 items/hour

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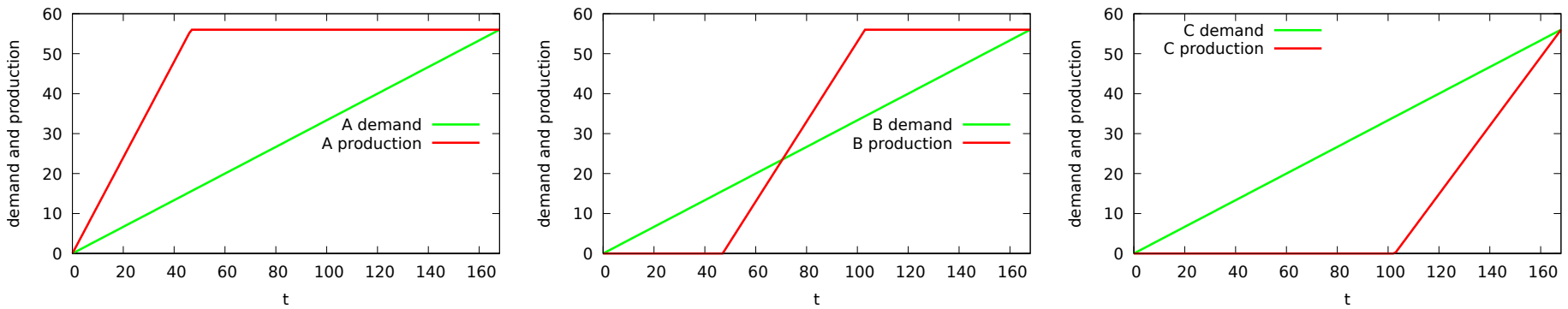
  - ⋆ 56 hours for B items at a rate of 1 item/hour
  - ⋆ 65 hours, 20 minutes for C items at a rate of .86 items/hour

Production smoothing

Mixing models

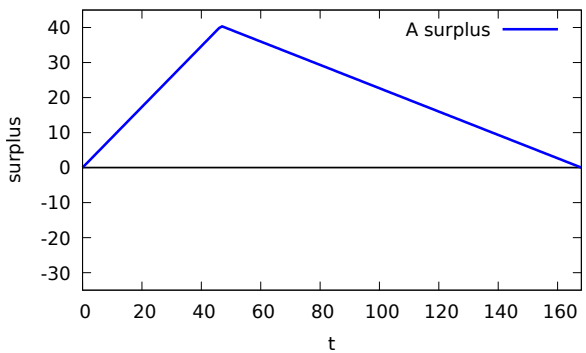


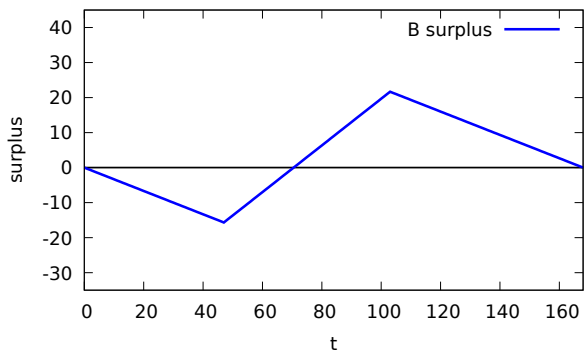
Cumulative production and demand if parts are produced

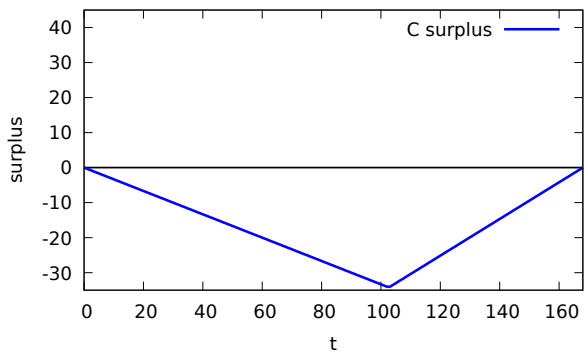
$$AAAA...BBBB...CCCC...$$

Production smoothing

Mixing models





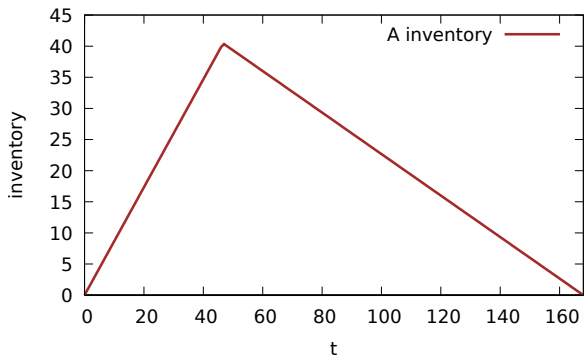


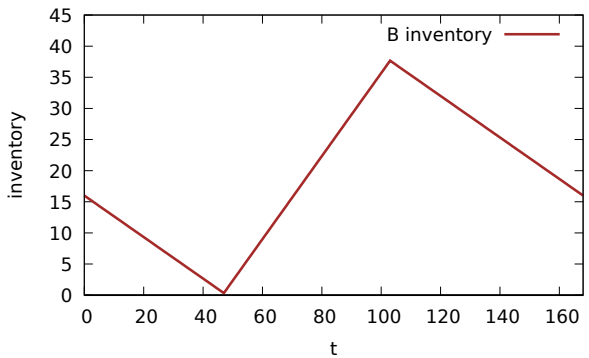
Surpluses *and backlogs* if parts are produced

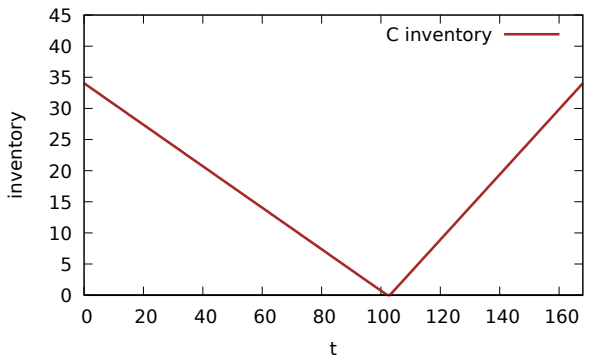
$$AAAA...BBBB...CCCC...$$

Production smoothing

Mixing models







Inventories if parts are produced

$$AAAA...BBBB...CCCC...$$

Production smoothing

Mixing models

- If the items are are produced $ABCABCABCABC...$ and demand is constant,

Production smoothing

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    - (3/(50+60+70)) = 3/180 = 1/60),

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Mixing models

- If the items are are produced $ABCABCABCABC...$ and demand is constant,
  - ⋆ the production rates are constant
    - (3/(50+60+70)) = 3/180 = 1/60),
  - ⋆ the surpluses and inventories are all small.
- This is possible only if the machines and the people in this factory are flexible.

Production smoothing

Example

- A plant produces 10,000 Toyota Coronas in a month.

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  - ⋆ 5,000 sedans, 2,500 hardtops, 2,500 wagons
- 1 month = 20 eight-hour shifts
- Production is divided equally. Every shift:
  - ⋆ 250 sedans, 125 hardtops, 125 wagons (500 cars).
- eight-hour shift = 480 minutes. Therefore *unit cycle time* = 480/500 = .96 minute = 57.5 seconds.

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- One wagon must be generated every 3 min, 50 sec.

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- Possible sequence: sedan, wagon, sedan, hardtop, sedan, wagon, sedan, hardtop, ...

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- As long as there is no setup cost, a sequence like this is desirable because it minimizes inventory.

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- Machines and people must be flexible for this.

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- This activity is called a *setup change.*

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- They reduce the time that a machine can be used for productive work.
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- Machines that have very short (or even zero) setup times are said to be *flexible* .

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- One element of the setup time reduction strategy is to convert internal setup change activity to external.

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- Minimize WIP.
  - ⋆ There is a *standard quantity of work-in-process.*

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- Lines are rebalanced so that cycle time is less than, and as close as possible to, the takt time.

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  - ⋆ Worker deals with one piece at a time *(one-piece flow)* .

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- Built-in mechanism to prevent production of defective products.

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- *Pokayoke:* "foolproof" system for checking to prevent defects.

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- When a worker stops a job, he turns on a red light.

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- Shitsuke: inspire workers, and have them make conforming to rules a habit.

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- This provides good ideas, and improves workers' morale.

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- Respect for people is an integral part of the system.

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