Lecture No. 10:
Improvement Activities and IE (Industrial Engineering)

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Devices for Productivity Increase

(1) Labor Management Approach

(2) Engineering Approach

Proprietary technology
(mechanical engineering, chemical engineering, etc.)

IE = promotion of efficiency of overall production process
IE in Narrow Sense

Taylor’s time study, work measurement;
  Succeeded Gilbreth’s motion study, method study

Production equipments/machineries were (are) in a black box.

Detailed analysis check on human works.

“Production management department”
① Process Analysis (analysis on process flow chart: already described)

② Combination Work Analysis (linkage of person to machine, person to person, etc.)

③ Motion Study (factor work analysis, two-hand work analysis, delicate motion analysis, etc.)

④ Time Study (measurement of work time using stop watch)

⑤ Operation Analysis (classification of work time into main work, related work, leeway, etc.)
Bracket of Process/Work/Motion and IE Method

Process
- Vehicle assembly process
- Body welding process

Process analysis

Operation
- Steering installation work
- Door installation work

Combination-work analysis

Factor work
- Move to get tool
- Bolt with tool

Factor work analysis

Motion
- Find
- Choose
- Grab
- Empty-handed

Delicate motion analysis

Note: Signs of motion were devised by Gilbreth, and are called “server rig signs”
Process Analysis (1) Process Flow Diagram

- film material
  - quantity setting
  - throw-in & heating
  - extrusion
  - stretch
  - surface treatment
  - take-up
  - width cutting
  - measurement of thickness
  - take-up on paper core
  - external inspection
  - packaging
  - packing

Process flow diagram of film manufacturing process

(flow chart)
Process Analysis (2) Layout and Flow Diagram

Improvement of layout, and simplification of product’s flow line

Sewing factory flow diagram (Present method)

Sewing factory flow diagram (Improvement idea)

Hideo Kuwata 'Production Management Outline'
THE NIKKAN KOGYO SHIMBUN, LTD. 1998
Problem is that the fine spinning room and the winder room are way apart despite of a large number of flow lines between them. Improvement need
### Process Analysis (4) Manufacturing Route Chart

<table>
<thead>
<tr>
<th>Process</th>
<th>Press</th>
<th>Lathe turning</th>
<th>Perforate</th>
<th>Tap</th>
<th>Milling</th>
<th>Gear cutting</th>
<th>Total number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td>4</td>
<td>5</td>
<td>27</td>
</tr>
<tr>
<td>Gear wheel</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td>4</td>
<td></td>
<td>58</td>
</tr>
<tr>
<td>Pinion</td>
<td>1</td>
<td></td>
<td>2</td>
<td></td>
<td>3</td>
<td></td>
<td>56</td>
</tr>
<tr>
<td>Axle bearing</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

These should be closely situated.

Hideo Kuwata 'Production Management Outline'
THE NIKKAN KOGYO SHIMBUN, LTD. 1998
Combination Work Analysis

Shorten set up time

Invest in backup frame

Separate time for frame washing/drying from one for table halting

(shift from internal set-up to external set-up)

Hideo Kuwata 'Production Management Outline' THE NIKKAN KOGYO SHIMBUN, LTD. 1998
## Motion Study (1) Factor Work Analysis

Unit: minutes in 1/100

<table>
<thead>
<tr>
<th>No.</th>
<th>要素作業</th>
<th>所要時間（×10⁻² 分）</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>反物と伝票を照合する</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>リフト・テーブル上の梱包反を延反台に押す</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>梱包のバンドを切る</td>
<td>55</td>
</tr>
<tr>
<td>4</td>
<td>梱包の包装紙を取除く</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>生地を延反台中央に移す</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>生地の左右上下を反転し生地の表を確認する</td>
<td>85</td>
</tr>
<tr>
<td>7</td>
<td>生地をパレットに積む</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>生地をパレット上で広げる</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>生地幅を切る</td>
<td>175</td>
</tr>
<tr>
<td>10</td>
<td>生地端に工番，生地名，反番を記入する</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>生地端を出しロッドにかける</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>次の反物の生地端を出し</td>
<td>95</td>
</tr>
<tr>
<td>13</td>
<td>前の生地端と今の生地端の耳を合わせる</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>ミシンを移動させる</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>生地をミシンにセットする</td>
<td>215</td>
</tr>
<tr>
<td>16</td>
<td>ミシン掛けする</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>ミシンを定位置に戻す</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>リフトテーブルの安全踏板を広げる</td>
<td>45</td>
</tr>
<tr>
<td>19</td>
<td>結反完了生地の下端をまくり上げる</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>結反生地を生地置場へ運ぶ</td>
<td>125</td>
</tr>
</tbody>
</table>

合計: 680

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Hideo Kuwata 'Production Management Outline'
THE NIKKAN KOGYO SHIMBUN,LTD. 1998
Ideas to use right hand and left hand simultaneously.

Ideas on sacking motion.
Delicate motion analysis on winder thread change, thread tying work (improve toward better motions)
### Express delicate motions by signs.

<table>
<thead>
<tr>
<th>番号</th>
<th>サーブリグ名</th>
<th>分類</th>
<th>サーブリグ記号</th>
<th>説明</th>
<th>例</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>検 す (Search)</td>
<td>2</td>
<td>ざんて物を探す形</td>
<td>鉛筆がどこにあるか探す</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>進 る (Select)</td>
<td>2</td>
<td>すこんでものを指示した形</td>
<td>数本の中から1本の鉛筆を選ぶ</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>採 かむ (Grasp)</td>
<td>1</td>
<td>物をつかむ手の形</td>
<td>鉛筆をつかむ</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>から 手 (Transport Empty)</td>
<td>1</td>
<td>空手の形</td>
<td>鉛筆へ手をのばす</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>進 る (Transport Loaded)</td>
<td>1</td>
<td>手に物をのせた形</td>
<td>鉛筆を持ってくる</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>保 持 (Hold)</td>
<td>3</td>
<td>砕石に物を吸付けた形</td>
<td>鉛筆を持ってままとている</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>放 す (Release Load)</td>
<td>1</td>
<td>手のひらを逆にした形</td>
<td>鉛筆を置く</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>位 置 き (Position)</td>
<td>2</td>
<td>物を指の先端に置いた形</td>
<td>鉛筆の先を特定の位置におく</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>前 置 き (Pre-Position)</td>
<td>2</td>
<td>ポーリングのピン</td>
<td>使いやすいように鉛筆を持ちなおす</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>調 べ る (Inspect)</td>
<td>1</td>
<td>レンズの形</td>
<td>字のできれば調べる</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>組 み 合 わ せ (Assemble)</td>
<td>1</td>
<td>井桁の形</td>
<td>鉛筆にキャップをはめる</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>分 解 (Disassemble)</td>
<td>1</td>
<td>井桁から1本はずした形</td>
<td>キャップをはずす</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>使 う (Use)</td>
<td>1</td>
<td>UseのU</td>
<td>字を書く</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>遅 れ ん く (Unavoidable Delay)</td>
<td>3</td>
<td>人がつまづいて倒れた形</td>
<td>停電で字が書けないので手持ちする</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>遅 れ ら り (Avoidable Delay)</td>
<td>3</td>
<td>人が寝ている形</td>
<td>よそ見をして字を書かずにいる</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>考 え る (Plan)</td>
<td>2</td>
<td>げんに手を当てて考えている形</td>
<td>どんな字を書くか考える</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>休 は む (Rest)</td>
<td>3</td>
<td>人がいすに腰かけて休む形</td>
<td>疲れたので休む</td>
<td></td>
</tr>
</tbody>
</table>

Hideo Kuwata 'Production Management Outline'
THE NIKKAN KOGYO SHIMBUN,LTD. 1998
Time Study

Time measurement of floor works with a stop watch in hand is a must.

decimal minute stop watch

observation board
Work Improvement (Kaizen)

bottom-up pattern ⇔ top-down pattern

floor-level participation pattern ⇔ special-staff lead pattern

Kaizen is a “total company IE”.
KAIZEN
(Ky’zen)

The Key to Japan’s Competitive Success

MASAAKI IMAI

Imai
“Kaizen”

Random House Business Division
New York
Standard Steps to Draw Improvement Plans in IE

Find problems → Analyze status quo → Apply improvement principles → Draw improvement plans

- process analysis, operation analysis, motion analysis, etc.
- principle of operational economics, principle of motion economics, etc.

Author making (reference: Koji Shioka 'Hand of IE')
Improvement is a process of “Problem Solving”.

Set goals → Plan
→ Measure status quo → ↓
→ Find problems (goal----status) → ↓
→ Search causes → ↓
→ Plan substitutes for improvement → ↓
→ Compare and evaluate substituting plans → ↓
→ Determine improvement plans → ↓
→ Execute → Do
→ Feed results back → Check
→ Correct → Action
PDCA Cycle

Plan
↓
Do
↓
Check
↓
Action

Similarities to “Classic Control Theory”
（ファヨール、ガーリック、アーウィックなど）
Control and Improvement

(1) **Status Quo Control**
   = fix a standard; set permissible range;
   analyze estrangement, corrective action

(2) **Improvement (Kaizen)**
   = modify a goal upward; revise a standard

Note: Improvement is not the denial of a standard, nor the absence of a standard.

“There is no improvement where there is no standard.” (Imai “Kaizen”)
Conceptual Chart on Control and Improvement

1. **status quo control**
   - Performance
   - Deviation
   - Correction
   - Upper limit of control goal
   - Lower limit of control goal

2. **improvement**
   - Performance
   - Revision of standard
   - Upper limit of control goal
   - Lower limit of control goal
Work Improvement as “Incremental Innovation”

(1) Incremental Innovation:
   Innovation accumulated little by little.
   A penny saved is a penny gained.

(2) Radical Innovation:
   Fundamental change. A big bang to score an upset victory.
   But, accompanied are investment risks and disorders.

   In a long term, organizational capabilities on both are necessary.
Revision of Standard at Toyota Automobiles (Democratic Taylorism)

(1) Work standards are drawn, not by IE experts, but by group leaders (foremen) at floor level.

(2) Group leaders (foremen) are veteran ex-skilled workers.

(3) Group leaders (foremen) are also labor union members.

(4) Before new work standards are determined, foremen by themselves actually implement them for demonstration.

(5) New standards are documented (standard work job cards, work manuals, etc.)

(6) Revise standards frequently.
## Toyota’s Work Standards (1)

### Work Instructions

#### Work Point (Success or not, safe or not, easily or not)

<table>
<thead>
<tr>
<th>序号</th>
<th>(4)</th>
<th>(5)</th>
<th>(6) 品质</th>
<th>(7)</th>
<th>(8) 時間</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>序</td>
<td>施工指示</td>
<td>右手で</td>
<td>03&quot;</td>
</tr>
<tr>
<td>2</td>
<td>CE-239</td>
<td>外、付、添</td>
<td>I/50</td>
<td>目視: センタの溝すぎは後工のLA、GR工で対策</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>LA-1306</td>
<td>外、付、添</td>
<td>I/50</td>
<td>目視: センタに確実に取り付けること</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LA-1307</td>
<td>外、付、添</td>
<td>I/50</td>
<td>目視: センタに確実に取り付けること</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>LA-1101</td>
<td>外、付、添</td>
<td>I/1</td>
<td>C: 22.5±0.25, 33.1±0.25 切削はテレッキで取ること</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DR-1544</td>
<td>外、付、添</td>
<td>I/1</td>
<td>目視: 切削状態を確認から確認する</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>SP-101</td>
<td>外、付、添</td>
<td>I/1</td>
<td>M-22, P-1.5 取付面切削清掃</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>MM-122</td>
<td>外、付、添</td>
<td>I/1</td>
<td>05&quot;</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>HP-657</td>
<td>外、付、添</td>
<td>I/1</td>
<td>Bッシュは油沼ぞか円周に切ってある方を上にして入れる</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>BR-410</td>
<td>外、付、添</td>
<td>I/1</td>
<td>取付面清掃</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td>1/10</td>
<td>0.25</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td>1/10</td>
<td>0.25</td>
</tr>
<tr>
<td>13</td>
<td>油槽、外、付、添</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>ニップル取り付け</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>テーキン打ち、外、付、添</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>完成品合</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Yasuhiro Monden 'Field Management of Toyota' Japan Management Association
<table>
<thead>
<tr>
<th>品名</th>
<th>ステアリングボストアッシー</th>
<th>分解番号</th>
<th>2/3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>応</th>
<th>品質</th>
<th>チェック</th>
<th>ケージ</th>
<th>正味時間</th>
<th>仕様</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ギャーボックスを組付治具に取り付ける</td>
<td>水平に押し込む</td>
<td></td>
<td>08&quot;</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>マスターシャフトにプレートシムをはめ込みギャーボックスに入れる</td>
<td>メーンシャフトをまわしながらマスターシャフトのローラー</td>
<td></td>
<td>15&quot;</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>マスタープレートを取り付ける</td>
<td>ボルト締付トルク 600～700 kg/cm</td>
<td></td>
<td>30&quot;</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>スラストスクリューを取り付ける</td>
<td>一杯に締めた後 1/3～1/4 もどしてロックする</td>
<td></td>
<td>15&quot;</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>スラストスクリューをセットする</td>
<td>ボルト締付トルク 600～700 kg/cm</td>
<td></td>
<td>12&quot;</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>マスターシャケットを入れて、クランプ</td>
<td>ボルト締付トルク 600～700 kg/cm</td>
<td></td>
<td>04&quot;</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>取り外し、ローラーコンベアに引き掛ける</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

work instruction

work

point (Success or not, safe or not, easily or not)
U字ライン
ヒトは巡回

Yasuhiro Monden 'Field Management of Toyota' Japan Management Association
Suggestion System and Small Group Activities

**Improvement Suggestion System:**
Primarily to recruit, screen, recognize, and execute individuals’ suggestions on a continuous basis.

**Small Group Activities:**
(QC circle, ZD activities, JK, suggestion group, etc.)

Their objectives are ----
(1) motivation, morale enhancement
(2) productivity increase and quality advancement

Their lead players?

*Floor-level workers vs. floor-level managers*
(group leaders, team leaders)
Toyota’s QC Circle

Office Organization of Factory/Department

factory manager

general manager

section chief

assistant manager

group leader

team leader

worker

actually, rather hierarchical

caretaker

sub-caretaker

adviser

sub-advisor

circle leader

theme leader

circle member

QC Circle Activities Promotion Committee

factory/department promotion committee

caretaker

sub-caretaker

adviser

sub-advisor

circle leader

theme leader

circle member

Structure of QC Circle and Its Relationship with Managerial Organization

Yasuhiro Monden 'Toyota System' Kodansha Ltd. 1989
Focus Points of Productivity Improvement (by the book)

ECRS (Euro-American style, analytical)
- Eliminate (eliminate wasteful works)
- Combine (combine with other works)
- Rearrange (rearrange sequences, locations, persons-in-charge of works)
- Simplify (simplify works)

5W1H (Who, What, When, Where, Why & How)

5 Whys (耐一 Ono)

7 Wastes (耐一 Ono)
7 Wastes (耐一 Ono)

1. Waste in overproduction
2. Waste in stocks
3. Waste in transportation
4. Waste in manufacturing per se
5. Waste in inventory
6. Waste in motion
7. Waste in making defects
Productivity Increase by Advancing Rate of Net Working Time

Operation Analysis: Decompose “standard time”

→ dismantle time not producing value (waste, related works, etc)

- waste → eliminate
- related works → shorten time with ideas

In result, the rate of net working time goes up, and productivity increases.
Toyota’s Operation Analysis

workers’ movements

operations

non-value-adding operations

net operations

waste

can be saved immediately

- waiting
- wasteful transportation
- stacking up semi-manufactured products
- changing hands
- duplicated transportation

under current working condition

- go get parts
- unpack subcontract parts
- to take out parts little by little from large pallet
- operating hand-push cutter button

Yasuhiro Monden ‘Field Management of Toyota’ Japan Management Association (p.179)
Advancement in Rate of Net Working Time

Kenichi Sekine 'Practice Toyota KANBAN system' THE NIKKAN KOGYO SHIMBUN,LTD. (p.103 figure.5.5)
Improvement and Productivity Increase
(Example of Nishikawa Kasei)
Case of Work Improvement

Operation of 4 men stuck to facilities → one-man operation in U-shape line (invested in conveyer)

Kenichi Sekine, Sumio Iwasaki, Keisuke Arai 'Assembly Number of Men 1/4 Making' THE NIKKAN KOGYO SHIMBUN,LTD. 1988
Case of Work Improvement

Reorganization (breaking down of operation) of by-function layout

Alteration to U-shape line

Productivity ↑
In-process inventory ↓
Defect rate in process ↓
Production lead time ↓

Kenichi Sekine, Sumio Iwasaki, Keisuke Arai
'Assembly Number of Men 1/2 Making'
THE NIKKAN KOGYO SHIMBUN,LTD. 1988
Productivity and Net Working Time
(Density Approach and Speed Approach)

Man-hour requirement per unit = \frac{\text{Total actual work hours per day}}{\text{Production units per day}} = \frac{\text{Total net work hours per day}}{\text{Production units per day}} \div \frac{\text{Total net work hours per day}}{\text{Total actual work hours per day}} = \frac{\text{Gross net work hours per unit}}{\text{Rate of average net work hours}}
Just in Time (JIT) and Problem Manifestation

JIT = reduction of in-process inventory
(produce whatever necessary at whenever necessary as much as necessary)

Its aims are:
1. Save inventory cost (interests, etc.) ---- elementary class
2. Expose production problem (waste) ---- middle class
3. Enforce problem consciousness throughout company ---- high class

No way out (system to make wastes surface)
Firstly process improvement (initiate a flow)
→ Next, improvement of each work
If inventory is zero

Requirements 480 units/day, 8H/day operation

Welding (24 spots)
3 tables
8 spots each
40” cycle
20” idling (waiting)
5 seconds/spots’ speed

painting
60”

After improvement

2 tables
12 spots each
60” cycle
60”

However

inventory increases

3 tables
existing

40” cycle
no idling

increases by 30 units per hour

(360 ÷ 40) − (360 ÷ 60) = 30

Improvement not progressing!
Increase in productivity ("spare labor")

Improvement activities

Exposure of problems

Minimization of inventory level

Kanban system

Small group activity program

Yasuhiro Monden 'Toyota System' Kodansha Ltd. 1989
Productivity Increase by Multi-Skilled Worker and Sparing Worker

**Multi-skill training**
= potential capability to handle variety of works in workplace

**Multi-task assignment**
= actually diversify jobs within one cycle

**Spare Labor**
= decrease workers by one-person unit, and increase productivity

**Less Labor**
= fluctuate number of workers as per ups and downs of production volume
Example of Multi-Table Assignment
例: 多タスク/テーブル割り当て

機種別配置

工程順配置（離れ小島）

直線型配置

歩行時間がムダ
Idea of “Spare Labor” (Example of Machine Process Line)

a. 現状
（手待ちに時間にばらつき）

b. 手待ち時間の均等配分案

（人数を一人削減）

c. 「省人化」の考え方

= 各作業者の正味作業時間。

Author making (reference: Yasuhiro Monden 'New Toyota system')
"Less Labor“
to flexibly change number of workers at each process in response to demand fluctuation

To expand or reduce job range of each worker

Layout of articulated U-shape line

"Spare Labor“
to reduce number of workers in process

Revision of job card for combination of standard work

Improvement of process

Various Factors to Realize "Less Labor"

Job rotation

Multi-skilled worker

Work improvement

Machinery Improvement (automation)

Yasuhiro Monden 'Toyota System' Kodansha Ltd. 1989 (p.211)
Labor Density and Labor Intensity

Intensity of labor:
Does it constitute labor intensity to advance the rate of net working time (productivity increase) accounting in actual working hours?

"Elimination of waste, irregularity, unreasonableness"

----- eliminate wastes, but no chance of unreasonable work design?

Things must be confirmed “at actual site, and with actual stuff”