

MIT 2.853/2.854
Introduction to Manufacturing
Systems
Toyota Production System

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TPS

- *Primary source: Toyota Production System* by Yasuhiro Monden
- *See also:* “Decoding the DNA of the Toyota Production System” by Steven Spear and H. Kent Bowen, *Harvard Business Review*, September-October, 1999.
- Goals of TPS:
 - ★ reduction of costs — ie, reduction of waste
 - ★ increase of total sales/total assets
 - ★ improvement of total productivity

TPS

- Developed by Toyota after WWII:
 - ★ In the postwar period, the West was prosperous. It was important to satisfy demand.
 - ★ Japan was poor. Cost minimization and efficiency were most important.
 - ★ TPS is low tech, not dependent on computers. All actions easily understandable.
- Currently, TPS is widely imitated — Ford PS, Alcoa PS, etc.

TPS

Basic ideas

Subgoals

- Quantity control: adapt to daily and monthly fluctuations in quantity and variety
- Quality assurance
- Respect for people

Basic ideas

TPS

Concepts

- Continuous flow of production
 - ★ Just in time: produce necessary units in the necessary quantities at the necessary time.
 - ★ “Autonomation” — jidoka — autonomous defects control.
- Flexible work-force — shojinka.
- Creative thinking — soikufu — capitalizing on worker suggestions.

TPS

Basic ideas

Systems and methods

- kanban
- production smoothing
- reduction of setup time
- standardization of operations to attain line balancing
- machine layout and multi-function workers
- improvement activities
- visual control
- functional management

TPS

Basic ideas

“DNA”

Spear and Bowen: *“We found that, for outsiders, the key is to understand that the Toyota Production System creates a community of scientists.”*

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.

TPS

Basic ideas

“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.

TPS

Basic ideas

Just in time

- In final assembly of a car, the subassemblies arrive just when they are needed.
- Inventories are therefore not needed.
- Cannot be achieved by central planning.
- People at each process withdraw from previous process only what they need.
- People at each process produce what is necessary to replenish what has been taken by next process.

TPS

Basic ideas

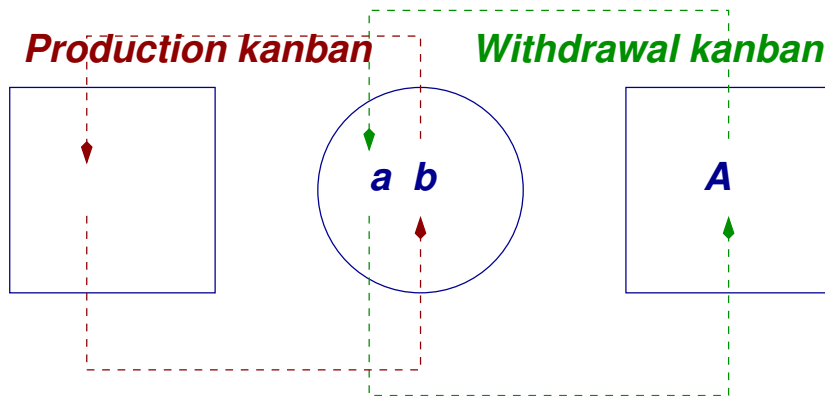
Kanban system

- A *part* of TPS.
- An information system to control production quantity.
- Kanban: a card in rectangular vinyl envelope.
- Withdrawal kanban: describes quantity that subsequent process must withdraw.
- Production-ordering kanban: describes quantity that preceding process must produce.
- Kanbans circulate within factories and between factories.

TPS

Basic ideas

Kanban system

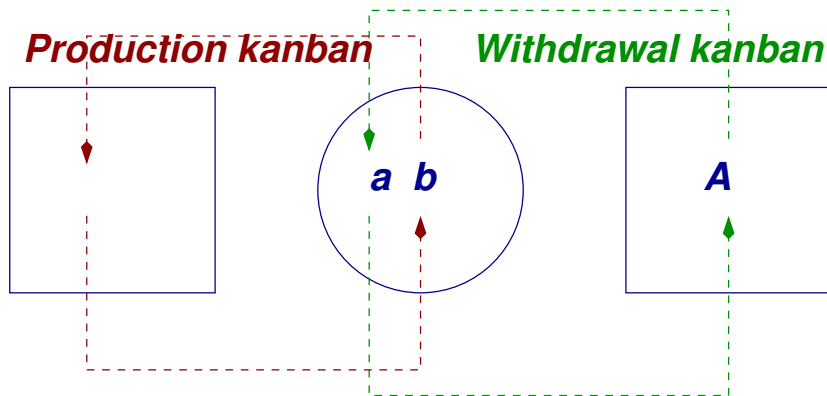


- Products: A, B, C
- Components: a, b
- a's and b's are made at upstream stage, and production kanbans attached to parts as they are put in storage.

TPS

Basic ideas

Kanban system

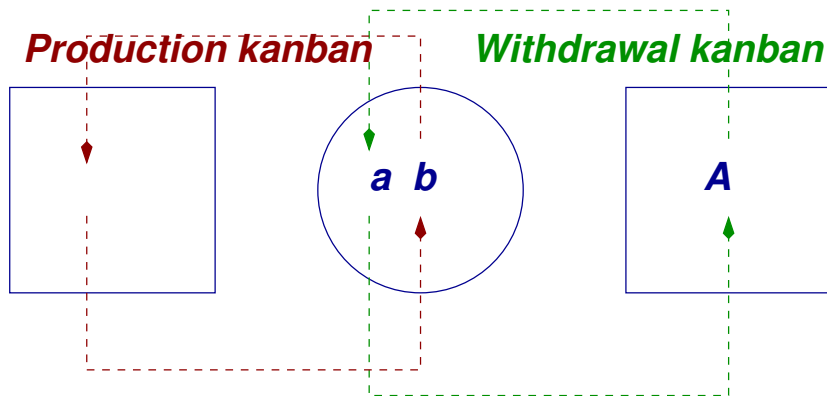


- Worker from downstream stage withdraws some a's from storage, with withdrawal kanban.
- He detaches production kanbans.

TPS

Basic ideas

Kanban system



B C

- Unattached production kanbans are the signal to tell upstream stage how much to produce.

TPS

Basic ideas

Fine tuning

- Engine line normally producing 100 engines per day.
- Next process requests lots of 5 with withdrawal kanban.
- Withdrawals occur 20 times per day.

TPS

Basic ideas

Fine tuning

- 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.

TPS

Basic ideas

Production smoothing

- If kanban is used and production at a stage fluctuates, the previous stage must hold inventory, and have excess capacity.
- Therefore, final assembly will use minimal lot sizes to reduce fluctuation.
- Also, final assembly will withdraw small lots from previous stages.

Basic ideas

TPS

Example

- Plant produces 10,000 Toyota Coronas in a month.
 - ★ 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.

Basic ideas

TPS

Example

- One sedan must be generated every 1 min, 55 sec.
- One hardtop must be generated every 3 min, 50 sec.
- One wagon must be generated every 3 min, 50 sec.
- Possible sequence: sedan, wagon, sedan, hardtop, sedan, wagon, sedan, hardtop, ...
- As long as there is no setup cost, a sequence like this is preferable because it minimizes inventory.
- Machines must be flexible for this.

Basic ideas

TPS

Setups

- Major emphasis on reduction of setup time.
- Pressing department setup times:
 - ★ 2-3 hours, 1945-1954.
 - ★ 15 min., 1955-1964.
 - ★ 3 min. after 1970.
- *External* setup: setup work that can be done while operation is taking place.
- *Internal* setup: only done while machine is stopped.

Basic ideas

TPS

Process Design

- Previous layout: rows of machines organized by type (lathe, mill, etc.), and one worker per machine.
- TPS layout:
 - ★ Machines organized to smooth material flow.
 - ★ Each worker handles three different machines.
 - ★ Worker deals with one piece at a time (*one-piece flow*) .

TPS

Basic ideas

Process Design

- Benefits

- ★ inventory reduced
- ★ fewer workers needed
- ★ workers feel better about their jobs
- ★ workers become part of factory team because of their increased knowledge

TPS

- *Standard operations routine sheets* are posted in the factory — visible to all workers.
 - ★ detailed sequences of operations
- *Takt time* = (duration of a time period)/(demand over the time period) = amount of time available to produce each demanded item
 - ★ Monden calls this *cycle time* . (*This is the third use of this term I have seen.*)

TPS

Basic ideas

Job Standardization

- Late in the month, central planning office tells each production department the volume required for the next month — ie, the next month's takt time (push system).
- Process managers determine how many workers are needed.
- Lines are rebalanced so cycle time = takt time.

TPS

Basic ideas

Autonomation

- Not automation.
- “The autonomous check of the abnormal in a process.”
- Built-in mechanism to prevent production of defective products.

Basic ideas

TPS

Autonomation

- If a machine produces a defect, it stops the whole line.
- For manual operations, workers can stop the entire line.
- *Pokayoke*: “foolproof” system for checking to prevent defects.

Basic ideas

TPS

Visible control system

- *Andon*: electric light board.
- Board is large and high and therefore visible from all points in factory.
- When a worker delays a job, he turns on a yellow light.
- When a worker stops a job, he turns on a red light.

TPS

Basic ideas

Improvement activities

- Worker suggestions via *Quality Control (QC) circle*.
- This provides good ideas, and workers become more part of the team.

Kanban

- Kanban is *not* TPS. Kanban is a subsystem of TPS.
- Information flow system.
- Low level shop floor control.

Kanban

- In ordinary production control systems, schedules are issued to all processes (*push*).
- It is difficult to adapt to demand fluctuations, disruptions, etc.
- Therefore, the company must hold inventory.

Kanban

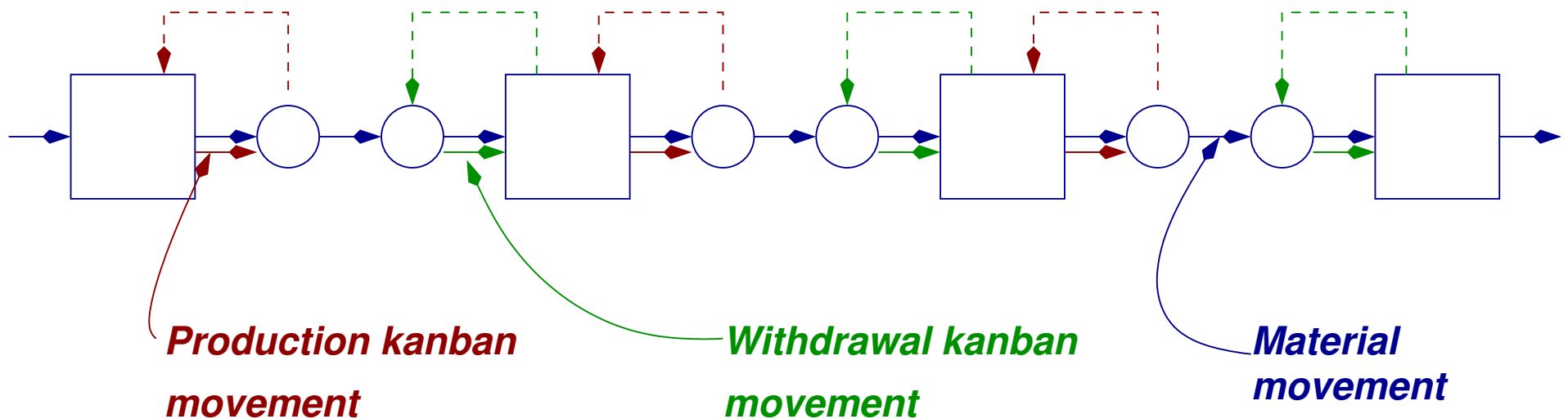
Pull

- Kanban is a *Pull system* .
- When scheduling changes occur, it is enough to notify final assembly.
- All preceding stages learn about changes through the kanban system.

Two cards

Kanban

Simplified flow

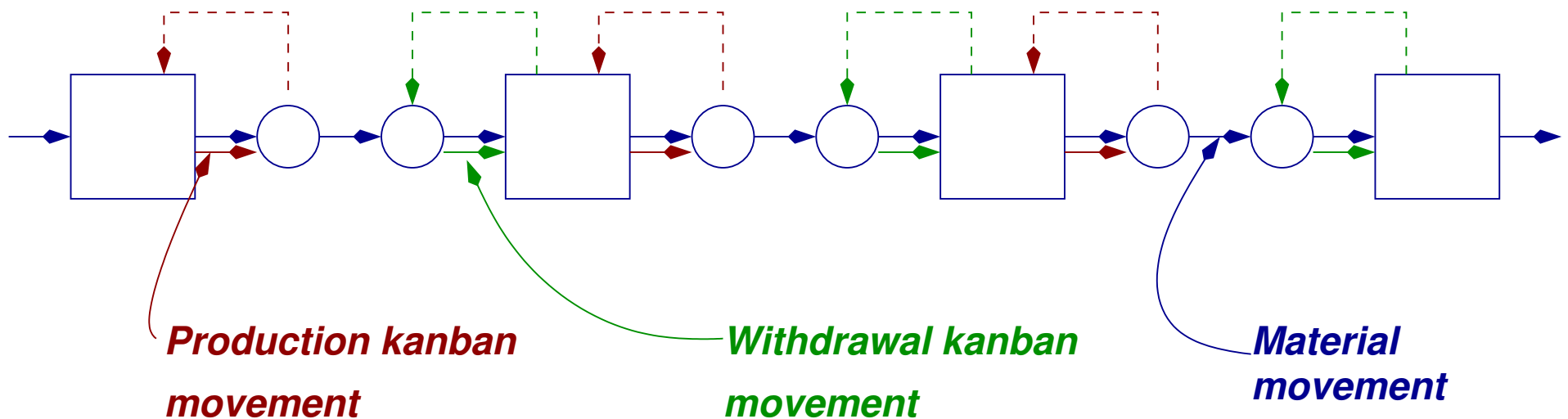


- When a machine is available, and it has a production kanban, a part and a withdrawal kanban move from upstream buffer to machine.

Two cards

Kanban

Simplified flow

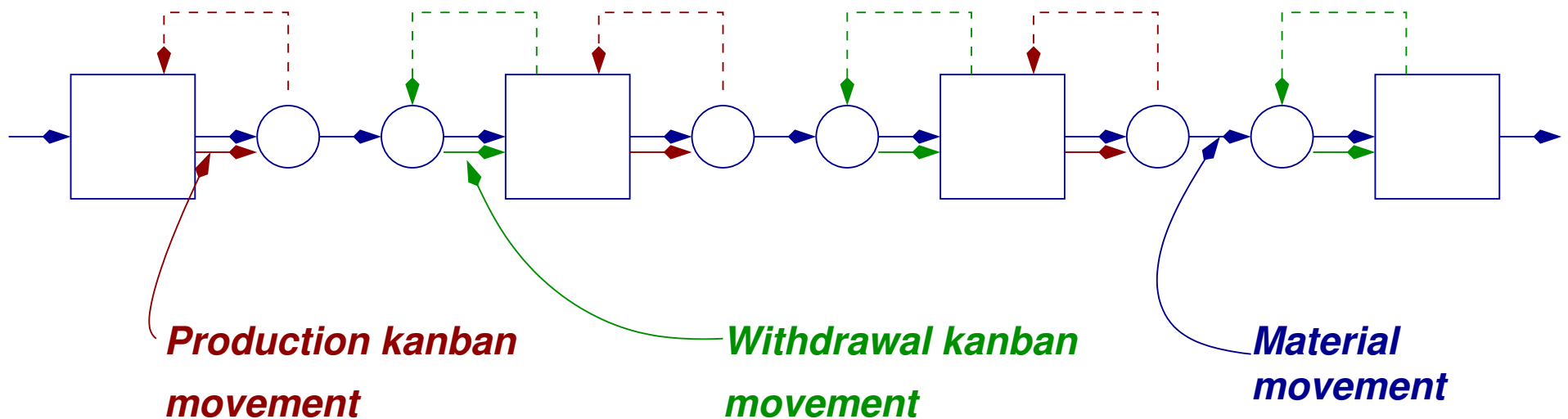


- After the operation, the withdrawal kanban returns to the upstream buffer, and a part and a production kanban move to the downstream buffer.

Two cards

Kanban

Simplified flow

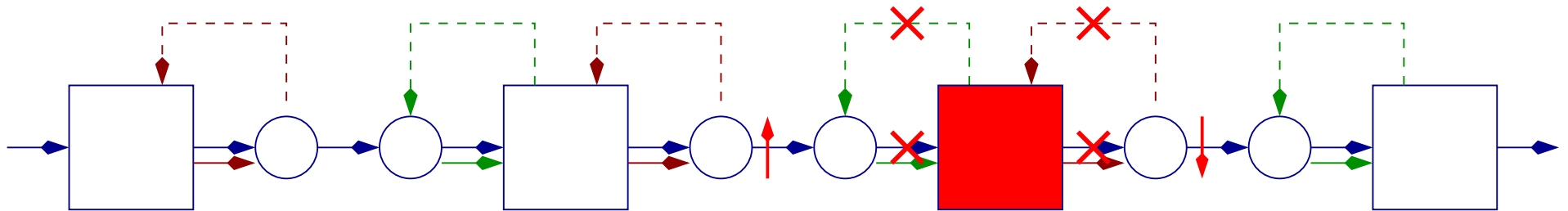


- When a buffer has a free withdrawal kanban, a part moves to it from the upstream buffer, and a production kanban moves to the machine.

Two cards

Kanban

Simplified flow



- The number of each kind of kanban is fixed at each stage.
- If a machine fails, the next machine can keep operating

Kanban

Two cards

Simplified flow

- Each box in this picture can represent a sub-process, consisting of several machines, rather than just a single machine.
 - ★ It could be an entire factory.
- Therefore, flow into and out of a box need not be the same, at each time instant.
- Actual movement of kanbans can be more complex.

Two cards

Withdrawal kanban

Kanban

Store

Shelf No. **5E215** Item Back No. **A2-15**

Item No. **35670S07**

Item Name **DRIVE PINION**

Car Type **SX50BC**

| Box Capacity | Box Type | Issued No. |
|--------------|----------|------------|
| 20 | B | 4/8 |

Preceding Process

FORGING

B-2

Subsequent Process

MACHINING

M-6

Two cards

Kanban

Production-ordering kanban

| | |
|---|--|
| Store Shelf No. <u>F26-18</u> Item Back No. <u>A5-34</u> | Process <u>MACHINING</u> <u>SB-8</u> |
| Item No. <u>56790-321</u> | |
| Item Name <u>CRANK SHAFT</u> | |
| Car Type <u>SX50BC-150</u> | |

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Kanban

- *Supplier kanban*: same as withdrawal, except for external supplier
- *Signal kanban*: same as production kanban, but sent to production station when inventory goes down to a reorder point.
- *Material requisition kanban*: same as production kanban, but sent to a material storage area when local inventory goes down to a reorder point.
- ... and more.

Kanban

Rules

1. Each process withdraws the *necessary* products from the previous in *necessary* quantities at the *necessary* time.
 - To enforce this, workers must first be won over.
 - Kanbans must be attached to the product.

Kanban

Rules

2. Each process produces only what is withdrawn by subsequent process.
3. Defective products are never moved to next process.
4. The number of kanbans should be minimized.
5. The kanban system should be used to adapt to small fluctuations in demand.

Smoothing Production Quantities

Total Production

- Minimize the variance of total output in a period.
 - ★ Produce the same amount every day.
- 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.

Smoothing Production Quantities

Total Production

Waste Reduction

- System must be set up for peak demand in a period. When demand is less than the peak, capacity is wasted.
- When production is not smoothed, inventory accumulates between stages.

Smoothing Production Quantities

Total Production

Adaptation to 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.

Smoothing Production Quantities

Total Production

Each Model's Production

- Mix models to minimize inventory.
- Mix models to maximize utilization. *Example:*
 - ★ *A* parts require 70 minutes in a line; *B* parts require 60 minutes; *C* parts require 50 minutes.
 - ★ If they are produced *AAAA...BBBB...CCCC...*, the production rate of the line changes over time ($1/70$; $1/60$; $1/50$).
 - ★ If they are produced *ABCABCABCABC...*, the production rate is constant ($3/180$).

Smoothing Production Quantities

Comparison with MRP

- MRP: more data handling.
- MRP: usually weekly time buckets.
- Kanban designed to absorb fluctuations; MRP must recalculate master production schedule weekly.
- MRP may be better with very short production runs, where smoothing is difficult.

5S

- Seiri: throw out what you don't need.
- Seiton: lay out things neatly.
- Seiso: clean up
- Seiketsu: standardize above activities.
- Shitsuke: inspire workers, and have them make conforming to rules a habit.

TPS

Toyota's Notion of the Ideal*

A common vision

The output of an *ideal* person, group of people, or machine:

- is defect free (features, performance the customer expects);
- can be delivered one request at a time (a batch size of one);
- 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.

* *Spear and Bowen*

TPS

- This has been a *very* brief overview.
- TPS has been extremely successful.
- TPS has been extremely influential.

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2.854 / 2.853 Introduction To Manufacturing Systems
Fall 2016

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