Introduction to the Toyota Production System (TPS)

2.810

T. Gutowski
Three Major Mfg Systems from 1800 to 2000

- Machine tools, specialized machine tools, Taylorism, SPC, CNC, CAD/CAM

1800
Interchangeable Parts at U.S. Armories

1900
Mass Production at Ford

2000
Toyota Production System
1980’s OPEC oil embargo drives up fuel prices, Japan imports small cars with increased fuel mileage
Consumer Reports
How we learned about TPS

• Quality of cars - but not right away
• Pilgrimages - Hayes, Wheelwright, Clark
• Joint ventures - Nummi-Geo…
• Japanese NA operations-Georgetown, KY
• Japanese sages- Ohno, Shingo, Monden
• American translation- “Lean”, J T. Black..
• Consulting firms-…Shingjutsu,…
Toyota Production System Development History - Taiichi Ohno

30 years of development 1945 to 1975
The Architecture of Manufacturing: Material and Information Flows

Introduction

The most striking thing about a factory is usually its machinery: in a steel mill, the sheer size, power, and noise of the electric arc furnace as it melts tons of scrap; in an automobile assembly plant, the rhythmic operation of the automated welding system; in a computer plant, the virtuosity of the assembly robots. But our research on high-performance manufacturing suggests that for all its sound and fury, the equipment, or hardware, by itself is rarely the primary source of a factory’s competitive advantage. What matters is how that hardware is used, and how it is integrated with materials, people, and information through software—the systems and procedures that direct and control the factory’s activities.

The “architecture” of a manufacturing system—which includes its hardware, its material and information flows, the rules and procedures used to coordinate them, and the managerial philosophy that underlies them all—largely determines the productivity of the people and assets in the factory, the quality of its products, and the responsiveness of the organization to customer needs. Indeed, two factories with almost identical hardware may perform very differently if they have different system architectures. Just how differently is demonstrated by the experience of Mazda, the Japanese auto firm, in the mid-1970s.

Translation: there is no “Silver Bullet Technology”. This is more system & management than technology.
REFERENCES ON THE TOYOTA PRODUCTION SYSTEM:

Taiichi Ohno, “The Toyota Production System” Productivity Press 1988


Yasuhiro Monden, “Toyota Production System”, 2nd Ed 1983

Hayes, Wheelwright and Clark, “Dynamic Manufacturing” Free Press 1988

Womack and Jones, “Lean Thinking” Simon and Schuster, 1996

Spear & Bowen, “The DNA of the TPS’” HBR 1999
Performance Observations

• Early observations of reliability, after some initial start-up problems
• IMVP got actual factory level data 1980’s
  – defect counts
  – direct labor hours for assembly
  – level of automation
### Summary of Assembly Plant Characteristics, Volume Producers, 1989
(Average for Plants in Each Region)

<table>
<thead>
<tr>
<th></th>
<th>Japanese in Japan</th>
<th>Japanese in North America</th>
<th>American in North America</th>
<th>All Europe</th>
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<tr>
<td>Performance:</td>
<td></td>
<td></td>
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<tr>
<td>Productivity (hours/Veh.)</td>
<td>16.8</td>
<td>21.2</td>
<td>25.1</td>
<td>36.2</td>
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<td>Quality (assembly defects/100 vehicles)</td>
<td>60</td>
<td>65</td>
<td>82.3</td>
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<td>Layout:</td>
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<td>Space (sq.ft./vehicle/yr)</td>
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<td>9.1</td>
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<td>Size of Repair Area (as % of assembly space)</td>
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<td>4.9</td>
<td>12.9</td>
<td>14.4</td>
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<td>Inventories (days for 8 sample parts)</td>
<td>0.2</td>
<td>1.6</td>
<td>2.9</td>
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<td>Work Force:</td>
<td></td>
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<td></td>
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<td>% of Work Force in Teams</td>
<td>69.3</td>
<td>71.3</td>
<td>17.3</td>
<td>0.6</td>
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<td>Job Rotation (0 = none, 4 = frequent)</td>
<td>3</td>
<td>2.7</td>
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<td>1.9</td>
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<td>Suggestions/Employee</td>
<td>61.6</td>
<td>1.4</td>
<td>0.4</td>
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<td>Number of Job Classes</td>
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<td>8.7</td>
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<td>Training of New Production Workers (hours)</td>
<td>380.3</td>
<td>370</td>
<td>46.4</td>
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<td>Absenteeism</td>
<td>5</td>
<td>4.8</td>
<td>11.7</td>
<td>12.1</td>
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<td>Automation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Welding (% of direct steps)</td>
<td>86.2</td>
<td>85</td>
<td>76.2</td>
<td>76.6</td>
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<td>Painting (% of direct steps)</td>
<td>54.6</td>
<td>40.7</td>
<td>33.6</td>
<td>38.2</td>
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<tr>
<td>Assembly (% of direct steps)</td>
<td>1.7</td>
<td>1.1</td>
<td>1.2</td>
<td>3.1</td>
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</tbody>
</table>

Cost Vs Defects

Ref. “Machine that Changed the World” Womack, Jones and Roos

**Figure 4.8**

Productivity versus Quality in the Assembly Plant, Volume Producers, 1989

**Source:** IMVP World Assembly Plant Survey, 1989
Cost Vs Automation

Ref. “Machine that Changed the World” Womack, Jones and Roos

**Figure 4.9**

*Automation versus Productivity, Volume Producers, 1989*

*Note:* "Automation" equals the percent of assembly tasks that have been automated. Automation includes both fixed automation such as multi-welders and flexible automation using robots. Automation of materials handling is not included.

History of the Development of the Toyota Production System

1945

- Just-in-time
- Intermediate warehouses abolished

1949

- Machining and assembly lines synchronized
- Assembly and body plants linked

1950

- Withdrawal by subsequent processes ("upstream" transport)
- Supermarket system in machine shop

1953

- Call system for the machine shop
- Whirling water system (small load/mixed transportation)

1955

- Kaizen
- Multi-process operation

1956

- Virtual control, Andon system adopted in engine assembly

1957

- Procedural chart (Andon) adopted

1958

- Warehouse withdrawal slips abolished
- Transfer system (in → in or in → out)

1959

- Red and blue-card system for ordering outside parts
- Transfer system (out → in)

1961

- Pallet kanban

1962

- Kanban adopted company-wide
- Kanban adopted for ordering outside parts; 100% supply system; began teaching Toyota system to affiliates

1963

- Use of inter-writer, system of automated selection of parts adopted; information indicator system adopted

1964

- Full-work control of machines, machine wake-up
- First automated line, Kamio plant

1965

- Transfer system (out → in)

1967

- Main office and Motomachi setups (3 minutes)
- Body indication system (Motomachi Crown line)

1971

- Production leveling
- First automated line, Motomachi assembly plant
- Fixed-position stopping system in assembly

1975

- Andon

References: Taiichi Ohno
Figure 1.2. How costs, quantity, quality, and humanity are improved by the Toyota production system.

Ref Yasuhiro Monden
Basic Goal

• To reduce cost by -

• Elimination of waste
  – Excessive production resources
  – Overproduction
  – Excessive inventory
  – Unnecessary capital investment

• Respect for people

See Toyota Production System, Yasuhiro Monden
Simulation of a 20 machine, 19 buffer (cap = 10 parts) Transfer line. Each machine with one minute cycle time could produce 4800 parts per week. MTTF 3880 minutes, MTTR 120 minutes. See Gershwin p63-64

Perfect machines, $\infty$ buffer

$\infty$ buffer

Ave (3249 sim, 3247 analy)

Zero buffer

$N^* \geq 240$ parts

Figure 3.2: Production Variability
Buffer capacity Vs MTTR

- MTTR = 120 minutes
- $N^* \sim 2 \times 120 \times 1 \text{ part/minute} = 240$
- $240 \times 19 \text{ buffers} = 4560 \text{ (~ one week)}$

- There must be a better way!

CHANGE THINKING, REDUCE VARIATION
What causes variation?

• Quality issues

• Delivery time issues

• Unavailable resources issues
What causes variation?

• Quality issues
  – Check quality, prevent propagation

• Delivery time issues
  – Just in Time, smooth flow, mix models, standard work

• Unavailable resources issues
  – Flexible machines and cross trained workers
Quality Issues

• Make quality problems obvious
  – Error checking (Pokeyoke), Pull system
• Reduce WIP, which hides problems
• Stop the line
• Fix it now
• Cooperative problem solving
Delivery Time Issues

• Kanban card: type & quantity needed
  – Smooth production
  – “Takt” time = available time/demand
  – Standardize work
  – Reduce set-up
  – Design machine layout - TPS cells
  – Autonomation - autonomous defect control

Monden
Unavailable Resource Issues

• Fast set up
  – Single Minute Exchange of Dies (SMED)
• Flexible (general purpose) machines
  – Toyota Cells
• Cross-trained work force
Autonomation…

• Monden claims that the word “autonomation” comes from the Japanese word *Jidoka*. which has two meanings, the first is automation in the usual sense, to change from a manual process to a machine process. The second meaning is “automatic control of defects”. He says this is the meaning coined by Toyota. This second meaning is sometimes referred to as *Ninbennoaru Jidoka*, which literally translates into automation with a human mind. Monden goes on to say that “although autonomation often involves some kind of automation, it is not limited to machine processes but can be used in conjunction with manual operations as well. In either case, it is predominantly a technique for detecting and correcting production defects and always incorporates the following devices; in mechanism to detect abnormalities or defects; a mechanism to stop the line or machine when abnormalities or defects occur. When a defect occurs, the line stops, forcing immediate attention to the problem, an investigation into its causes, and initiation of corrective action to prevent similar defects from occurring again…”

• Reference; Yasuhiro Monden, Toyota Production System,
J T. Black’s 10 Steps
Ref; JT. Black “Factory with a Future” 1991

1. Form cells
2. Reduce setup
3. Integrate quality control
4. Integrate preventive maintenance
5. Level and balance
6. Link cells – KANBAN
7. Reduce WIP
8. Build vendor programs
9. Automate
10. Computerize
J T. Black –1, 2

1. Form Cells
   Sequential operations, decouple operator from machine, parts in families, single piece flow within cell

2. Reduce Setup
   Externalize setup to reduce down-time during changeover, standardize set-up
Toyota Cell, one part is produced for every trip around the cell.

Key:
- S = Saw
- L = Lathe
- HM = Horizontal milling machine
- VM = Vertical milling machine
- G = Grinder
- ❌ = Worker positions

Path(s) of worker(s) moving within cell
- Material movement paths within cell
- Kanban square (Decoupler)

FIGURE 4.2
3. Integrate quality control
   Check part quality at cell, poke-yoke, stop production when parts are bad, make problems visible, Andon - info about work being done…

4. Integrate preventive maintenance
   worker maintains machine, runs slower, operator owns production of part
5. Level and balance
   Produce to Takt time, reduce batch sizes, smooth production flow, produce in mix to match demand

6. Link cells- Kanban
   Create “pull” system – “Supermarket” System that indicates the status of the system
Balancing and Leveling

- **Balanced line:** adjust process time for smooth flow “Takt time”

- **Leveled Line:** each product is produced in the needed distribution.
Pull System at the Supermarket
Pull Systems-
The orders arrive at the end of the line and are “pulled” out of the system. WIP between the machines allows quick completion.

- System stops when there are no orders
- Disruptions are obvious
- Product differentiation at the end
Push Systems –

Order (from centralized decision process) arrives at the front of the system and is produced in batches of size “B”. Process time at each step may not be balanced.

Time = 0

Time = T₁

Time = T₂

Time = T₃

Time = Tₙ
7. Reduce WIP

Make system reliable, build in mechanisms to self correct, reduce inventory

8. Build Vendor program

Propagate low WIP policy to your vendors, reduce # of vendors, make on-time performance part of expectation
TPS Cell: Example

1. Work flow (part separate from worker)
2. Standard work (highly specified)
3. Production rate flexibility

Ref: J T. Black Ch 4
Machining Cell

Operator moves part from machine to machine (including “decouplers”) by making traverse around the cell.
Cell Features

• “Synchronized”, sequential production
• Operator decoupled from individual machines
• Operator integrated into all tasks
• Goal: single piece Flow
• Best with single cycle automatics, but can be done manually too

See Brigg & Stratton Video
Machining Cell

<table>
<thead>
<tr>
<th>segment</th>
<th>Manual (Sec)</th>
<th>Walk to (Sec)</th>
<th>Machine (Sec)</th>
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<tbody>
<tr>
<td>1</td>
<td>Raw</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Saw</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>L1</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>L2</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>HM</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>VM1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>VM2</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>G</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>F.I.</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Finish part</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>M+W</td>
<td>153</td>
<td>490</td>
</tr>
</tbody>
</table>

Key:
- S = Saw
- L = Lathe
- HM = Horizontal milling machine
- VM = Vertical milling machine
- G = Grinder
- ☒ = Worker positions
- Path(s) of worker(s) moving within cell
- Material movement paths within cell
- Kanban square (Decoupler)

FIGURE 4.3
# Machining Cell

<table>
<thead>
<tr>
<th>Part</th>
<th>Manual (Sec)</th>
<th>Walk to Machine (Sec)</th>
<th>Machine (Sec)</th>
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<tr>
<td>Raw</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Saw</td>
<td>15</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>L1</td>
<td>10</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>L2</td>
<td>12</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>HM</td>
<td>12</td>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td>VM1</td>
<td>20</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>VM2</td>
<td>20</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>G</td>
<td>15</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>F.I.</td>
<td>19</td>
<td>3 + 3</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td><strong>M+W = 153</strong></td>
<td><strong>490</strong></td>
</tr>
</tbody>
</table>

Parts in the cell ~ 14

---

**Key:**
- S = Saw
- L = Lathe
- HM = Horizontal milling machine
- VM = Vertical milling machine
- G = Grinder
- Clip = Worker positions

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**Direction of part movement within cell**

**FIGURE 4.2**

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Path(s) of worker(s) moving within cell

Material movement paths within cell

Kanban square (Decoupler)

---

13 parts
Standard Work for Cell

Cell produces one part every 153 sec

Note: machine time Max (MTj) < cycle time CT

i.e. 120+12 < 153
TPS Cell

1. Production rate = $\lambda$

$$\lambda = \frac{1\, \text{part}}{153 \, \text{sec}} = 23.5 \, \text{parts/hr}$$

2. WIP = L?

3. Time in the system = W?
### Machining Cell

<table>
<thead>
<tr>
<th>Operation</th>
<th>3+15</th>
<th>153</th>
</tr>
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<tbody>
<tr>
<td>Saw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#1 decoupler</td>
<td>1.5</td>
<td>+153</td>
</tr>
<tr>
<td>L1</td>
<td>1.5+10</td>
<td>+153</td>
</tr>
<tr>
<td>Grind</td>
<td>1.5+15</td>
<td>+153</td>
</tr>
<tr>
<td>Manual walk</td>
<td>19+3</td>
<td>out</td>
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</tbody>
</table>

| Total        | 150  | 153X13 = 1989 |

1989 + 150 = **2139**

**FIGURE 4.2**

- **Key:**
  - S = Saw
  - L = Lathe
  - HM = Horizontal milling machine
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  - G = Grinder
  - ◯ = Worker positions
  - Path(s) of worker(s) moving within cell
  - Material movement paths within cell
  - Kanban square (Decoupler)
By Little’s Law

L = (13 + 1) \times \frac{150}{153} + 13 \times \frac{3}{153} = 13.98 \text{ parts}

rate, \lambda = \frac{1}{153} \text{ parts/second}

W = 153 \times 13.98 = \textbf{2139 sec}
TPS Cell

Increase production rate:

   a) add additional worker to cell
   b) modify machine bottlenecks
To increase production rate add 2\textsuperscript{nd} worker

<table>
<thead>
<tr>
<th></th>
<th>Manual (Sec)</th>
<th>Walk to (Sec)</th>
<th>Machine (Sec)</th>
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<tr>
<td>Raw</td>
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<tr>
<td>Saw</td>
<td>15</td>
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</tr>
<tr>
<td>L1</td>
<td>10</td>
<td>3+3</td>
<td>70</td>
</tr>
<tr>
<td>L2</td>
<td>12</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>HM</td>
<td>12</td>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td>VM1</td>
<td>20</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>VM2</td>
<td>20</td>
<td>3+3</td>
<td>60</td>
</tr>
<tr>
<td>G</td>
<td>15</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>F.I.</td>
<td>19</td>
<td>3 + 3</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>M+W</td>
<td>159</td>
<td>490</td>
</tr>
</tbody>
</table>

Work 1 80

Work 2 79

Key:
- $S$ = Saw
- $L$ = Lathe
- HM = Horizontal milling machine
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- $G$ = Grinder
- $\times$ = Worker positions

Path(s) of worker(s) moving within cell
Material movement paths within cell
Kanban square (Decoupler)
What is the production rate for this new arrangement?

Check \( \text{max}(MT_j) < CT \)

Worker 1; \( 80 = 80 \)

Worker 2; \( 12+120 > 79 \)

One part every 132 seconds

We are limited by the HM (horizontal mill)

\[
\lambda = \frac{1 \text{part}}{132 \text{ sec}} = 27.3 \text{ parts/hr}
\]

Can we shift work off of the HM to reduce the cycle time?
<table>
<thead>
<tr>
<th></th>
<th>Manual (Sec)</th>
<th>Walk to (Sec)</th>
<th>Machine (Sec)</th>
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<td>Raw</td>
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<tr>
<td>Saw</td>
<td>15</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>L1</td>
<td>10</td>
<td>3+3</td>
<td>70</td>
</tr>
<tr>
<td>L2</td>
<td>12</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>HM</td>
<td>12</td>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td>VM1</td>
<td>20</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>VM2</td>
<td>20</td>
<td>3+3</td>
<td>60</td>
</tr>
<tr>
<td>G</td>
<td>15</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>F.I.</td>
<td>19</td>
<td>3+3</td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>M+W</strong> = 159</td>
<td></td>
<td>490</td>
</tr>
<tr>
<td>Work 1</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work 2</td>
<td>79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4.2**

Key:
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- = Worker positions
- Path(s) of worker(s) moving within cell
- Material movement paths within cell
- Kanban square (Decoupler)
Standard Work for Worker #2

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>TIME [secs]</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Rod Support</td>
<td></td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Tool changement</td>
<td></td>
<td>1.2</td>
<td>3</td>
</tr>
<tr>
<td>Feed adjustment</td>
<td></td>
<td>1.2</td>
<td>3</td>
</tr>
<tr>
<td>L2</td>
<td></td>
<td>1.2</td>
<td>3</td>
</tr>
<tr>
<td>HM</td>
<td></td>
<td>1.2</td>
<td>3</td>
</tr>
<tr>
<td>VM1</td>
<td></td>
<td>2.0</td>
<td>3</td>
</tr>
<tr>
<td>VM2</td>
<td></td>
<td>2.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Cycle # 1

Cycle # 2

Operator waiting
On machine

+3
What is the new production Rate?

Check max(MTj) < CT

Worker 1; 80 = 80

Worker 2; 110 > 79

Hence Worker #2 will be waiting on Vertical Mill #2
What is the new production Rate?

• The new production rate is; one part every 110 sec

• Pro and Cons; Worker “idle”, can’t speed up by adding additional worker

• Design for flexibility make;

\[
\text{Max(MTj)} < \frac{\text{CT}}{2}
\]

\[
\lambda = \frac{1\text{ part}}{110 \text{ sec}} = 32.7 \text{ parts/hr}
\]
### Table

<table>
<thead>
<tr>
<th></th>
<th>Manual (Sec)</th>
<th>Walk to (Sec)</th>
<th>Machine (Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Saw</td>
<td>15</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>L1</td>
<td>10</td>
<td>3+3</td>
<td>70</td>
</tr>
<tr>
<td>L2</td>
<td>12</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>HM</td>
<td>12</td>
<td>3</td>
<td>120</td>
</tr>
<tr>
<td>VM1</td>
<td>20</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>VM2</td>
<td>20</td>
<td>3+3</td>
<td>60</td>
</tr>
<tr>
<td>G</td>
<td>15</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>F.I.</td>
<td>19</td>
<td>3 + 3</td>
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<tr>
<td>Totals</td>
<td>M+W</td>
<td>= 159</td>
<td>490</td>
</tr>
</tbody>
</table>

**Work 1**

80

**Work 2**

79

### Diagram

**Alternative solution add 2 HM’s**

\[
\lambda = \frac{1 \text{ part}}{90 \text{ sec}} = 40 \text{ parts/hr}
\]

Almost double!
TPS cell summary

1. Original cell - 23.5 parts/hr
2. Additional worker- 27.3 parts/hr
3. + Shift work- 32.7 parts/hr
4. ++ add additional VM 40 parts/hr
TPS Implementation

- Physical part (machine placement, standard work etc)
- Work practices and people issues
- Supply-chain part
- Corporate Strategy (trust, job security)
Is there a best way to build a car?

- Maccoby HBR 1997
- Other Ref: “Just Another Car Factory” Rinehart, Huxley and Robertson, “Farewell to the Factory”, Milkman
Work practices and people issues

• “Failed” TPS attempts; GM Linden NJ, CAMI, GM-Suzuki, Ontario Canada.
• Successes GM NUMMI, Saturn. Toyota Georgetown, KY
  • Maccoby HBR 1997
  • Other Ref: “Just Another Car Factory” Rinehart, Huxley and Robertson, “Farewell to the Factory”, Milkman
According to Maccoby’s Review

• Failure Examples:
  – failures at middle management
  – pressure from above to meet targets, lack of trust from below, but…
  – both plants adopted some aspects of lean, and
  – both plants improved
NUMMI and Georgetown

- workers have different attitude
- do not fear elimination
- play important role
- ...go to Georgetown and find out
NUMMI plant today - Tesla
TPS Summary

- High quality and low cost paradigm shift
- Many elements to the system
  - Make system observable
  - Produce to demand
  - Study defects and eliminate
  - Institutionalize change
  - Trust
- Many companies have imitated TPS
# Key Elements for New Mfg Systems

<table>
<thead>
<tr>
<th>Element/System</th>
<th>Need of Society</th>
<th>Work Force Motivation</th>
<th>Enabling Technology</th>
<th>Leader</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interchange-able Parts</td>
<td>Military</td>
<td>“Yankee Ingenuity”</td>
<td>Machine Tools, Division of Labor</td>
<td>Roswell Lee/John Hall</td>
<td>U.S. Govt</td>
</tr>
<tr>
<td>Mass Production</td>
<td>Transportation</td>
<td>$5/day Immigrant</td>
<td>Moving Assembly Line, etc</td>
<td>Henry Ford</td>
<td>Earnings</td>
</tr>
<tr>
<td>Toyota Production System</td>
<td>Post War Jobs, Security</td>
<td>Systems approach</td>
<td>Taiichi Ohno</td>
<td>Japanese Banks</td>
<td></td>
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Readings

James Womack, Daniel T. Jones and Daniel Roos, *The Machine that Changed the World*, 1990, Ch 3 and 4

J T. Black “The Factory with a Future” Ch 2 & 4

Yasuhiro Moden Ch 1

Michael Maccoby, “Is There a Best Way to Build a Car?” HBR Nov-Dec 1997
“The DNA of the TPS”

• Spear and Bowen
• 4 years 40 plants
• HBR Sept-Oct 1999
• Four Rules:
Four Rules...

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

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

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

• Rule 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.

Spear and Bowen