Toyota Production System
(Textbook)

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1. The Concept of the Toyota Production System

1.1 The Importance of Cost Reduction

(1) The necessity of cost reduction

- It is important to earn a profit, perpetually prosper, and strive to improve our daily lives while also nurturing harmony with society. Cost reduction is promoted in order to achieve these objectives.

(2) Selling price and cost

\[
\text{Selling price} = \text{cost} + \text{profit} \quad \text{Demand > Supply} \quad \text{In this case, cost basis is acceptable (Seller’s market)}
\]

\[
\text{Profit} = \text{selling price} - \text{cost} \quad \text{Demand < Supply} \quad \text{Cost reduction is necessary (Buyer’s market)}
\]

- Raise the selling price … The selling price is determined by the actual conditions in the market
  Market competition is severe and this is often difficult

- Lower the cost … Cost reduction increases the profit greatly
  It is possible to reduce the cost through effort
1.2 The Basic Concepts of the Toyota Production System

“Thoroughly eliminate muda (waste) and make things with efficient just-in-time production”

(1) The aims of the Toyota Production System

[1] Thoroughly eliminate muda and strive to reduce the cost of production

[2] Make it easy to ensure and guarantee manufacturing quality

[3] Create a workplace in which all members can fully exercise their capabilities, and which is founded on respect for humanity, trust, and mutual support

[4] Create genba (work sites) that are able to respond quickly and flexibly to the changes in the fluid marketplace

(2) The way of making things and cost

- Cost is controlled by the way that things are made and the way that the work is performed. The technology of the way of making things is called manufacturing technology

Cost basis cannot be applied
The selling price is determined by the actual conditions in the market
If profits are not increased, then corporate activity will not be viable

- Investigate the way of making things from a variety of different angles, thoroughly eliminate muda, and reduce the cost of production
1.3 Awareness of *Muda* (Waste)

*Muda* is “an element of production that only increases cost”.

(1) Movement and work

\[
\text{Work} = \text{shigoto} + \text{muda}
\]

*Shigoto* (value-adding work) is any process that increases the added value

*Muda* is any process that does not increase the added value

(2) *Shigoto* and *muda*

If the movements performed during operations are closely observed when work is being carried out as part of production activities, then it is possible to divide operations largely into 3 categories

- *Muda*
- Incidental work
- Net work

(3) Production lead time

Production lead time = processing time + waiting time

This does not add any value to the item being produced. The items are in a state of waiting (in inventory), being conveyed, or being inspected

This increases the value added to the item through cutting, assembly, changing the shape, or changing the quality

Processing time : waiting time = 1 : 100 to 200 (in severe cases)

By making the effort to shorten the waiting time, various types of *muda* will become obvious.
(4) *Shigoto* done by people and *shigoto* done by machines

- *Kaizen* (continuous improvement) of work and *kaizen* of equipment

By conducting *kaizen* as shown below, it becomes possible to do another item of work during the time of waiting.

<table>
<thead>
<tr>
<th>Present conditions</th>
<th>Set</th>
<th>Hold (waiting)</th>
<th>Set</th>
<th>Hold (waiting)</th>
<th>Set</th>
<th>Hold (waiting)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spot welding</td>
<td></td>
<td>Spot welding</td>
<td></td>
<td>Spot welding</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>After <em>kaizen</em></th>
<th>Set</th>
<th>Set</th>
<th>Set</th>
<th>Set</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spot welding</td>
<td>Spot welding</td>
<td>Spot welding</td>
<td></td>
</tr>
</tbody>
</table>
1.4 The Types of Muda (Waste)

(1) The types of muda

- Muda of overproduction
  - [1] Consumption of materials and parts
- Muda of inventory
  - [2] Wasted energy from electricity, air, and oil, etc.
- Muda of waiting
  - [3] Increase in the number of pallets and boxes, etc.
- Muda in motion
  - [4] Increase in conveyance vehicles and lifting machines
- Muda in conveyance
  - [5] Establishment of new storage areas and warehouses
- Muda of correction
  - [6] Increase in machines and man-hours to manage inventory
- Muda in processing itself
  - [7] Other

(2) Muda created by overproduction

- Problematic points in the production process and muda become hidden
- By eliminating muda due to overproduction, the problematic points and muda become obvious
- The muda from overproduction creates all the other types of muda and has a large influence on corporate efficiency

(3) The reasons that overproduction occurs

[1] Abnormalities such as breakdowns of machinery, defects, absence of operators, and other changes, etc.
[2] There are many operators
  - Safeguards for “just in case something happens,” a proper operational balance is not being maintained
  - The relationship with the company is thought of as contractual
[3] Variations in the amount of load
[4] Production is poorly structured
  - Way of combining processes and lot production
[5] Increases in mistaken rates of operation and increases in apparent efficiencies
[6] Thinking that it is wrong to stop the production line
1.5 Efficiency and Corporate Efficiency

(1) Efficiency and corporate efficiency

Efficiency and corporate efficiency are different. Even if efficiency is improved, corporate efficiency cannot be allowed to decrease. Production of the required number of units is the main prerequisite for improving corporate efficiency.

- Improving efficiency will have meaning for the first time when it is tied to cost reduction
- In order for this to be achieved, it is necessary to promote the concept of producing the necessary items with the fewest people possible

(2) True efficiency and apparent efficiency

Improvement of apparent efficiency will not lead to cost reduction
Improvement of efficiency becomes useful when it is tied to cost reduction

<table>
<thead>
<tr>
<th>Efficiency Type</th>
<th>Normal: 100 units made by 10 people</th>
<th>Kaizen: 120 units made by 10 people</th>
<th>20% improvement in efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement of apparent efficiency</td>
<td>Normal: 100 units made by 10 people</td>
<td>Kaizen: 100 units made by 8 people</td>
<td>20% improvement in efficiency</td>
</tr>
</tbody>
</table>

(3) Rate of operation and operational availability

The rate of operation is the time that is worked in order to produce the required number of units and this rate increases and decreases with the amount of production.

The operational availability refers to the facilities and machines that are able to operate at the necessary time. The target is to achieve an operational availability that is always 100%.

However, it is a mistake to think that when the machinery is stopped that this causes the rate of operation to decline and generates a loss. Demand should be directly connected to the rate of operation. It is not the correct choice to improve the rate of operation in a situation where, even when products are produced, they cannot be sold.
1.6 The Two Pillars of the Toyota Production System

(1) The two pillars of the Toyota Production System

Just-in-time: production (conveyance) of only what is needed, when it is needed, and in the amount that is needed

*Jidoka* (automation with a human touch): defective parts are not allowed to flow on to the subsequent process

(2) The concept and principle of just-in-time production

Just-in-time means that what is produced (conveyed) is only what is needed, when it is needed, and in the amount that is needed. By applying this method, *muda* can be eliminated from the *genba* (worksite) and the work done by the operators can be concentrated.

![Diagram showing the two pillars of the Toyota Production System and their related concepts](image-url)
2. Just-in-Time

2.1 Heijunka (Leveled Production)

(1) What is heijunka?

*Heijunka* is a technique in which parts are produced after first leveling or making constant all the factors related to the amount of production, the types of parts produced, and the time it takes to produce them.

The more fluctuation there is in production, the more difficult it becomes to carry out just-in-time and the more muda that is generated (batch production).
(2) *Heijunka* and batch production

<table>
<thead>
<tr>
<th>Vehicle model</th>
<th>Amount produced</th>
<th>Amount produced per work shift</th>
<th>Takt time</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle A</td>
<td>9,600 vehicles</td>
<td>240 vehicles</td>
<td>2 minutes</td>
<td></td>
</tr>
<tr>
<td>Vehicle B</td>
<td>4,800 vehicles</td>
<td>120 vehicles</td>
<td>4 minutes</td>
<td>ρ</td>
</tr>
<tr>
<td>Vehicle C</td>
<td>2,400 vehicles</td>
<td>60 vehicles</td>
<td>8 minutes</td>
<td>ρ</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>16,800 vehicles</td>
<td>420 vehicles</td>
<td>1.1 minutes</td>
<td></td>
</tr>
</tbody>
</table>

(Batch production)

(Heijunka)
2.2 Basic Principles of Just-in-Time

Production (conveyance) of only what is needed, when it is needed, and in the amount that is needed

(1) The production line takt time is determined by the required number of units

- The required parts are produced at the required speed and only in the required amount
- The required number of parts to be produced will change according to demand
- Production shall be tied to demand

(2) Pull system

- The production plan is indicated to the final process. In the production line, the subsequent processes go to the preceding process and pull only the amount of parts that they will use. The preceding processes then produce only the amount of parts that were pulled.

(3) Continuous flow processing

- The processes are collected together so that each individual piece proceeds from one process to the subsequent process in a continuous flow.

- This is the same for a process composed of many operators as it is for a process run by 1 operator.

Conditions of continuous flow production:

- Equipment is lined up in the process order
- Pieces flow down the line one by one
- The processes are synchronized

\[\{\begin{align*}
\text{The operator shall handle multiple processes} \\
\text{Multi-skill development of operators} \\
\text{Work is performed while standing}
\end{align*}\]

Multi-process handling and a slim, fast flow:

- If one operator works at a single machine, then there are many in-progress parts in between the processes, there is a lot of in-process stock, and the lead time becomes long.

- By using single-piece flow with multi-process handling, the progress of the parts is fast and the lead time becomes shorter.
2.3 *Jidoka* (Automation with a Human Touch)

(1) The difference between *jidoka* and automation

<table>
<thead>
<tr>
<th>Jidoka</th>
<th>Automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manpower saving</td>
<td>Labor saving</td>
</tr>
<tr>
<td>If an abnormality occurs, the machine will make a judgment and stop itself</td>
<td>The line and machines continue to move so long as no one throws a switch</td>
</tr>
<tr>
<td>No defects are produced</td>
<td>There are many defects</td>
</tr>
<tr>
<td>Machines, molds, and jigs do not break</td>
<td>There are many breakdowns</td>
</tr>
<tr>
<td>Problems are clearly visible</td>
<td>There are many problems and it is difficult to find the causes</td>
</tr>
<tr>
<td>It is possible to prevent recurrence of problems</td>
<td>Extra operators are used to handle the problems, so it takes more time to prevent recurrence</td>
</tr>
</tbody>
</table>

- The automatic loom created by Sakichi Toyoda some 70 to 80 years ago would automatically and immediately stop itself if even one of the thousands of warp threads broke or ran out.

(2) Another kind of *jidoka*

- The *jidoka* that is utilized on the production line

  (a) If work cannot be performed according to the standardized work, then the call button is pressed and the production line is stopped.
  (b) The line stoppage is indicated by an *andon* (signboard) and this leads to *kaizen* of the problem.
  (c) *Kaizen* is carried out and if this solves the problem, then the solution is later incorporated into the standardized work.
2.4 Means of Assisting *Jidoka*

(1) *Poka-yoke* (fool-proofing)

- This refers to production in which defective parts are not produced. The *poka-yoke* mechanisms build in quality during the production processes and do not allow defective parts to be sent on to the subsequent process. Consequently, work mistakes, injuries, defects, and many other problems are naturally eliminated without having to pay close attention to each issue individually.

(2) Fixed-position stop system

- If an operator feels that they have fallen behind in their work for any reason and they send a line stop signal, the production line will always stop in the same place.

(3) Visual controls (*andon*)

- It is important to immediately alert someone if a problem occurs during work. The *andon* system is a management tool that allows the line managers and supervisors to understand the content of a problem that they want to know about.
2.5 Kanban (Signaling System Using Signs)

(1) The role of kanban: To prevent overproduction muda

1. Production and conveyance instruction information
   - On the kanban the part name, amount to be produced (time), sequence, and destination that it will be conveyed to are all written down. Therefore, it is easy to understand what to produce, how much of it to produce, by when it should be produced, and then where it should be conveyed to.

2. Visual controls
   
   a. Inhibiting overproduction
      It is not possible to produce an excess amount
      The order of production priority is understood
   
   b. Detecting the progress or delay of a process
      The process can be controlled easily
      - Strict compliance with standardized work
      - Grasp the ability to build in quality in your process
      - Status of inventory in your process
      - State of progress of the subsequent process
      - Urgency of the subsequent process
      - Order of priority for the work in your process

3. A tool for process kaizen and work kaizen
   - Hidden problems are identified by reducing the number of kanban

(2) Types of kanban

- Production instruction kanban
- Pick-up kanban
- In-process kanban (used in continuous flow production)
- Signal kanban (used in lot production)
- Inter-process pick-up kanban
- Supplier kanban
Production instruction *kanban*:

In-process *kanban* (1 *kanban* for 1 part)

<table>
<thead>
<tr>
<th>Process name</th>
<th>Production instruction <em>kanban</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>SD code</td>
<td>Part No. &amp; part name</td>
</tr>
<tr>
<td></td>
<td>Number of <em>kanban</em> cards issued</td>
</tr>
<tr>
<td></td>
<td>Name of subsequent process</td>
</tr>
<tr>
<td></td>
<td>Amount to produce</td>
</tr>
<tr>
<td></td>
<td>Container</td>
</tr>
<tr>
<td></td>
<td>Storage area for finished parts</td>
</tr>
</tbody>
</table>

This *kanban* is used on exclusive lines, such as for the assembly process, or production lines with essentially no set-up, even if they produce multiple parts.

Signal *kanban* (lot)

<table>
<thead>
<tr>
<th>Line Storage area</th>
<th>Part No. Part name</th>
<th>Storage area for finished parts</th>
<th>Storage area for materials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lot size (Amount to produce)</td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Container</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Name of subsequent process</td>
<td>Standard number</td>
</tr>
</tbody>
</table>

This *kanban* is used for lot production that requires a little time to set up, such as the press and die-casting processes.
Pick-up *kanban*:

**Inter-process pick-up kanban**

<table>
<thead>
<tr>
<th>SD code (identification number)</th>
<th>Part No. &amp; part name</th>
<th>Number of <em>kanban</em> cards issued</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Container</td>
</tr>
<tr>
<td>Preceding process storage area</td>
<td>Subsequent process storage area</td>
<td>Capacity</td>
</tr>
</tbody>
</table>

At the assembly line, parts from many different preceding processes, such as machining, pressing, painting, plating, and resin molding, must be collected together. This *kanban* is used to collect these parts.

**Supplier kanban**

<table>
<thead>
<tr>
<th>Name of manufacturer</th>
<th>Type of packaging</th>
<th>Delivery cycle</th>
<th>Delivery time</th>
<th>Line storage area</th>
<th>Number of <em>kanban</em> cards issued</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SD code (identification number)</td>
</tr>
<tr>
<td>Manufacturer No.</td>
<td>Part No. &amp; part name</td>
<td></td>
<td></td>
<td></td>
<td>Receiving area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Receiving entry</td>
</tr>
</tbody>
</table>

This is the same concept as the inter-process pick-up *kanban*, but this *kanban* is used in the case where the preceding process is supplier.
2.6 Kanban Rules

(1) Rules for production instruction *kanban*

[1] Parts are produced only in the amount of *kanban* that have been withdrawn and in the same order that the *kanban* were withdrawn.
[2] The part and its corresponding *kanban* must always flow down the line together.
[3] Parts that do not have a *kanban* are absolutely never produced.

(2) Rules for pick-up *kanban*

[1] If you are the first person to place your hands on the first of the parts containers, withdraw the *kanban*.
[2] Take the *kanban* that was withdrawn to the preceding process to pull the necessary part.
[3] At the store where you pull the part, replace the in-process *kanban* with the *kanban* you brought with you.
[4] Parts that do not have a *kanban* are absolutely never conveyed.

(3) Additional points to pay attention to when operating a *kanban* system

[1] The size of the lots assigned to a single *kanban* shall be as small as possible.
[2] The necessary number of *kanban* cards shall never exceed what is required.
[3] *Kanban* shall be put out as diligently as possible and also collected as diligently as possible.
[4] Consider 100% as non-defective parts
How *Kanban* Circulate

(1) Leave in the specified place
(2) Take the pick-up *kanban* and go to pull the part
(3) Replace the production instruction *kanban* with the pick-up *kanban*
(4) Convey

(1) to (4) is the flow of a pick-up *kanban*
[1] to [3] is the flow of a production instruction *kanban*

[1] The production *kanban* is withdrawn
[2] It becomes a production instruction
[3] The production *kanban* flows along with the part
(4) Delivery cycle

What is the delivery cycle?

<table>
<thead>
<tr>
<th></th>
<th>(X)</th>
<th>(Y)</th>
<th>(Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

On what day should delivery occur?

When it is a “2” … Once every 2 days
When it is a “3” … Once every 3 days

When you bring the kanban back, to which time should the delivery be made?

How many times per day should delivery occur?

Reference:

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 1 - 1</td>
<td>○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 2 - 1</td>
<td>① ○ → ○ → ○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>② ○ → ○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 2 - 2</td>
<td>① ○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>② ○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 4 - 2</td>
<td>① ○ → ○ → ○ → ○ → ○ → ○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>② ○ → ○ → ○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>③ ○ → ○ → ○ → ○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>④ ○ → ○ → ○ → ○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 - 1 - 1</td>
<td>○ → ○ → ○ → ○ →</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

20
(5) Number of rotating *kanban* cards

[1] Rotation of *kanban*  
Example: Delivery cycle 1-4-2

**In-house inventory**

- Inventory
- Number of goods received per 1 delivery
- Minimum inventory
- The inventory is at maximum immediately after receipt of goods

**Rotation of *kanban***

- (N-1) days
- N days
- I: Amount received on delivery (1)
- II: Amount taken back
- III: *Kanban* at the manufacturer, brought back by previous delivery (delivery (4) of previous day)

The *kanban* rotates in the group (delay factor 1)

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I: Amount received on delivery (1)</td>
<td>II: Amount taken back</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III: <em>Kanban</em> at the manufacturer, brought back by previous delivery (delivery (4) of previous day)</td>
<td>The <em>kanban</em> rotates in the group (delay factor 1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(2) Calculation step for the number of rotating kanban cards

Example: Find the number of rotating kanban cards (safety value is 0.2 per day) if a parts container holds 10 parts and 120 parts are used in 1 day.

In the case of a 1-4-2 delivery cycle:

\[ \downarrow \downarrow \downarrow \]
\[ x \quad y \quad z \]

a) The number of kanban cards used in 1 day:
   Number of parts used per day / number of parts per container = 120/10 = 12 kanban cards per day \( \Rightarrow A \)

b) The number of goods received per 1 delivery:
   \( A/y = 12/4 = 3 \) kanban cards per 1 delivery \( \Rightarrow B \)

c) Kanban group: \( (z + 1) \times B = (2 + 1) \times 3 = 9 \) kanban cards \( \Rightarrow C \)

d) Safety inventory: \( A \times 0.2 = 2.4 \rightarrow 3 \) kanban cards (currently this is rounded up) \( \Rightarrow D \)

e) Number of rotating kanban cards: \( C + D = 9 + 3 = 12 \) cards

f) (Reference) Maximum and minimum inventory: Maximum inventory is \( B + D = 3 + 3 = 6 \)
   Minimum inventory is \( D = 3 \)

(3) Equation

\[
\text{Number of rotating kanban cards} = \frac{\{\text{Number of parts used per day} \times x\}}{y} \times \left\{\frac{z+1}{y} + \text{Safety value}\right\} \frac{\text{Number of parts per container}}{}
\]
Example calculation of the number of rotating *kanban* cards:

- Delivery cycle : 1-4-2
- Necessary number of parts per work shift : 320/shift
- Number of parts per container : 20/container
- Safety factor : 0.2 per day

What is the number of rotating *kanban* cards?
2.7 Conveyance

(1) Inter-process conveyance

- In order to realize just-in-time production, it is necessary to convey the parts in a timely manner between production processes that are separated so that production can be carried out smoothly.

(2) Conditions of inter-process conveyance

[1] Collection of information a little at a time : frequent conveyance
[2] Pulling of different parts in a variety of small amounts : mixed-load conveyance
[3] Pulling from line-side part storage areas : frequent conveyance and direct conveyance

(3) Inter-process conveyance methods

(a) Conveyance of fixed amounts at irregular times
   In this method, at the time that the subsequent process has used up a fixed amount of parts they then go to the preceding process to pull more parts and the amount of parts that are consumed is standardized.

(b) Conveyance of irregular amounts at fixed times
   The concept is the same as for conveyance of fixed amounts at irregular times. This is a conveyance method used to standardize the elapsed time.
3. Standardized Work

3.1 Standardized Work

(1) What is standardized work?
- In the Toyota Production System this is the foundation of the way that parts are produced, _kaizen_, and the way the system is managed, etc.
- Standardized work is a means of determining the way that _shigoto_ (value-adding work) shall be performed so that high quality products can be produced safely and inexpensively.

(2) Conditions of standardized work

[1] Centered on the movements of people
[2] Repetitive work

(3) The 3 elements of standardized work

| 1. Takt time |
| - This is the amount of time in which 1 vehicle or 1 part must be produced |

| 2. Working sequence |
| - In the case where parts are processed or assembled, this is the sequence of operations that an operator performs, such as conveying parts, placing parts in machines, and removing parts from machines, in order to assemble a part. |

| 3. Standard in-process stock |
| - This is the minimum necessary amount of work pieces so that the operator can perform the same operation repetitively in the same order each time. |
3.2 Principle of Standardized In-process Stock

<table>
<thead>
<tr>
<th>Process sequence (Flow of pieces)</th>
<th>(a) Work in forward direction</th>
<th>0 piece</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b) Work in reverse direction</td>
<td>1 piece</td>
<td></td>
</tr>
<tr>
<td>Automatic feeding by machine</td>
<td>(c) Yes, automatic feeding</td>
<td>1 piece</td>
</tr>
<tr>
<td></td>
<td>(d) No, manual labor</td>
<td>0 piece</td>
</tr>
</tbody>
</table>

(1) Standardized in-process stock according to combination of conditions

<table>
<thead>
<tr>
<th>A</th>
<th>(a)+(c) Process sequence, work in forward direction</th>
<th>0 piece</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>When there is automatic feeding by machine</td>
<td>1 piece</td>
</tr>
<tr>
<td>B</td>
<td>(a)+(d) Process sequence, work in forward direction</td>
<td>0 piece</td>
</tr>
<tr>
<td></td>
<td>When there is not automatic feeding by machine</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>(b)+(c) Process sequence, work in reverse direction</td>
<td>2 piece</td>
</tr>
<tr>
<td></td>
<td>When there is automatic feeding by machine</td>
<td>1 piece</td>
</tr>
<tr>
<td>D</td>
<td>(b)+(d) Process sequence, work in reverse direction</td>
<td>1 piece</td>
</tr>
<tr>
<td></td>
<td>When there is not automatic feeding by machine</td>
<td></td>
</tr>
</tbody>
</table>

(2) Example of the number of standardized in-process stock within a process

![Diagram of process sequence](image)
3.3 Standardized Work and *Kaizen* (Continuous Improvement)

“There is no *kaizen* (continuous improvement) in places where there is no standardization”

- “Superficial” standardized work (before *kaizen*) shows the current situation as it appears on the surface.
- Standardized work reflects *kaizen* and the supervisor integrates their own will into the work, turning it from “superficial” into true standardized work.

(1) *Kaizen* based on standardized work

   [1] Reduction of man-hours
   [3] Reduction of quality defects
   [5] Layout (organization)

(2) Standardized work and work standards

- Work standards are those things that are standardized, such as the way that work is performed and machines are operated, in order to carry out standardized work. The work procedure sheet is a representative example of a work standard.
3.4 Main Points for Creating Standardized Work

Standardized work is established by determining the following:

1. Takt time
2. Work standards
3. Standardized in-process stock

Procedure 1: Creation of Process Capacity Sheet

(1) Process sequence: the number in the sequence of the processing process
(2) Process name: Enter the name of the process where the part receives processing
   (a) When there are 2 or more machines in the same process that perform the processing, they shall be entered separately.
   (b) In the case where 1 machine takes 2 parts or 3 parts, this should also be entered.
   (c) Work that is conducted regularly with a certain frequency, such as sweeping away grinding swarf and quality checks, for example, shall also be entered along with their frequency.
(3) Machine No.: Enter the machine number
(4) Basic time
   (a) Manual labor time: The amount of time the operator spends performing manual labor at the machine (process) shall be measured and entered. This does not include walking time.
   (b) Automatic feeding time: The amount of time required for the machine to perform processing on the work piece shall be measured and entered.
   (c) Completion time: The amount of time necessary for a machine (process) to complete 1 part (or 2 parts in the case where 2 parts are taken). In general:
      Completion time = manual labor time + automatic feeding time
      Note 1: In the case of work that is conducted with a certain frequency, the manual labor time per work piece shall be entered.
(5) Cutting tools
   (a) Number of cutting tools replaced: Enter for each cutting tool and grinding stone
   (b) Cutting tool replacement time: Enter for each cutting tool and grinding stone
(6) Processing capacity: Number of parts that can be processed within the fixed time of 1 shift

<table>
<thead>
<tr>
<th>Processing capacity =</th>
<th>Operation time of a work shift</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Completion time per work piece + cutting tool replacement time per work piece</td>
</tr>
</tbody>
</table>

Note 2: Anything after the decimal point is ignored. When the machine is different, write it separately
<table>
<thead>
<tr>
<th>Process sequence</th>
<th>Process name</th>
<th>Machine No.</th>
<th>Manual labor time</th>
<th>Automatic feeding time</th>
<th>Completion time</th>
<th>Cutting tools</th>
<th>Processing capacity</th>
<th>Remarks</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Booster attachment, surface milling</td>
<td>Mi 1764</td>
<td>3 minutes</td>
<td>25 seconds</td>
<td>28 minutes</td>
<td>100</td>
<td>1 minute</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Booster hole, boring</td>
<td>Dr 2424</td>
<td>3 minutes</td>
<td>21 seconds</td>
<td>24 minutes</td>
<td>1000</td>
<td>30 seconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Booster hole, tapping</td>
<td>Tp 1101</td>
<td>3 minutes</td>
<td>11 seconds</td>
<td>14 minutes</td>
<td>1000</td>
<td>30 seconds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Quality check (1/1) (Measure the screw diameter)</td>
<td>—</td>
<td>5 minutes</td>
<td>—</td>
<td>5 minutes</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total 14

Operation time: 7 hours and 50 minutes (470 minutes) / work shift
## Example of a Process Capacity Sheet

<table>
<thead>
<tr>
<th>Process sequence</th>
<th>Process name</th>
<th>Basic time</th>
<th>Cutting tools</th>
<th>Processing capacity (966)</th>
<th>Remarks</th>
<th>Illustration</th>
<th>Replacement time per part</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Manual labor time</td>
<td>Automatic feeding time</td>
<td>Completion time</td>
<td>Number replaced</td>
<td>Replacement time</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>minutes seconds</td>
<td>minutes seconds</td>
<td>minutes seconds</td>
<td></td>
<td>minutes seconds</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Booster attachment, surface milling</td>
<td>3</td>
<td>25</td>
<td>28</td>
<td>100</td>
<td>1 minute</td>
<td>966</td>
</tr>
<tr>
<td>2</td>
<td>Booster hole, boring</td>
<td>3</td>
<td>21</td>
<td>24</td>
<td>1000</td>
<td>30 seconds</td>
<td>1173</td>
</tr>
<tr>
<td>3</td>
<td>Booster hole, tapping</td>
<td>3</td>
<td>11</td>
<td>14</td>
<td>1000</td>
<td>30 seconds</td>
<td>2009</td>
</tr>
<tr>
<td>4</td>
<td>Quality check (1/1) (Measure the screw diameter)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5640</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 14

Operation time: 7 hours and 50 minutes (470 minutes) / work shift
Procedure 2: Creation of Standardized Work Combination Table

(1) Work sequence: The sequence in which work is performed is indicated by numbers (1, 2, 3…)
(2) Name of work: The machine No. and content of manual labor is indicated
(3) Time: Enter the manual labor time and automatic feeding time from the Process Capacity Sheet
(4) Work time: 
- solid line: manual labor time
- dotted line: automatic feeding time
- wavy line: walking time
(5) Takt time

\[
\text{Takt time} = \frac{\text{Operation time of a work shift}}{\text{Required number of units per work shift}}
\]

Procedure for creating the Standardized Work Combination Table

(1) Draw a red line for the takt time on the time axis of the work time
(2) Determine the extent of the process per person
   Use the Process Capacity Sheet to obtain a total work time that is almost equal to the takt time indicated by the red line. Then determine the process that is nearly per person. In addition, the walking time will also be added, so a certain amount of time shall be estimated.
(3) Enter a summary description of each kind of manual labor on one line each in the “Name of work” column.
(4) Enter each amount of time in the time column.
(5) Determine the first kind of work in the sequence and then draw in the manual labor time and automatic feeding time on the time axis.
   In the case where the automatic feeding time exceeds the takt time, draw in the amount of excess from the start position. In this case, the lines for the manual labor time and automatic feeding time shall not overlap with each other.
(6) Determine the second kind of work in the sequence
   Normally the work in the row below the first work will become the second in the sequence, but when the work changes and walking is required, this is indicated by a wavy line on the time axis.
- Repeat this process and determine the entire work sequence. However, in the case where there are 2 machines in the process, a machine takes 2 parts, or the machine is also part of another process, then it is necessary to think up a work sequence in which the operator will not have to wait during the automatic feeding time of the machine.

(7) Examine whether the work combination has been realized
In the case where the automatic feeding time exceeds the takt time, the amount of excess is redrawn from the starting point. However, if this line overlaps with the manual labor time in the same process, then this work combination is not compatible and it is necessary to select the work over again.

(8) Look at the relationship between the scheduled work and the takt time
When the scheduled work is completed, return to the first work row on the sheet. When walking time is necessary it shall be indicated by a wavy line.

(9) Look to see if the amount of work is appropriate
If the point of return in (8) above is in alignment with the red line (takt time) then it can be said that this is an appropriate combination of work. If the work is completed in front of the red line, then the amount of work is insufficient, and it shall be examined to see whether other work can be added to the combination or not. If the work time extends beyond the red line and this is left unaddressed, then the work will not be completed at the specified time and will result in overtime and a shortage of parts. In this case each kind of work in the combination shall be reviewed to see if it is possible to shorten the work time by the amount that it exceeds the takt time.

(10) Enter the work sequence
Once the work combination has been determined, enter the numbers in the work sequence column based on the lines drawn in the illustration.

| Obtain the takt time when the operation time of a work shift is 7 hours and 40 minutes and the required number of items to produce per shift is 920. |
### Standardized Work Combination Table

<table>
<thead>
<tr>
<th>Work sequence</th>
<th>Name of work</th>
<th>Time (manual labor)</th>
<th>Work time (10&quot;, 20&quot;, 30&quot;, 40&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Take the materials</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Remove the work piece, place it in the machine, and perform automatic feeding of Mi-1714</td>
<td>3 25 2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Remove the work piece, place it in the machine, and perform automatic feeding of Dr-2424</td>
<td>3 21 2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Remove the work piece, place it in the machine, and perform automatic feeding of Tp-1101</td>
<td>3 11 2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Measure the screw diameter</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Place the completed part in appropriate area</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Operation time of the work shift is 7 hours and 40 minutes
Procedure 3: Creation of Standardized Work Chart

(1) Description of work
Enter the first work and last work that are listed on the Standardized Work Combination Table.

(2) Work sequence
On the Machine Layout Diagram, enter the numbers according to the work sequence indicated on the Standardized Work Combination Table and then connect them with solid lines. Indicate the return trip from the last work to the first work with a dotted line.

(3) Work standards
- Quality check: Enter a diamond mark (◇) on the machines (processes) that require a quality check.
- Safety precautions: Enter a plus mark (+) on the machines (processes) that require safety precautions.
- Standard in-process stock: Any inventory that is absolutely necessary when performing work according to the work standards is called standard in-process stock. Enter a circle mark (●) on the machines (processes) where the stock is located.
- Takt time: Clearly specify the takt time that was calculated from the Standardized Work Combination Table.
- Net time: Enter the work time that results from performing the work according to the work standards.

Standardized Work Chart (Example)

<table>
<thead>
<tr>
<th>Description of work</th>
<th>From: take the materials</th>
<th>Until: place the completed part in appropriate area</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Quality check</th>
<th>Safety precautions</th>
<th>Standard in-process stock</th>
<th>Amount of stock</th>
<th>Takt time</th>
<th>Net time</th>
<th>Piece No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>◇</td>
<td>+</td>
<td>●</td>
<td>3</td>
<td>30&quot;</td>
<td>30&quot;</td>
<td>1/1</td>
</tr>
</tbody>
</table>
3.5 Elemental Work Analysis

(1) Elemental work analysis and analytic units

Think of each individual action used to operate something as 1 unit.
(The objective of an action, such as picking up or putting down a target object)

(2) Procedure for measuring time
(The observation point is the instant that the work is completed)
1. Look at the work sequence and memorize it
2. Enter work elements
3. Measure the time for 1 cycle
4. Measure the time for each elemental work
5. Combine the time for 1 cycle and the time for each elemental work
6. Measure any unmeasured elemental work
7. Measure any exceptional work
(3) Analytic units and observation points of elemental work

Analytic units of elemental work:
[1] Pick up the target object
[2] Carry out the objective of the action
[3] Put down the target object

Analytic units and observation points of elemental work:

<table>
<thead>
<tr>
<th>Element No.</th>
<th>Movement</th>
<th>Observation point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stand</td>
<td>Instant that you stood up from the chair</td>
</tr>
<tr>
<td></td>
<td>Walk</td>
<td>Instant that you reached the chalk board</td>
</tr>
<tr>
<td>2</td>
<td>Pick up a piece of chalk</td>
<td>Instant that you picked up the chalk</td>
</tr>
<tr>
<td></td>
<td>Write</td>
<td>Instant that you finished writing</td>
</tr>
<tr>
<td></td>
<td>Put the chalk down</td>
<td>Instant that you put the chalk down</td>
</tr>
<tr>
<td>3</td>
<td>Walk</td>
<td>Instant that you returned to the chair</td>
</tr>
<tr>
<td></td>
<td>Sit down</td>
<td>Instant that you sat down on the chair</td>
</tr>
<tr>
<td>4</td>
<td>Sit on the chair</td>
<td>Instant that you stand up from the chair</td>
</tr>
</tbody>
</table>
(4) **Main points of time measurement**

Procedure 1: Look at the work sequence and memorize it

```
1 2 3 4
```

Procedure 2: Enter the elemental work

```
1 2 3 4 5 6 7 8 9
```

Procedure 3: Measure the time for 1 cycle

```

```

Procedure 4: Measure the time for each elemental work

```
1 2 3 4 5 6 7 8 9
```

Procedure 5: Combine the time for 1 cycle and the time for each elemental work

```
1 2 3 4 5 7 8 9
```

Procedure 6: Measure any unmeasured elemental work

```
2 4 7 8 9
```

Procedure 7: Measure any exceptional work
3.6 Work Kaizen and Equipment Kaizen

Work kaizen refers to things such as, determining the work rules, reassigning the allotments, clearly specifying the arrangement and storage areas for items, and the kaizen of work movements, etc.

(1) The structure and equipment of production

The structure of production refers to the process of turning materials into completed products and includes such things as the manufacturing method and the procedures of shigoto (value-adding work), etc.

(2) Problem points of equipment kaizen

[1] Equipment kaizen is expensive
[2] Equipment kaizen cannot be redone from the start
[3] There is a strong possibility that equipment kaizen will fail at a genba (work site) where work kaizen has not progressed
3.7 Points of Focus in Work \textit{Kaizen}

The starting point is discovering the needs of \textit{kaizen}

\begin{quote}
\begin{tabular}{|p{15cm}|}
\hline
“Superficial” standardization $\rightarrow$ problems become obvious $\rightarrow$ \textit{kaizen} $\rightarrow$ standardization \\
\hline
\end{tabular}
\end{quote}

(1) Standardized work and \textit{kaizen} items

\begin{itemize}
\item [1] Reduction in number of man-hours
\item [2] Reduction of work-in-process inventory
\item [3] Reduction of quality defects
\item [4] Enhancement of production capacity
\item [5] Layout [method of combining processes]
\item [6] Visual controls
\end{itemize}
3.8 Principles of Motion Economy

(1) Principles for the use of the human body
   [1] The motions of both arms should be made simultaneously in opposite and symmetrical directions.
   [2] The portions of the body that move should be confined to the smallest portion possible.
   [3] It is preferable to use the hands and lower arms for light work than to use the upper arms and shoulders.
   [6] Select the sequence for the motions and establish a natural rhythm.
   [7] Reduce the need for attentiveness as much as possible and arrange work so that motions can be conducted without resistance.

(2) Principle for the arrangement of the workplace
   [1] There should be a fixed place for all tools and materials.
   [2] Tools and materials should be located close to and directly in front of the operator.
   [3] Items should be moved horizontally, while up and down movement should be avoided.
   [5] Materials and tools should be located in a place that promotes the best sequence of motions.
   [6] The height of the work bench should be suitable for the nature of the work and the height of the operator.
   [7] Adequate lighting and ventilation should be provided that is suitable for the nature of the work.

(3) Principles for the design of tools and instruments
   [1] Motions that require the materials and tools to be held in the hand[s] should be avoided as much as possible.
   [3] Two or more tools should be combined whenever possible.

---

Good range of motion

Preferable range of motion