

TPS Origins, Kaizen Patterns, & TWI Influence:

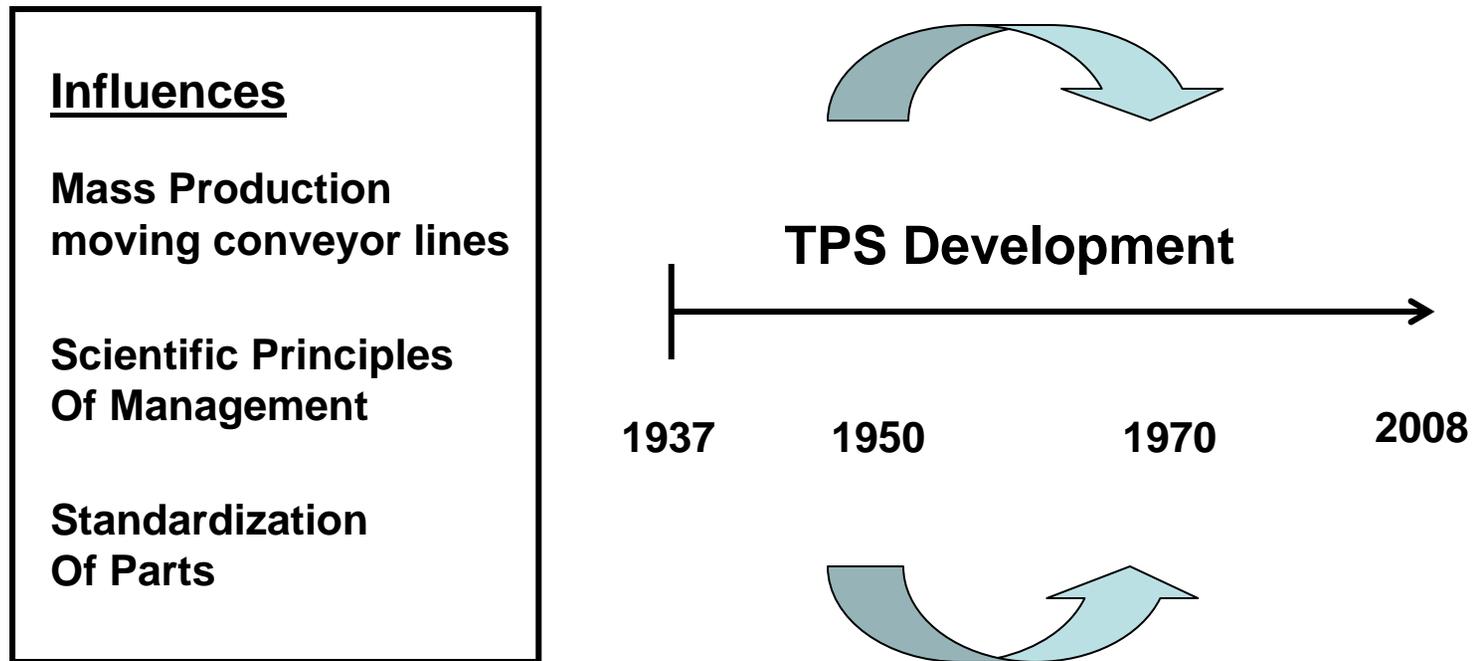
Some key points and reflection from TPS history and implementation

Art Smalley
President

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TPS development timeline



Guess what – it did not just happen overnight!

TPS Summary* 1945-1965

Topic / Dates		1945-55	1955-65
JIT	Process flow	'50 Machining and Assembly Line Flow '50 Machine Shop Flow	'55 Engine to Vehicle Plant Flow '60 Intra Plant Flow
	Conveyance	'53 1-4 Material Handling Call System	'60 Intra Plant Time Delivery '55 Fixed quantity unfixd time based system
	Set up Reduction	'50 1-4 Hour Set Up Time	'62 15 Minute Average C/O (New Technology – Danly Stamping Presses)
	Kanban	'48 Replenishment pull pilot '53 Machine shops implement pull & level scheduling	'62 Company wide pull established
	Purchase Parts Management		'55 Fixed quantity delivery control system '65 Adoption of supplier kanban
	Ordering System	'55 Monthly Production Plans	
	Production Instruction	'57 Adoption of Sequence List '63 JIT Production Instruction Signals	
Jidoka	Multi-Process Handling & Standardized Work	'47 1 Man 2 Machines '53 Standardized Work '49 1 Man 4 Machines	'55 1 Man 7 Machines (average in machine shop)
	Visual Control & In Process Control	'50 Andon lights on engine assembly line '62 Full work control system / Pokayoke	



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*Source: 創造限りなくトヨタ自動車50年史. Toyota 50 Year History Published 1987

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TPS Summary* 1965-1985

Topic / Dates		1965-75	1975-85
JIT	Process flow	'75 Synchronization of Flow Between Plants	'75 Development of Equipment for Flow Production
	Conveyance	'70 All Plants on Call Conveyance Method '77 Cross Docking Methods	'83 Review from Sales to Manufacturing
	Set up Reduction	'71 3 Minute Average C/O Press Machines '75 Single Minute C/O Machines at Suppliers	
	Kanban		'77 Kanban Auto Sorting and Reading
	Purchase Parts Management		'77 Bar Code Reader for Supplier Kanban
	Ordering System	'65 10 Day Order Entry System '70 Daily Order Entry System	'74 New Order System '85 Lead Time Reduction Project
	Production Instruction	'71 Development Plant Production Instruction Signals '80 Adoption of Automatic Signals	'86 New Technology System
Jidoka	Multi-Process Handling & Standardized Work		'75 Company Wide Standardized Work
	Visual Control & In Process Control	'66 Full Automated Machining Lines (JIT & Jidoka Fulfilled Kamigo Model Plant)	



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Early Developments 1890-1924



**Sakichi
Toyoda
“Inventor”**



**1890
Wooden
Loom**



**1896
Auto
Loom**



**1924
Type G
Auto Loom**

- Automated machine
- Low capital cost
- Jidoka stoppage features
- 1 person ran 24-36 machines
- Zero shuttle change over time
- 24 technical patents
- “Magic loom”

Separation of man from machine in loom plants



- 1890 Wooden Japanese Loom
- 1 Person – 1 Machine
- Low Productivity



- 1924 Type G Loom by Toyoda
- 1 Person – 24 to 36 Machines
- High Productivity

Toyota Auto Loom Factory in 1920's

Initial Assembly Flow at Toyoda



Toyoda Looms were built in a factory designed by Sakichi's son Kiichiro in 1927 using the basic principles of Henry Ford.

Several hundred per month were made at the peak of production.

The manufacturing system employed:

- Flow production in assembly (moving conveyor line)**
- Scientific principles of management (Taylor)**

Build in quality 1924 Toyoda Auto Loom



1. Automated processes cycling normally



2. Mechanical probe detects if there is a broken thread or not. This time okay!

Build in quality 1924 Toyoda Auto Loom

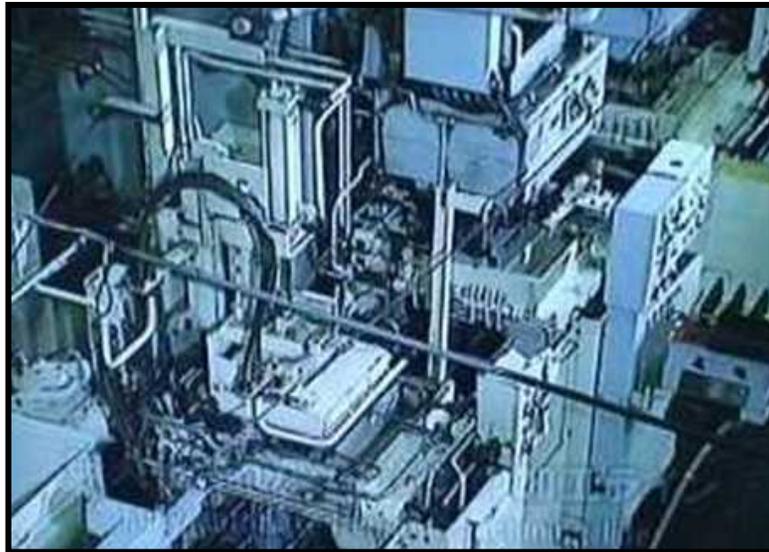


3. This time the thread is broken and the probe will stop the machine (i.e. Jidoka)



4. Production team member responds and fixes the broken thread with a new shuttle

Build in quality 1990 Toyota Motor Corporation



1. Automated process cycling normally



2. Mechanical probe detects broken cutting tool and stops the machine

Build in quality 1990 Toyota Motor Corporation



3. Probe signals an “andon” board for visual display

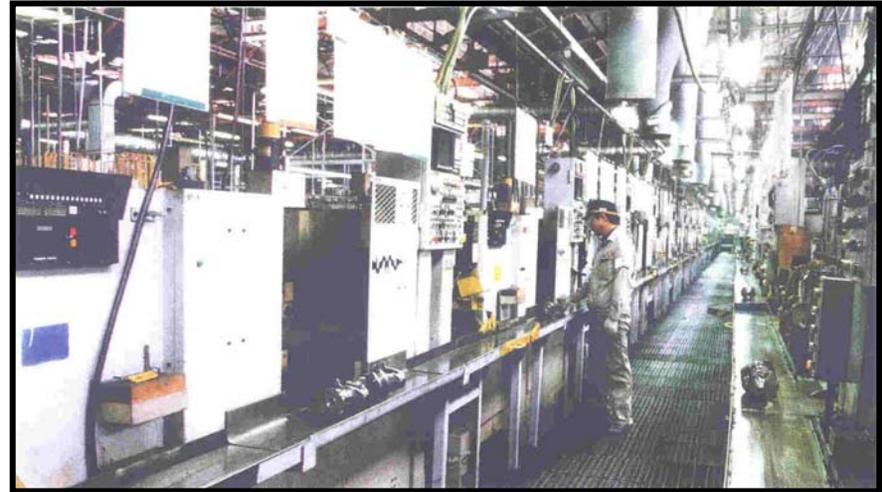


4. Production team member responds and replaces the broken tool

Separate man from machine in engine plants



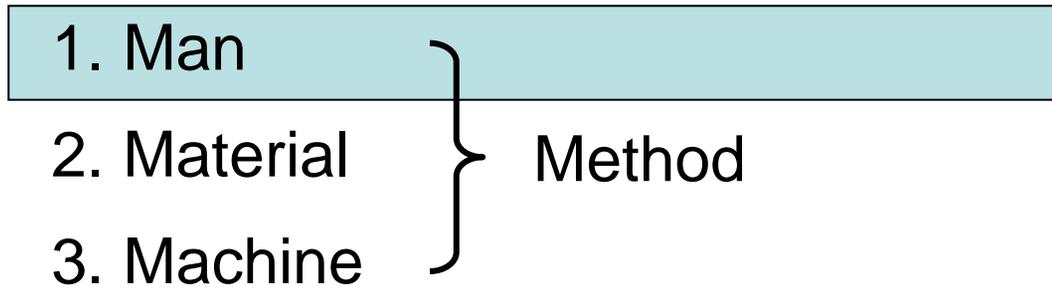
- 1945 Machine Tool in Toyota
- 1 Person operates 1 machine
- Low Productivity / Low Quality



- 1990 Machining Line in Toyota
- 1 Person operates 20+ machines
- High Productivity / High Quality

TPS Kaizen Patterns (e.g. “Method”)

- Three main types (and many derivatives...)



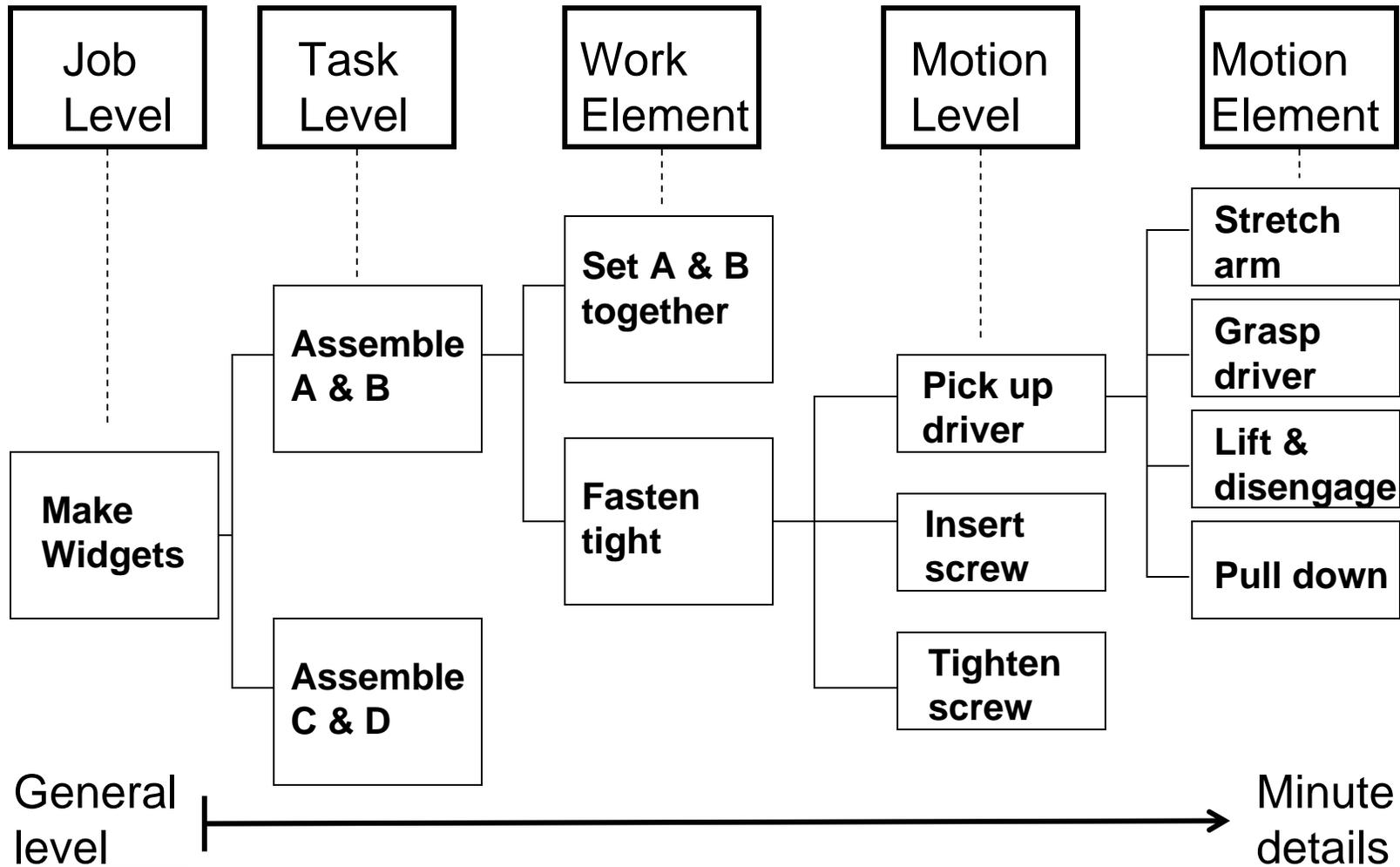
Manpower Related Kaizen

- Time Study
- Motion Analysis
- Work Element Analysis
- Standardized Work & Kaizen

Motion Study (Therbligs)

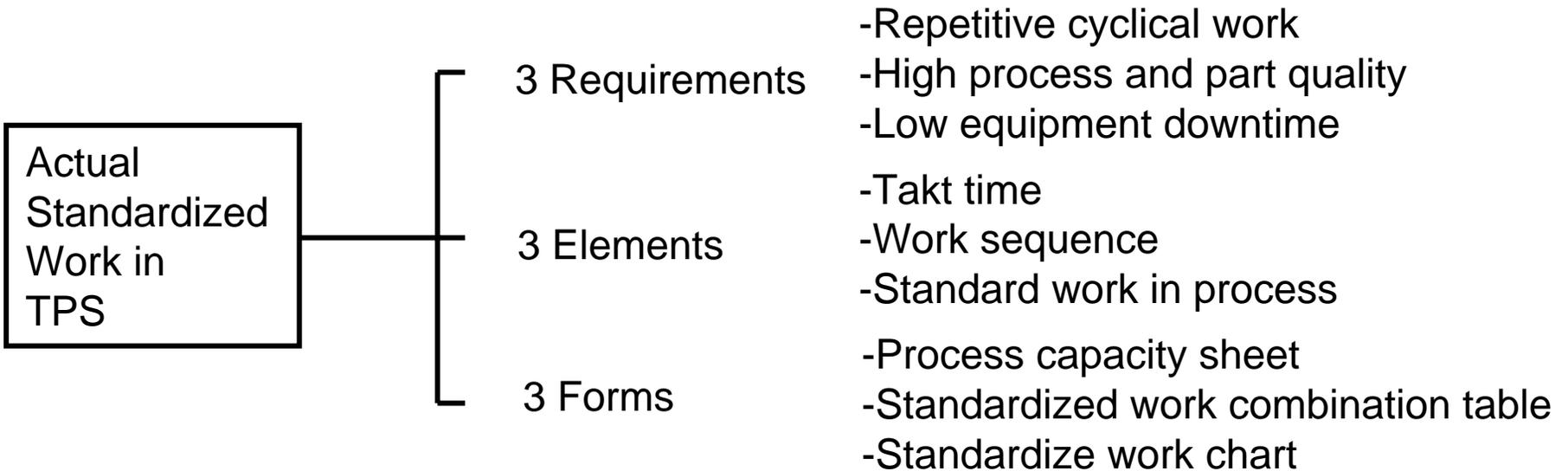
	SEARCH		INSPECT
	FIND		PRE-POSITION
	SELECT		RELEASE LOAD
	GRASP		TRANSPORT EMPTY
	TRANSPORT LOADED		REST FOR OVER COMING FATIGUE
	POSITION		UNAVOIDABLE DELAY
	ASSEMBLE		AVOIDABLE DELAY
	USE		PLAN
	DISASSEMBLE		

Work Elements & Analysis Unit



Standardized Work

Definition: a document centered around *human motion* that combines the elements of a job into the most effective sequence without waste to achieve the most efficient level of production.

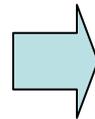


Standardized Work Forms

Sample Process Capacity Sheet

Definition:
A basic tool used to measure process output capability considering the time available and time required for change over work. It represents the maximum output possible from the process under current operating conditions.

Process Capacity Sheet									
		Dept:			Line:				
		Product:			Created by:				
Step #	Process Name	Machine Number	Manual Time	Auto Time	Total CT	# Pcs. / Change	Time to Change	Time Per Pc.	Shift Capacity
1	Mill Face	MI1764	3"	25"	28"	100	60"	0.6"	965
2	Drill Holes	DR2424	3"	21"	24"	1000	30"	0.03"	1148
3	Tap Holes	TP1101	3"	11"	14"	1000	30"	0.03"	1967



Standardized Work Combination Table

Acme Corp.		Plant: Acme	Product: 8" Pinion Gear
Standardized Work Combination Table		Area: Machining	Op. 1 of 1
		Process: Gear Cutting Exercise	Pg. 1 of 1
Date: 5/23/2006	By: Art of Lean	Line Takt: 46 secs	Shifts: 2
		Volume: 600 / Shift	Manual Work Automatic

No.	Major Steps	T	A	M	I	A	I	M	L	M	Time Graph (Seconds)										
											R	O	E	T	E	E	E	E	E	E	E
1	Pick up raw material	1	--	--	--	--	--	--	--	--	[Graph showing manual time bar at 0-1s]										
2	Unload / load and start M/C GC-614	5	38	--	--	--	--	--	--	--	[Graph showing manual time bar at 1-5s, auto time bar at 5-43s]										
3	Unload / Load and start M/C CH-228	6	7	--	--	--	--	--	--	--	[Graph showing manual time bar at 43-49s, auto time bar at 49-55s]										
4	Unload / Load and start M/C GC-1444	6	38	--	--	--	--	--	--	--	[Graph showing manual time bar at 55-61s, auto time bar at 61-99s]										
5	Unload / load and start M/C GC-1445	6	30	--	--	--	--	--	--	--	[Graph showing manual time bar at 99-105s, auto time bar at 105-135s]										
6	Unload / load and start M/C TS-110	7	3	--	--	--	--	--	--	--	[Graph showing manual time bar at 135-142s, auto time bar at 142-145s]										
7	Pack Part	1	--	--	--	--	--	--	--	--	[Graph showing manual time bar at 145-146s]										
Totals		32									TT 46 Secs										

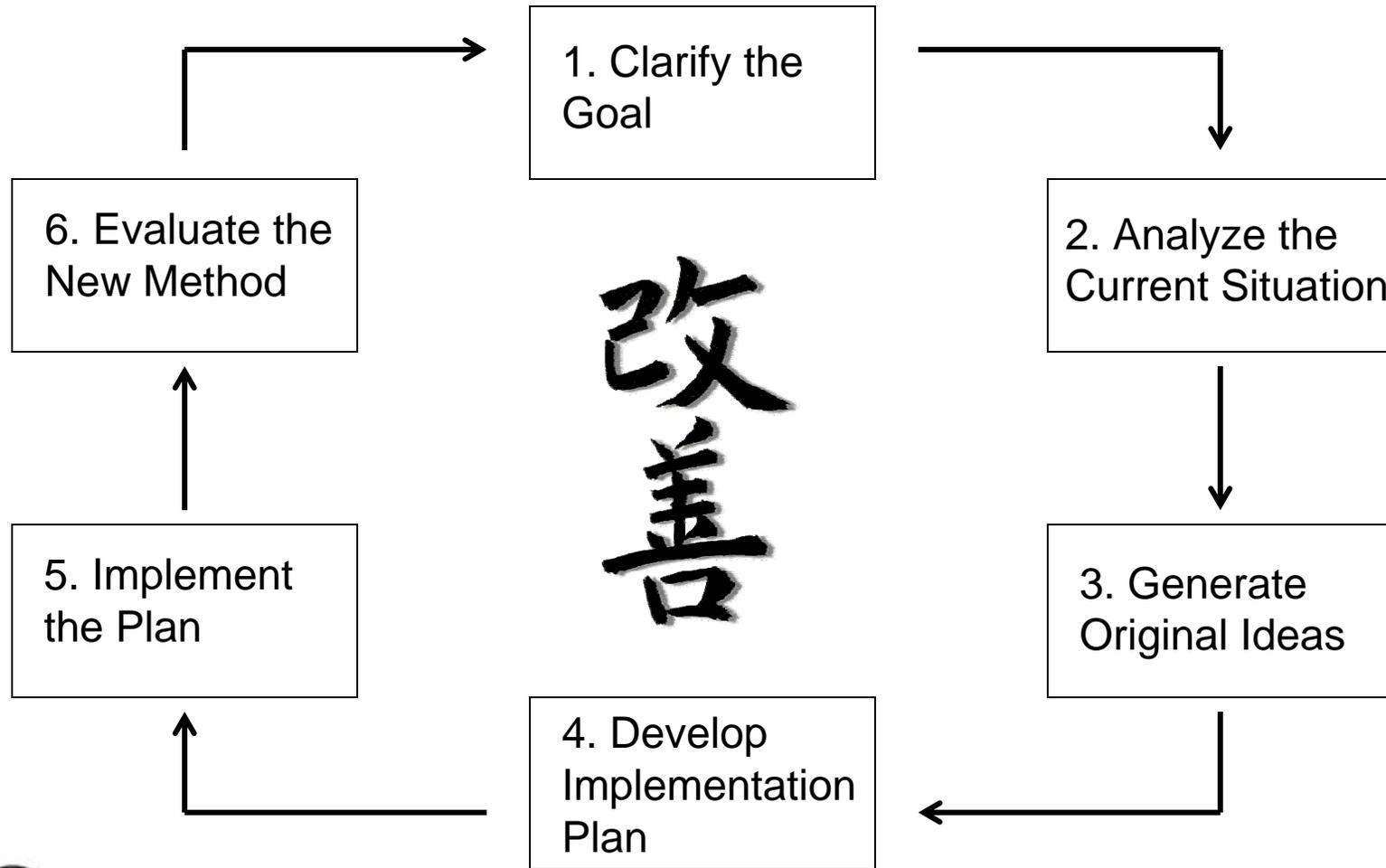
Standardized Work Chart

Acme Corp.		Plant: Acme	Product: 8" Pinion Gear
Standardized Work Combination Table		Area: Gear Machining	Op. 1 of 1
		Process: Gear cutting exercise	Pg. 1 of 1
Date:	By:	Approved By:	Shifts: 2
		Volume: 600	Takt Time: 46 secs. Cycle Time: 46 secs.

No.	Major Steps	T	A	M	I	A	I	M	L	M	Working Sequence			Safety	SWIP	Quality
											R	O	E	+	⊗	◇
1	Pick up raw material	1	--	--	--	--	--	--	--	--						
2	Unload, load part and start M/C GC614	5	38	--	--	--	--	--	--	--						
3	Unload, load part and start M/C CH228	6	7	--	--	--	--	--	--	--						
4	Unload, load part and start M/C GC1444	6	38	--	--	--	--	--	--	--						
5	Unload, load part and start M/C GC1445	6	30	--	--	--	--	--	--	--						
6	Unload, load part and start M/C TS110	7	3	--	--	--	--	--	--	--						
7	Pack FG in pallet	1	--	--	--	--	--	--	--	--						

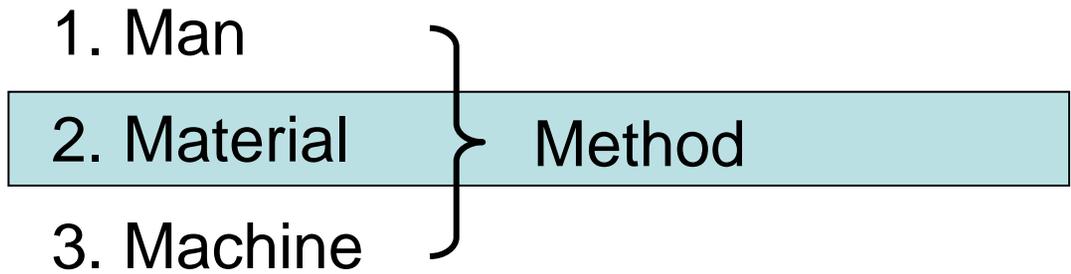


Standardized Work & Kaizen

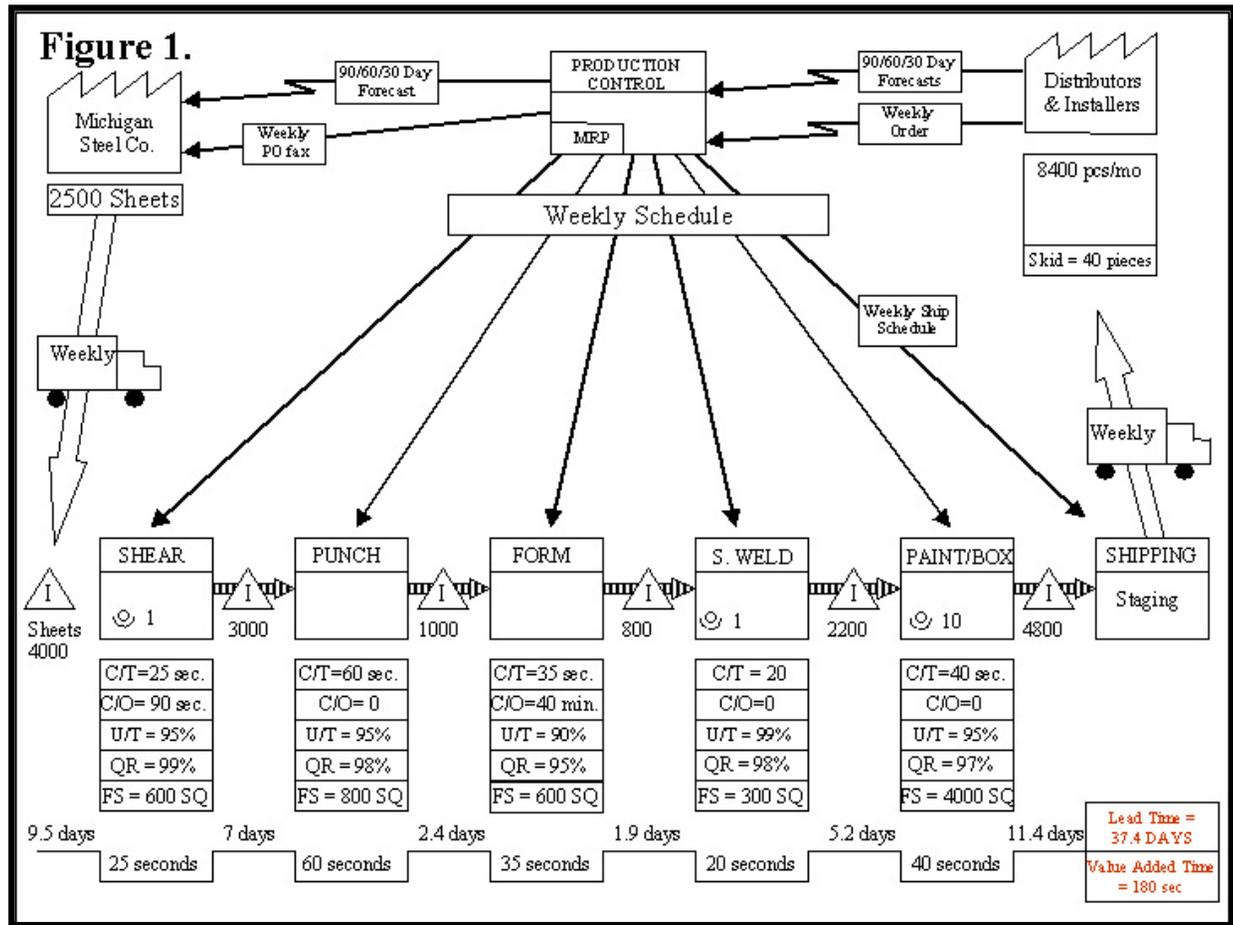


Kaizen Patterns

- Three main types (and many derivatives...)



Material Information Flow Analysis (VSM)



Takt Time

**Flow
-Material
-Information**

Inventory

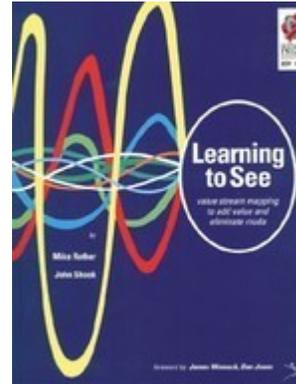
Process Info

Lead-time

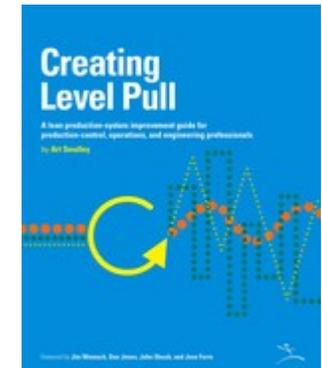


Learning To See

1. What is takt time?
2. How to create flow?
3. Where is the pacemaker?
4. How to implement pull?
5. Make to order to make to stock?
6. How to level production?
7. What pitch increment?
8. How to improve process flow?



1. Which products should you hold in a finished-goods inventory, and which to stock?
2. How much of each product should you hold in finished goods?
3. How will you organize and control the finished-goods store?
4. At what single point will you schedule the value stream?
5. How will you level production at the pacemaker?
6. How will you convey demand to the pacemaker?
7. How will you manage information and material flow upstream?
8. How will you size your markets and trigger withdrawal pull?
9. How will you control batch processes upstream from the market?
10. How will you expand the level pull system across the facility?
11. How will you sustain your level pull system?
12. How will you improve your level pull system?



Kaizen Patterns

- Three main types (and many derivatives...)

1. Man

2. Material

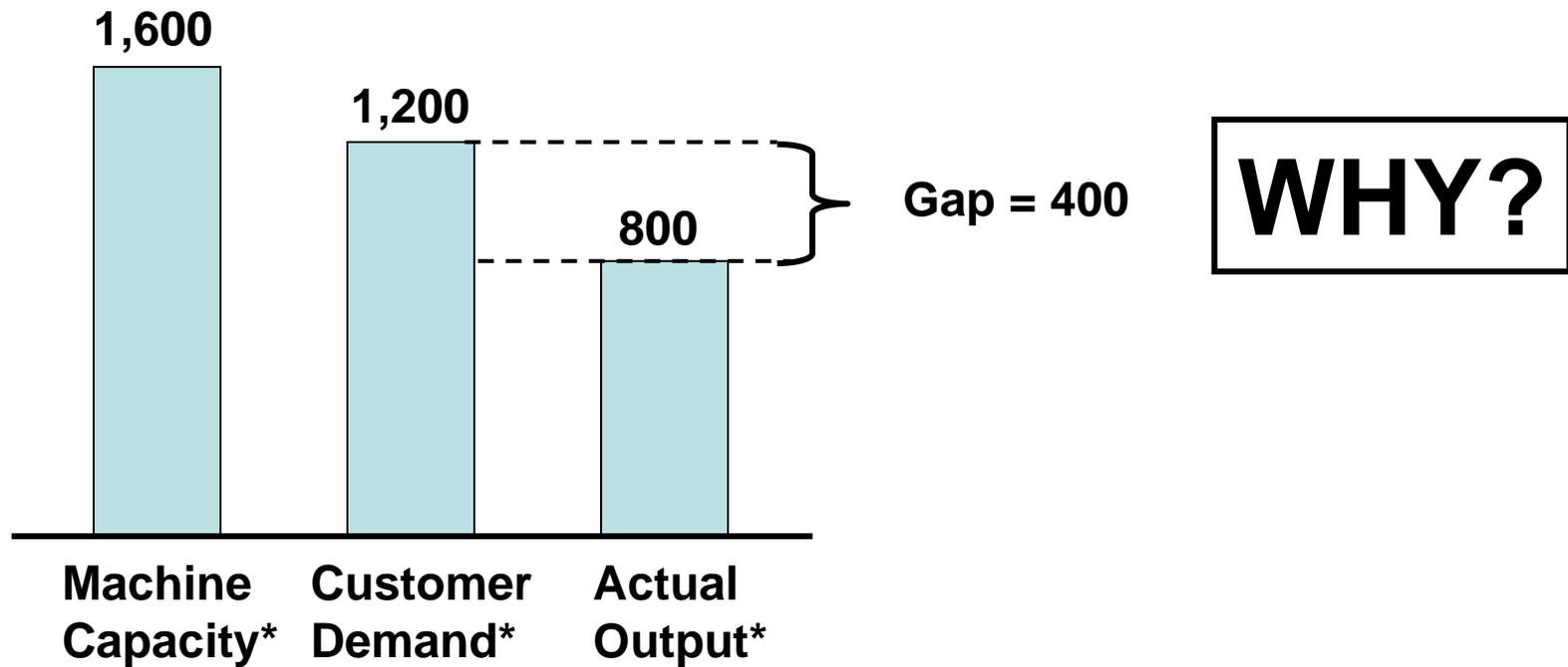
3. Machine



Method

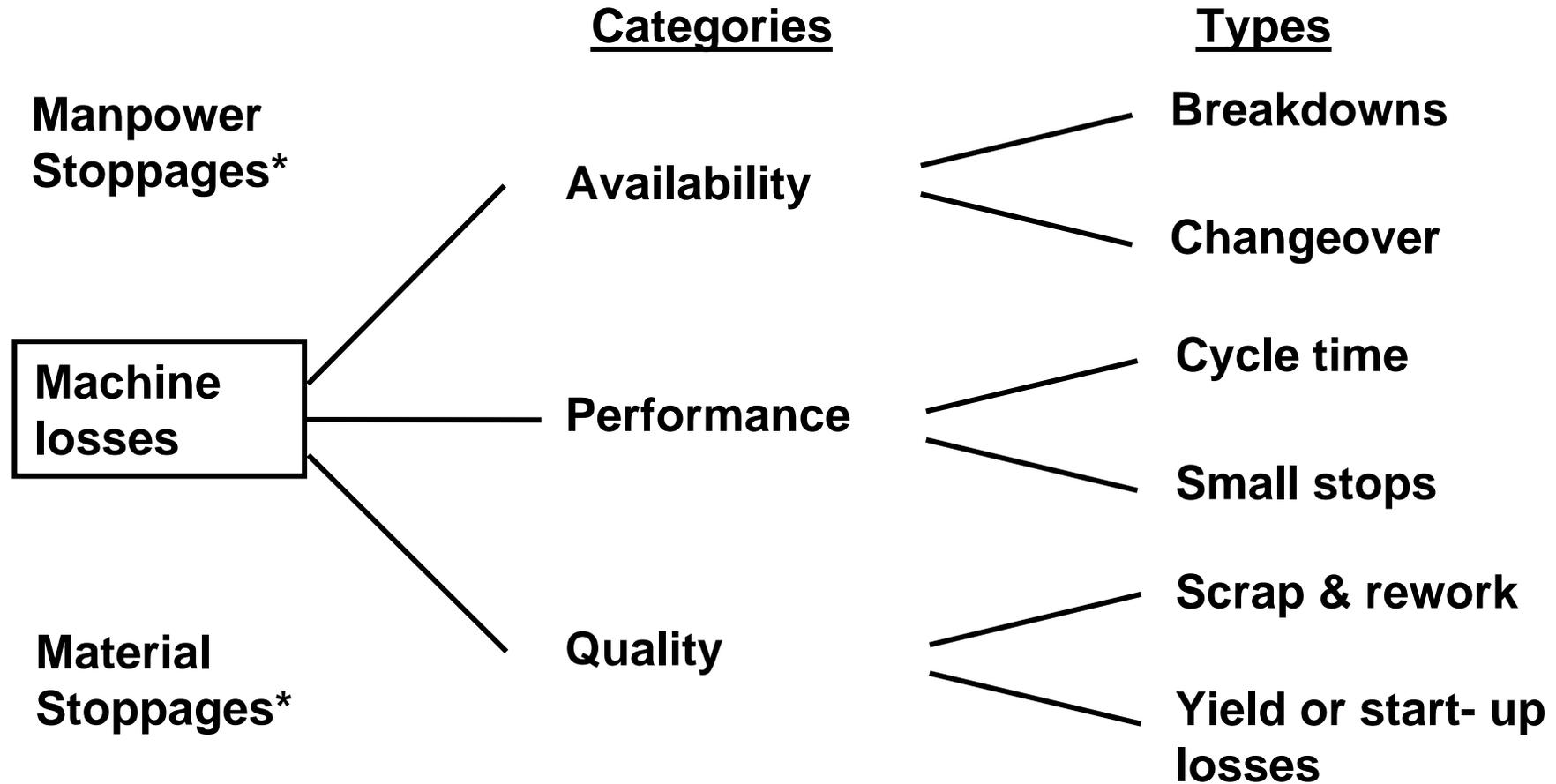


Machine Related Workshop



*Per Shift in this example

Six Machine Losses



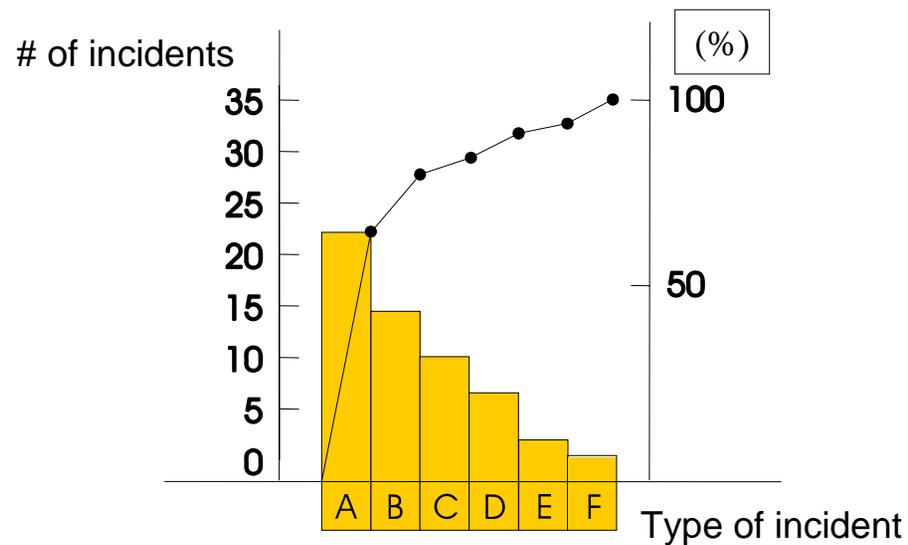
Six Sample Losses (One Example)

Illustrative Example

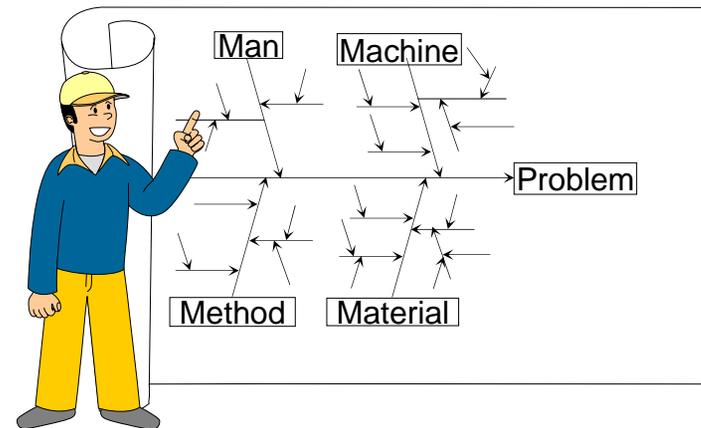


1. Breakdowns

Pareto's Curve Graph



Cause and Effect Diagram



The same type of rigor that is used in “quality” problem solving should be applied to “machine breakdown” problem solving...

2. Set Up Reduction For Changeover

Line Name		Set Up Reduction Worksheet						
Part Name		(Work element analysis, time study, problem identification sheet)						
Process Name		Machine Name			Part Number			
No.	Main Set Up Work Elements	Time Study			Category		Problem Point	Countermeasure
		Start	End	Total	Int.	Ext.		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								



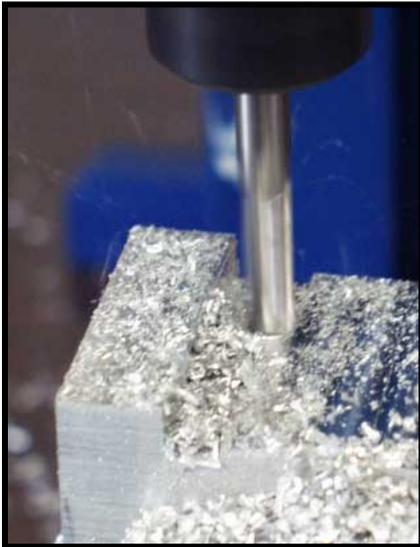
3. Machine Cycle Time Study

1. Automatic doors open	2"
2. Remove part from machine (or auto eject, etc.)	2"
3. Load next part	2"
4. Clamp part / Coolant on	3"
5. Table index	3"
6. Grinding wheel on (or tool rotates, etc)	4"
7. Rapid feed advance	4"
8. Air cut	2"
9. Rough cut	18"
10. Dwell	2"
11. Finish cut	20"
12. Air cut	2"
13. Rapid feed retract	4"
14. Table return / Coolant off / Air blow	4"
15. <u>Unclamp part</u>	2"
16. Automatic door open – Repeat cycle	76"

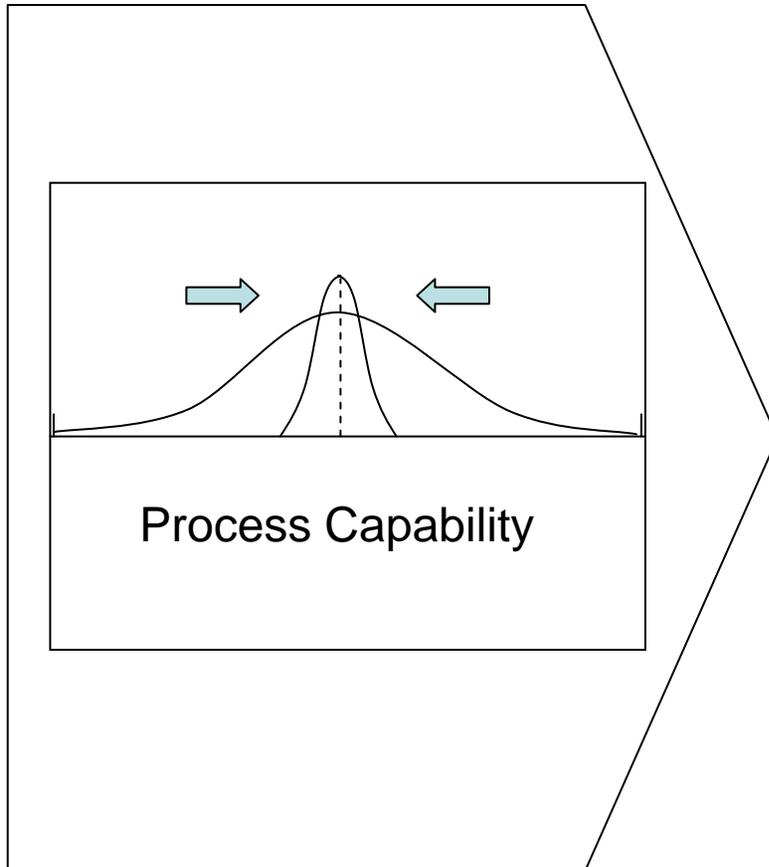
Usually only 50% of the machine cycle time is value add...

4. Minor Stops (Machining example)

1. Cutting chips on fixtures
2. Limit or proximity switch problems
3. Part jamming
4. Operator adjusting “something”
5. Confusion of on-line and off-line work for operator
6. Etc.



5 & 6. Scrap and Yield Losses (Machining Example)



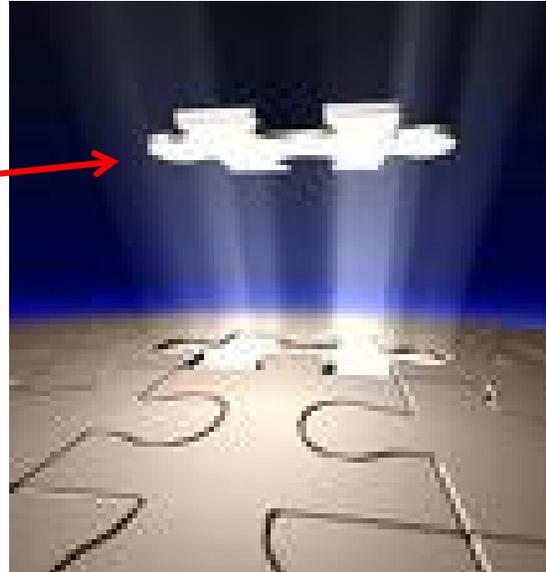
1. What is the actual capability of the process?
2. Which dimension is in trouble? By exactly how much? Since when?
3. How is the condition of the tool?
4. Where is the datum? What is its condition?
5. How is the part located and clamped?
6. How is the part measured and gauged?
7. What is the condition of the various fluids (coolant, oil, grease, etc.)
8. What is the actual machining cycle?
9. What mechanical interference might be occurring?
10. What is misaligned in the machine – how much?
11. What is the condition of the spindle head / bearing unit (e.g. run out)
12. How is the tool holder condition?
13. How good is the incoming material?
14. What else is worn that can cause variation?

How does this all relate to TWI?



A piece of the TPS puzzle...

TWI?



Question: Is it a missing piece for you?

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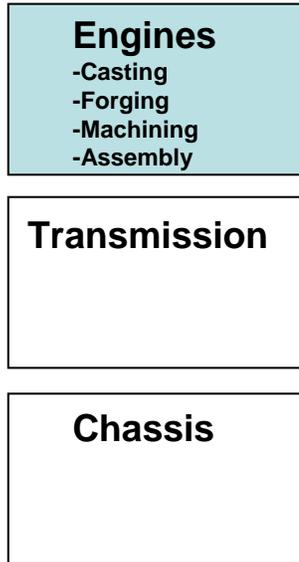
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TPS timeline selected events

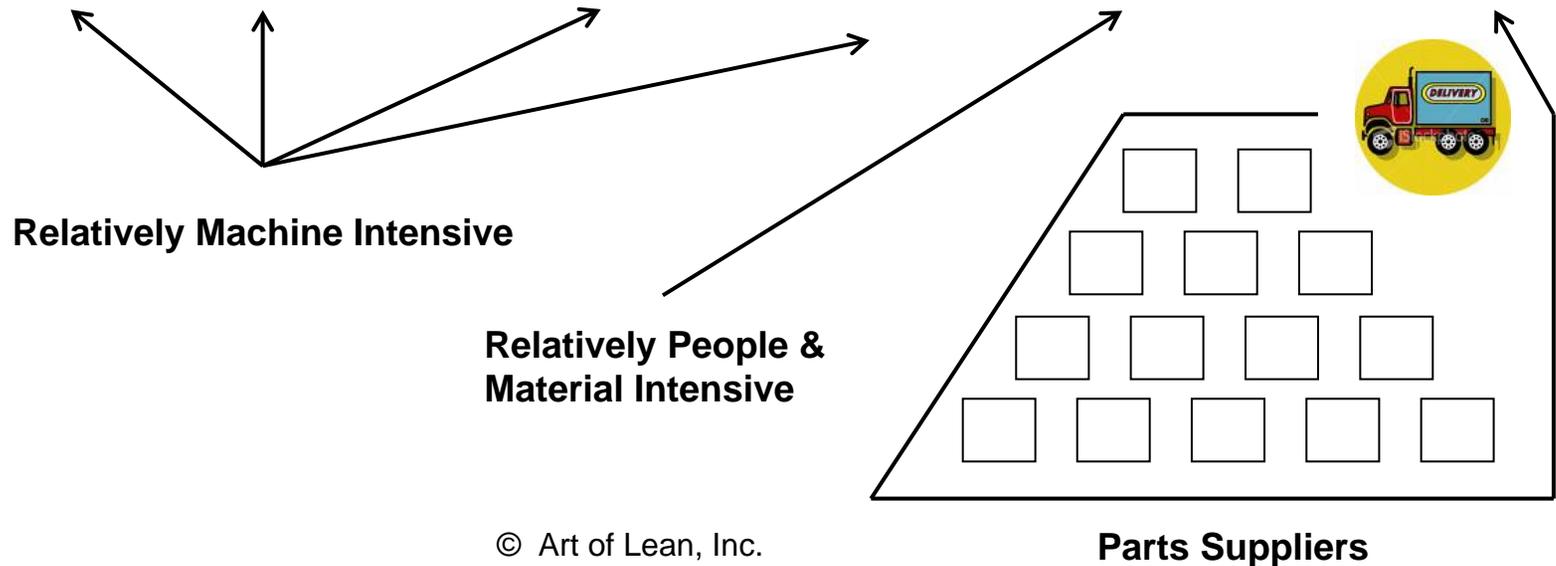
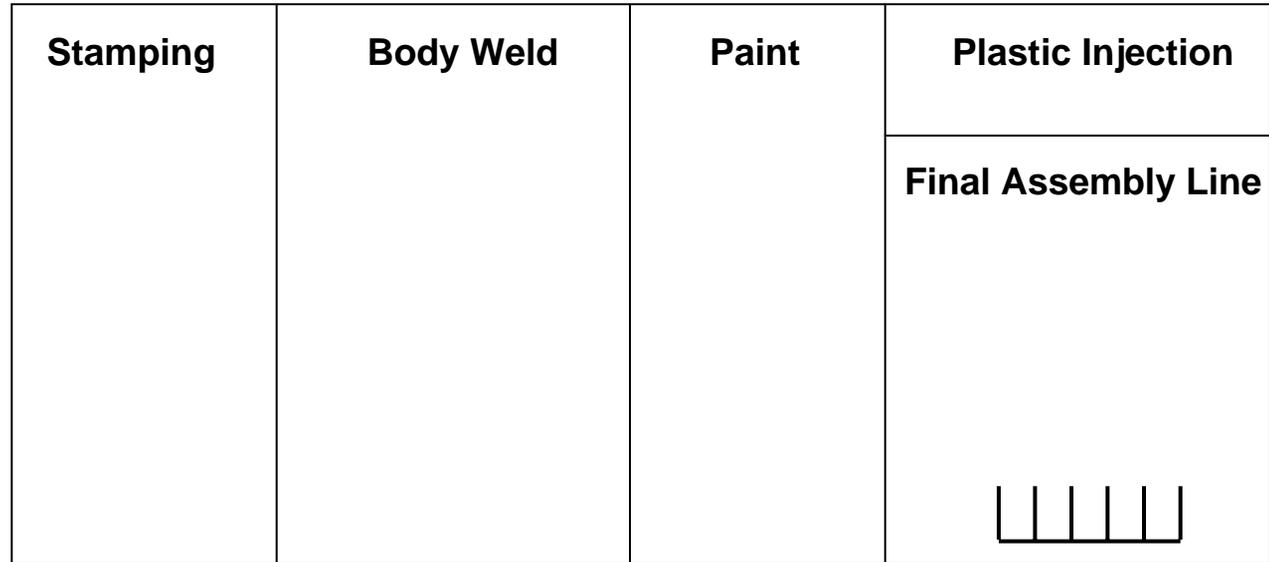
- 1902 Jidoka features appear on Toyoda Looms
- 1924 Magic Loom (1 person many machines, auto stop, zero shuttle change over time, etc.)
- 1927 First moving conveyor assembly line inside Toyota Loom plants
- 1937 Start of Toyota Motor Corporation
- 1947 - 49 TPS experiments start in the machine shops under Taiichi Ohno
- 1950 Improved product flow and multi-process handling
- 1951 - 53 TWI training courses commence for supervisor development**
- 1955 Emergence of more “efficient production system” (Machining plant with product flow, multi-process handling, elementary visual control, limited WIP, job instructions / initial forms of standardized work)
- 1956 Basic establishment of replenishment pull and initial leveling
- 1957 Expansion outward from the machine shops
- 1961 TQC efforts begin (driven by Eiji Toyota)
- 1962 Synchronization of plants and full kanban adoption as well as 15 minute average changeover time across the company
- 1965 Toyota awarded Deming prize for quality
- 1969 Toyota establishes OMCD internal consultants / TPS codification begins
- 1971 Toyota group related plants receive TPM awards
- 1972 Regular supplier improvement workshops commence
- 1973 TPS basic format complete and initial education handbook created
- 1984 First major TPS launch overseas in the U.S. (NUMMI)
- 1991 Mass intro of TPS (i.e. lean production) to outside world by J. Womack and D. Jones

Generic Automotive Plant

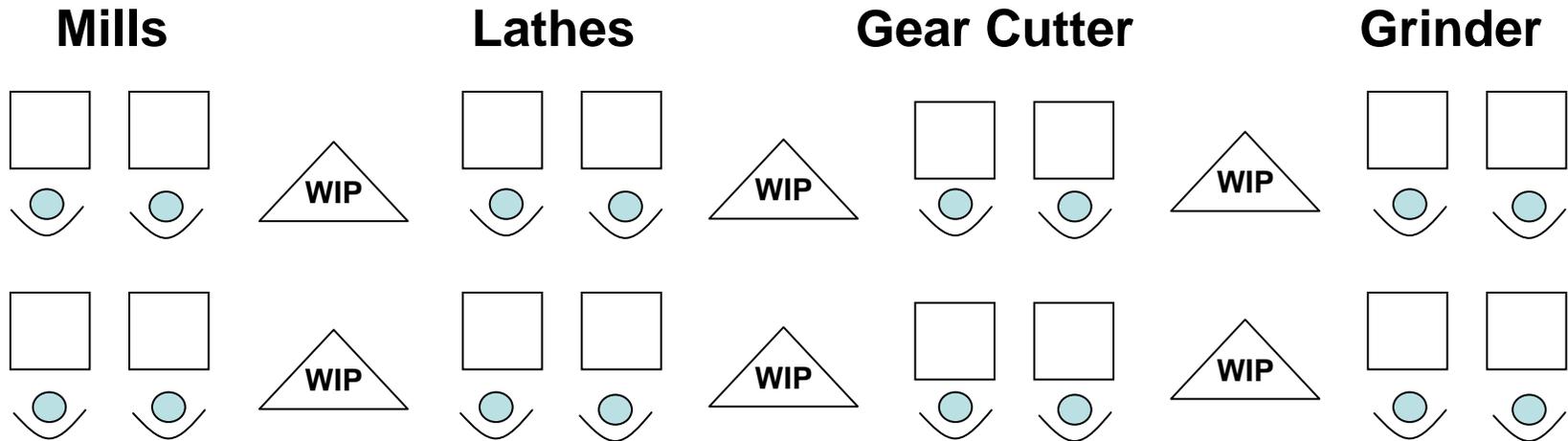
Components



Vehicle Plant

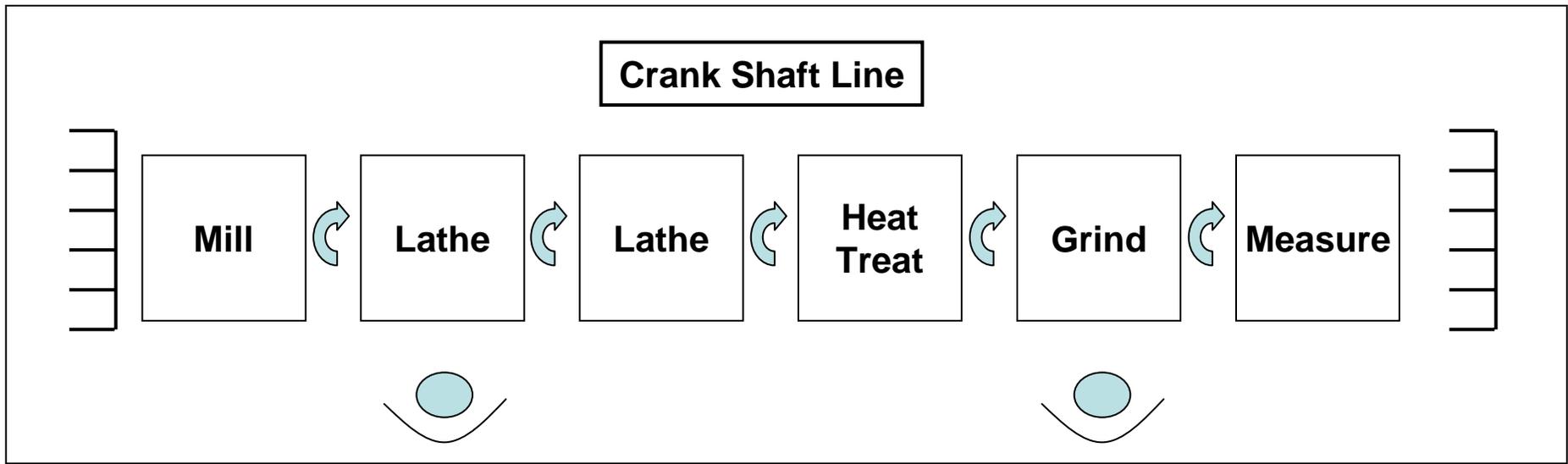


Process Based Layout In Ohno's Machine Shops



- Build up of WIP between stations and departments
- Over-production of wrong items / under-production of needed items
- Specialized operators only ran one type of machine
- Hard to realize productivity gains / work un-balanced
- Defects were hidden
- Down time problems were not obvious
- Lot's of “busy” work but too little value added work

Conversion To Product Flow In Ohno's Machine Shops

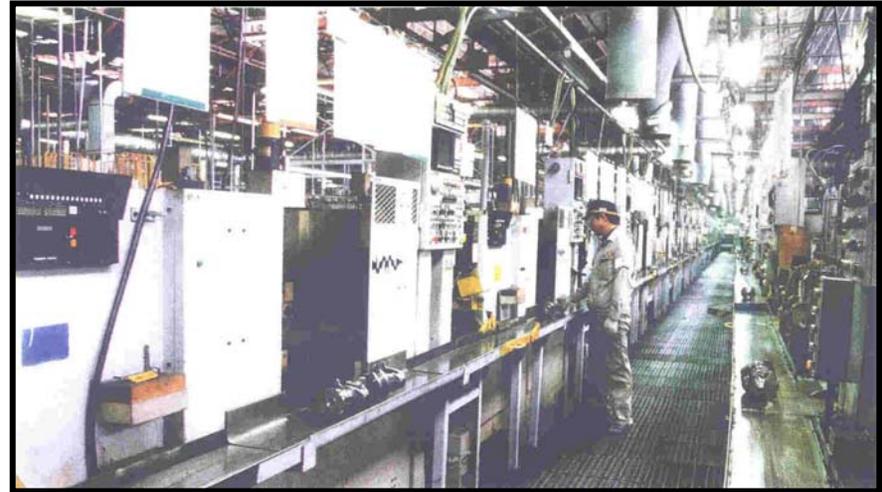


- Stop overproduction. Avoid build up of WIP between stations
- Build in quality at the source
- Level the quantity produced on a daily basis (don't over-produce or under-produce)
- Pull production based upon downstream demand not a push
- Operators run more than one type of machine (multi-machine handling & multi-skilled)
- Work load balanced to takt time and adjusted monthly
- Defects are surfaced rapidly and dealt with as they happen (ideal case)
- Down time problems are surfaced and dealt with as they happen (ideal case)
- Reduction of waste in the overall sense and total system productivity gain

Toyota Machine Tools 1950 versus 1990



- 1945 Machine Tool in Toyota
- 1 Person operates 1 machine
- Low Productivity / Low Quality



- 1990 Machining Line in Toyota
- 1 Person operates 20+ machines
- High Productivity / High Quality

Start with some basic TPS questions...

	<u>Key TPS Questions</u>	<u>Typical Problems</u>	<u>Countermeasures or analysis tools</u>
<p>1. How will you satisfy the customer and obtain a <u>profit</u>?</p> <p>2. What are your <u>main problems</u> in production (or elsewhere) ?</p>	3. How will you produce 100% JIT?	<ul style="list-style-type: none"> •On-time delivery •Inventory •Lead-time 	<ul style="list-style-type: none"> •VS Mapping •Flow of product •Pull system / kanban
	4. How will you build in 100% quality?	<ul style="list-style-type: none"> •Customer defects •Scrap •Rework 	<ul style="list-style-type: none"> •Abnormality detection •Stop the machine •Process Cpk
	5. How will you stabilize the operation 100%?	<ul style="list-style-type: none"> •Capacity losses •Downtime •Scrap & Rework 	<ul style="list-style-type: none"> •6 losses •OA / Maintenance •Problem solving
	6. How will you standardized work 100%?	<ul style="list-style-type: none"> •Labor productivity •Scrap & rework •Safety 	<ul style="list-style-type: none"> •Job Instruction •Standardized work •Motion analysis
	7. How will you develop natural work team leaders?	<ul style="list-style-type: none"> •Team supervision •Skills development •Small improvements 	<ul style="list-style-type: none"> •TWI/JR •TWI/JI •TWI/JM
	8. How will you sustain and improve?	<ul style="list-style-type: none"> •Recurring problems •Firefighting •Poor problem solving 	<ul style="list-style-type: none"> •PDCA •Root cause analysis •Recurrence prevention



TWI Introduction at Toyota

TWI Course Description	Date of Initial Training	Number of Trainers Developed
Job Instruction	December 1951	290
Job Methods	June 1952	366
Job Relations	March 1953	265
		Total 921

Job Instruction Skill Set

How to teach an employee to do a particular job

- Safely
- Correctly
- Conscientiously

JI Motto –

If the employee has not learned,
then the instructor has not taught!



Job Method Skill Set

1. Eliminate unnecessary details (ムダの排除?)
2. Combine details when practical
3. Rearrange work details for a better sequence
4. Simplify all remaining necessary details
 - a. Make the work easier
 - b. Pre-position materials, tools, and equipment at the best places
 - c. Use gravity feed hoppers and drop chute delivery
 - d. Let both hands do useful work
 - e. Use jigs and fixtures instead of hands for holding work
5. Work out your ideas with other
6. Write up your proposed new method

Job Relations Skill Set

The primary concept behind JR is that a supervisor gets results through people. Good relations = Good results!

Foundations for Good Relations

- Let each worker know how he is doing
 - Figure out what you expect from him or her
 - Point out ways to improve (feedback)
- Give credit when due
 - Look for extra or unusual performance
 - Tell him while it is still fresh
- Tell people in advance about changes that affect them
 - Tell them why if possible
 - Get them to accept change
- Make the best use of each person's ability
 - Look for ability not now being used
 - Never stand in a person's way

People must be treated as individuals!



Sample early training courses in Toyota

- **Training Within Industry (TWI) Courses - Started in 1951 & influence continues today**
 1. **Job Instruction**
 2. **Job Relations**
 3. **Job Methods -- Replaced in 1955 by the P-course training**
 4. **Job Safety -- Added by Toyota to the above courses**
- **P-Courses taught by Mr. Shingo – Started in 1955 and continued until 1980**
 1. **Motion analysis**
 2. **Time study analysis**
 3. **Operational analysis**
 4. **Process analysis**
- **TQC related courses (Starting around 1962 with the TQC program)**
 1. **QC Circle activity**
 2. **Basic problem solving**
 3. **Statistical quality control**
- **Standardized work – established in the early 1950's and refined up until 1978**
- **Kaizen training course – formalized in 1978 and replaced the P-course**
- **Role of a Supervisor – formalized in 1970 and continues today**
 1. **Role of a Team Leader**
 2. **Role of a Group Leader**



TWI and TPS (Is / Is Not)

TWI (3J) IS...

A way to breakdown jobs
A method for teaching skills
A plan for skills development
A proactive form of problem solving
A way to identify unnecessary details
A way to promote small improvement
A method of improving work relations
A technique for resolving work problems
Etc.

TWI IS NOT...

Standardized Work
Flow
Pull
Level
SMED
Takt-time
Jidoka
Visual control
Etc.



TPS Summary 1973

論より実践

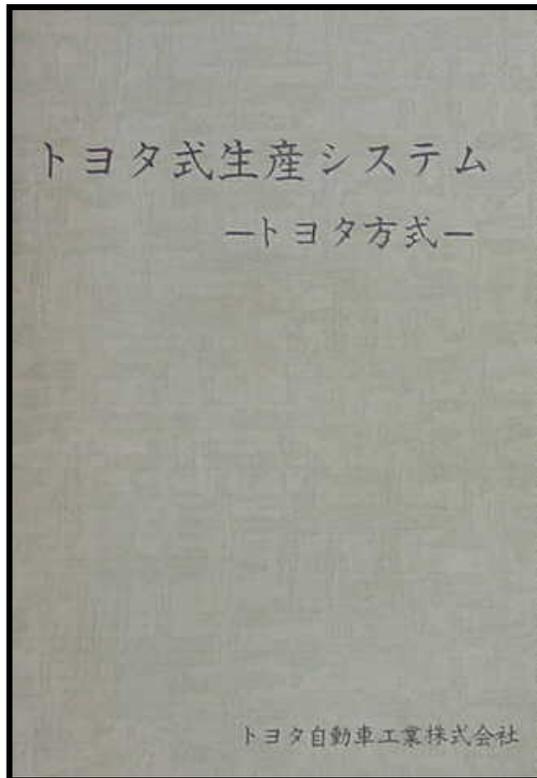
“Practice over theory”

専務取締役 Managing Director



大野耐一

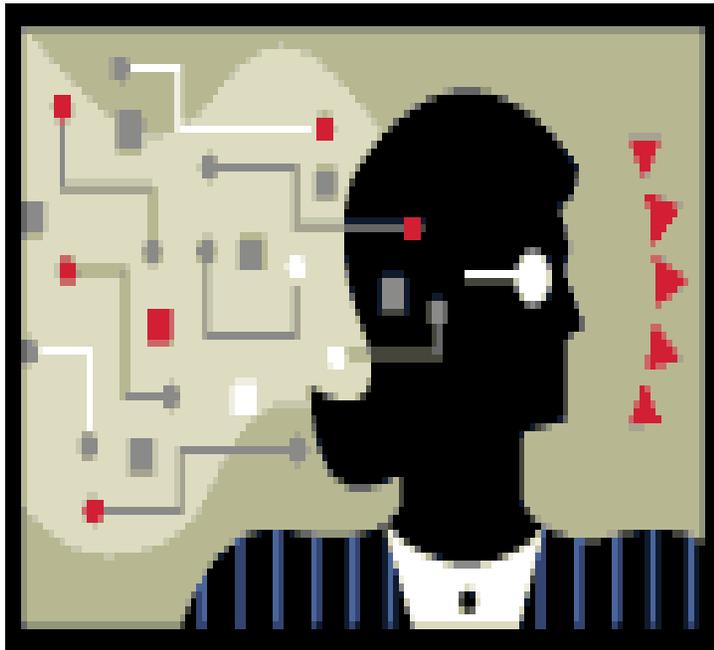
Ohno Taiichi



First TPS Manual.
1973 Education &
Training Department

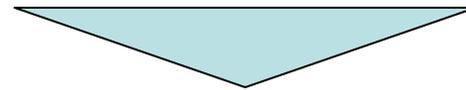
1. TPS is a series of related activities aimed at elimination of waste in order to **reduce cost, improve quality, and improve productivity.**
2. **Scientific Mindset:** On the shop floor it is important to start with **actual phenomenon** and search for the **root cause** in order to solve the problem. In other words we must emphasize **getting the facts..**
3. In problem solving the **purpose** must be made clear...in Kaizen the **needs** must be made clear.

TPS is built on the scientific way of thinking...



General Scientific Method

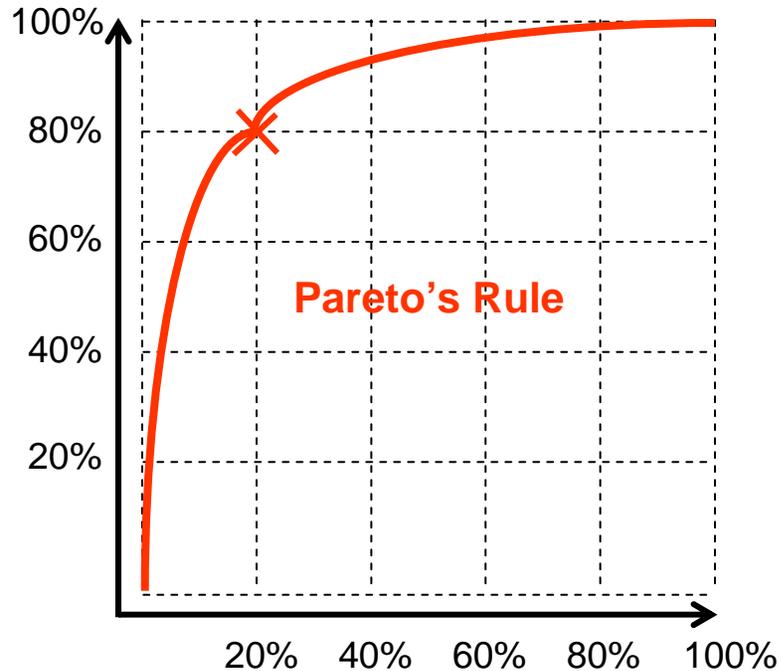
1. Define the question / make observations
2. Gather information and facts
3. Form hypothesis
4. Perform experiment and collect data
5. Analyze data
6. Interpret data and draw conclusions
7. Summarize results



TPS Basic Problem Solving / Kaizen

1. Define the problem / opportunity
2. Analyze the causes
3. Set a goal
4. Implement the action items
5. Check the results
6. Follow up / Standardize

Learn to focus on what matters the most...



Original: 80% of wealth is in the hand of 20% of the population

Quality: 80% of total incidents are caused by only 20% of the items

Lead-time: 80% of lead-time is tied up by 20% of the operations

*“In problem solving learn to separate the **vital few** from the **trivial many**”*

Dr. Joseph Juran

In other words there are a thousand plus problems and things that we would like to do in any facility. But there are probably a few things that will matter more and we'll achieve impact faster by focusing on the vital few items first...

Top 10 Reasons for Doing TWI

- Promotes critical skill development and capability in **supervisors**
- JI Method for training (and not just documentation)
- JI Simple ways to break down a job and promote cross training
- JI Proactive form of problem solving
- JR Simple framework for resolving work team relations problems
- JR Promotes good foundational principles for leaders to follow
- JR Addresses invisible forms of waste
- JM Simple framework for identifying unnecessary details
- JM Promotes eliminating, combining, rearranging, & simplifying work details
- JM Gets people to look more closely at processes and spot problems

This can be an awfully nice bit of help?

Discussion / Q&A

