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Lean Principles and Tools

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Lean Principles and Tools

- In this session, we will discuss Lean Tools for Improving a Process
  - 5S, Poka Yoke, Visual Controls
  - Failure Mode and Effects Analysis (FMEA)
  - Quick Changeovers (Single Minute Exchange of Dies or SMED)
  - Batch vs. Single Piece Flow
  - Cellular Design
  - Kaizen Blitz
  - Total Productive Maintenance (TPM)
  - Overall Equipment Effectiveness (OEE)
  - Flow and Pull
  - Kanbans
  - Inventory
  - Theory of Constraints
  - Little's Law

- A list of supplemental material and additional practice/review questions for this session are provided at the end of this presentation
- You can download the pdf of this presentation, along with any supporting data files, on the site where you are accessing this course

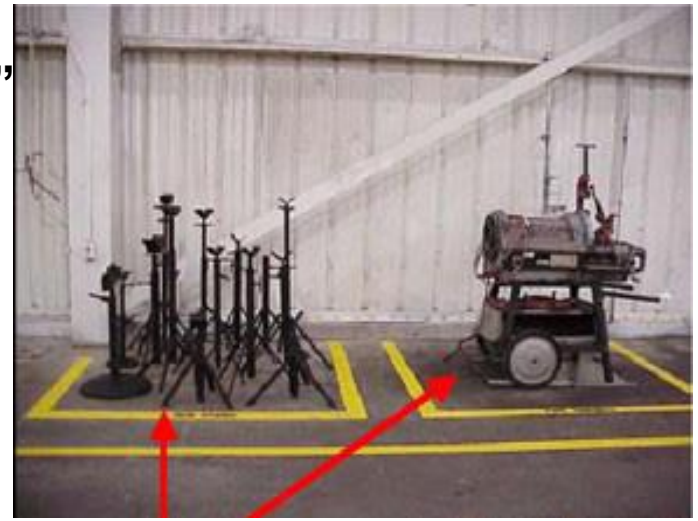
5S … Organizing the Workplace

- 5S is a methodology to implement and maintain a clean and well-organized workplace to <u>maintain high performance</u>

- 5S is based on the adage “a place for everything and everything in its place”

“Before”

“After”



tools and fixtures in their proper location

equipment located where it is needed

The 5S System

Organize the workplace …

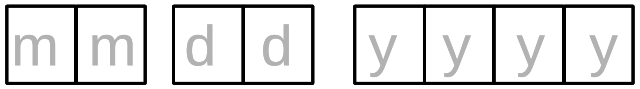
S
A
F
E
T
Y

1. **Sort** - Identify what is needed (keep) and what is not (remove)
2. **Set in Order** - Determine a place for needed items … identify the storage place with clear markings
3. **Shine** - "Clean" the office and maintain the equipment
4. **Standardize** - Office procedures, systems, and policies
5. **Sustain** - Review regularly the SOPs and ensure compliance

Provide documentation so that the work environment is clearly defined, self-regulating, and self-improving. Makes the "hidden factory" more apparent

Poka Yoke

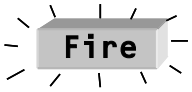
- Error or Mistake Proofing
- 2 Key Goals:
  - Detect or prevent errors at their source
  - Do not pass errors on to the next step
- Methods
  - Physical Design
    - Guides
    - Barriers
    - Sensors
    - Alarms
    - Automation
  - Logical Design
    - Data Validation
      - Double Keying
      - Data Limit Checks
      - Data Type Check
    - Checklists, Templates/Pictures



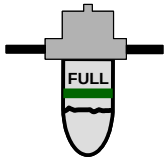
Poka Yoke + Visual Controls

- Management of Activities Through Visual Cues

- Examples of Good Controls
  - Alert to abnormal conditions



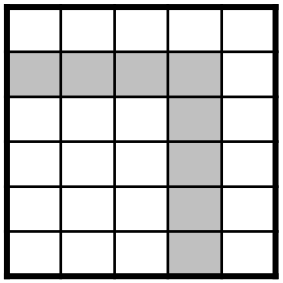
  - Indicate condition where action is desired



  - Indicate limits

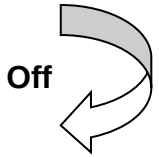
  - Help understand situation or guide actions

Follow the Gray Tiles

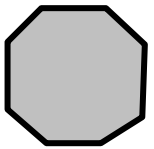


Poka Yoke + Visual Controls

- Examples of Good Controls (cont.)
  - Help avoid mistakes or errors



  - Provide quick pattern recognition



  - Prevent confusion

- Helpful Hints
  - Need to be immediately and easily recognized by all
  - Add words along with shapes or colors
  - Measurements should be meaningful to all
  - Employee and customer involvement is crucial
  - Avoid sensory over-stimulation

Benefits of Visual Controls

Visual controls are all around us, and we use them every day to stay within recommended guidelines. Speed limit signs, directional signs, yield signs, parking signs, signs are everywhere

- Cleaner and Safer Workplace
- Decreased Inventories
- Less Wasted Time
- Improved Morale
- Improved Product Quality
- Make Working Areas User Friendly by:
  - Answering questions
  - Identifying equipment, materials and locations
  - Describing actions and procedures
  - Providing safety warnings and precaution information

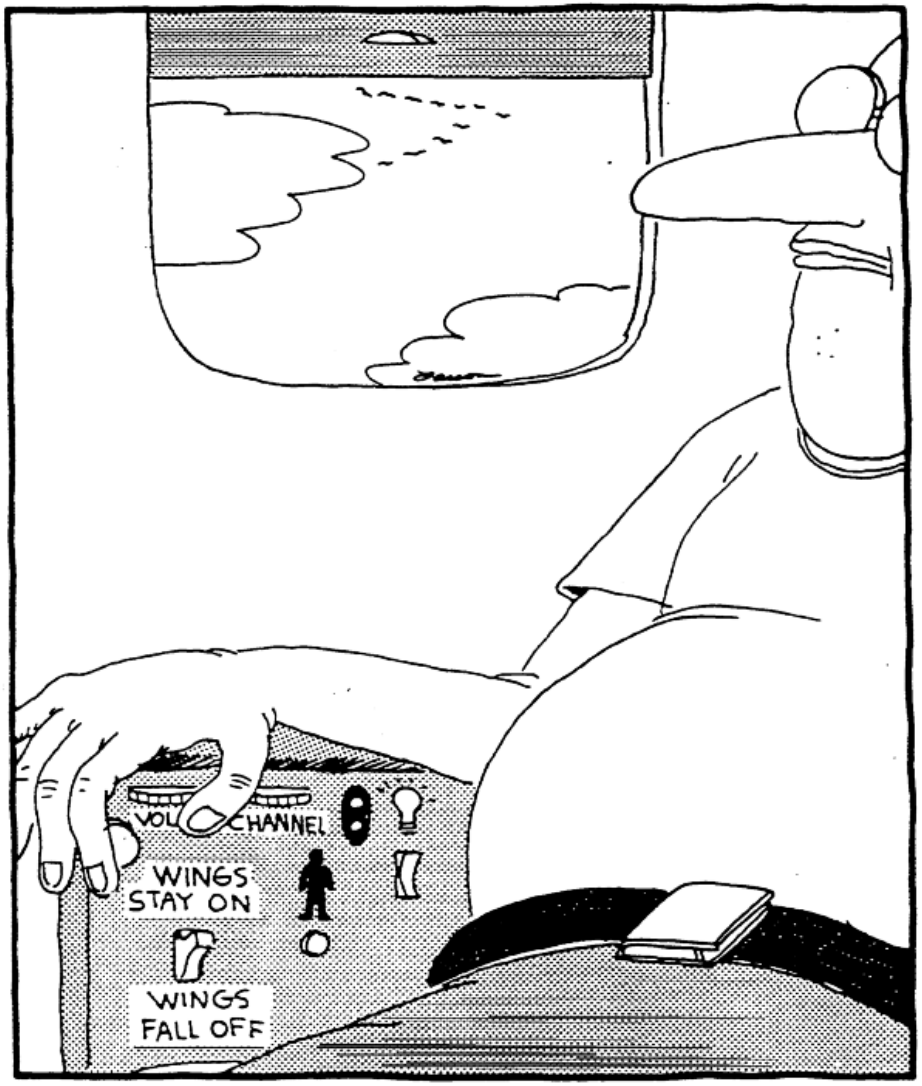
FMEA

Failure Mode and Effect Analysis is a quality planning tool that can be used in all phases of DMAIC. It is a formal way to achieve Poka Yoke or Mistake Proofing.

- Risk Management Tool
- The goal is to mitigate the risk and/or prevent the failures (mistake proof)
- What is it?

  FMEA is a systematic method for identifying, analyzing, prioritizing, and documenting potential failure modes, their effects on a system, product or process performance, and the possible causes of failure

Why FMEA?



Fumbling for his recline button,

Ted unwittingly instigates a disaster.

Source: The Far Side

Why FMEA? (cont.)

GAZETTE TELEGRAPH Sunday, Dec. 3, 1995

NATION

Physician fined, barred for 6 months

Florida doctor amputated wrong foot

Associated Press

MIAMI – A doctor who amputated the wrong foot of a diabetic patient and cut off another patient's toe without her consent was fined $10,000 on Saturday and barred from practicing medicine for six months.

The 15-doctor state Board of Medicine voted unanimously to reduce the sentence recommended last month by a state hearing officer. The board cited Dr. Rolando Sanchez's previously unblemished record and noted that the diabetic's other leg would probably have been amputated anyway.

"I'm not saying what he did wasn't wrong," board member Dr. Edward A. Dauer said. "But doctors are not God, and hospitals are not heaven."

The hearing officer had proposed a two-year punishment and a $15,000 fine and recommended that Sanchez be directly supervised by another surgeon during a five-year probation.

Sanchez can apply the 140 days he has been suspended under an emergency order, so he could be back in the operating room by early 1996. He will be on probation for two years with indirect supervision.

He has 30 days to appeal to a state appeals court. His lawyer called the punishment fair and declined to say if he will appeal.

State and federal investigators found a series of procedural problems at University Community Hospital contributed to the wrong-foot amputation on Willie King in [illegible]uary. King, 52, later had his gangrenous other foot amputated at another hospital. He and Sanchez came to a private settlement.

In the second amputation several months later, the board found that Sanchez failed to warn the patient that amputation was a possibility.

Types of FMEAs

- Process: Used to analyze processes and identify potential process failure modes (machines, tools, work stations, product lines, testing, measurement systems, service and administration)

- Design/Product: Used to analyze products and identify potential failure modes early in the development cycle (components, subassemblies)

- Defect: Used to analyze and prioritize defects (errors, mistakes) to prevent reoccurrence (in products and processes)

- There are two ways to accomplish an FMEA:
  - A simplified FMEA (using structured brainstorming). Very similar to a 5 Why's process. We won't cover this method in this course
  - A more formal FMEA (using a spreadsheet, scoring, and such)

FMEA Major Components

- Product Components or Process Steps
- Failure Modes
- Potential Effects and Severity of Failure Modes
- Potential Causes and Likelihood of Occurrence
- Current Design or Process Controls in Place and their Effectiveness
- Risk Priority Number
- Recommended Actions

Process/Product FMEA Template

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Product Component or Process Step	Failure Mode	Failure Effects (Consequence of Failure Mode)	SEV	Causes (of Failure Mode)	OCC	Controls	DET	RPN	Actions	Plans	pSEV	pOCC	pDET	pRPN

Risk Priority Number (RPN) = Severity x Occurrence x Escaped Detection

SCORING: **(Product and Process FMEAs)**

Category \ Score	5 (Very Bad)	4	3	2	1 (Good)
Severity (SEV)	Severe consequence of failure	High	Moderate consequence of failure	Minor	Negligible consequence of failure
Occurrence (OCC)	Very high probability cause of failure mode will occur	High	Moderate probability cause of failure mode will occur	Low	Very low probability cause of failure mode will occur
Escaped Detection (DET)	Very high probability failure will escape detection before reaching the "customer"	High	Moderate probability failure will escape detection before reaching the "customer"	Low	Very low probability failure will escape detection before reaching the "customer"

Sample Process FMEA: Self-Serve Gas

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Process Step	**Failure Mode**	**Failure Effects (Consequence of Failure Mode)**	**SEV**	**Causes (of Failure Mode)**	**OCC**	**Controls**	**DET**	**RPN**	**Actions**	**Plans**	**pSEV**	**pOCC**	**pDET**	**pRPN**
Find gas pump	All pumps busy	Must wait for pump	1	Friday / pm rush hour	3	Fill on Thursday	1	3						
		Find another station	3	Impatient / hurry	3	More exercise	2	18						
	Gas cap on other side of vehicle	Must move car	2	Poor planning	2	None	5	20						
Get correct hose	Unavailable	Must move car	1	Poor planning	1	None	5	5						
		Buy different octane	2	Impatient / hurry	3	Exercise	5	30						
Initialize pump	Pump won't reset	Can't pump gas	2	Previous person has not paid	1	Choose better station	1	2						
			2	Attendant failed to reset	1	Choose better station	1	2						
	Pump won't read credit card	Must pay cash	4	Credit card dirty	1	Replace card	1	4						
Dispense fuel	Auto shut-off fails	Spill gas on ground	5	Pump failure	1	None	5	25						
			5	Auto tank design	5	None	5	125						
		Pay for gas on ground	2	Auto tank design	5	None	5	50						

Sample Product FMEA: Automobile Glass

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Product Components	Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Design Controls	DET	RPN	Actions	Plans	pSEV	pOCC	pDET	pRPN
Windshield Washer	Does not squirt washer fluid on windows	Obscured vision for driver and passengers	4	No fluid in reservoir	5	Item on periodic maintenance checklists	3	60	Add fluid low level light	Engineering to review by 7/1/01	4	2	1	8
			4	Blocked line	2	Screen installed	1	8	None					
			4	Pump doesn't work	1	None	5	20	Review historical failure data	Design eng'r'g review by 6/1/01	4	1	3	12
			4	Disconnected line	2	Pressure fit	2	16	None					
Windshield	Cracked / broken	Unsightly Distorted view Broken glass in car	3	Impact by object like a rock or gravel	4	Plastic lamination	2	24	Consider tempered glass	Materials to review by 6/1/01	3	4	1	12
			3	Accident/ collision	4	Plastic lamination	2	24	Consider tempered glass	Materials to review by 6/1/01	3	4	1	12
			3	Torquing due to poor fit	1	Road test for prototypes	2	6	None					
	Leaks during rain	Water in car Streaking on inside windshield	2	Poor seal	2	Sealant 1000 Rubber gasket 75	2	8	None					
			2	Seal degrades over time	3	Accelerated ageing tests	2	12	None					
Side Windows	Cracked / broken	Unsightly Broken glass in car	2	Impact by object like a rock or gravel	2	None	5	20	None					
	Won't open or close	High customer dissatisfaction No access to outside air	3	Broken mechanism	3	Lab failure tests for accelerated ageing	3	27	Review of historical failure data	Engineering to review by 7/1/01	3	2	2	12
			3	Ice build up in mechanism	1	Door seals	2	6	None					
			3	Failed motor	1	None	5	15	None					
			3	Blown fuse	1	None	5	15	None					
			3	Loose connection to electric motor	2	Crimp connector	2	12	None					

Quick Changeovers
Single Minute Exchange of Dies (SMED)

- Traditional thinking says:
  - Long changeovers lower machine/process availability
  - Startup and alignment after changeovers always create scrap/waste at first
  - Because changeovers take so long, we need to run longer lot sizes

- Benefits of SMED:
  - Higher Productivity – Reduced changeover time means increased machine efficiency
  - Flexibility – Faster response to changing customer demands
  - Employee benefits – Simpler and safer setups with less chance of errors
  - Standardization – Because the right tools and equipment are at the right place at the right time, everyone wins

What Has Been Done?

Hitachi Automotive Products
Reduced changeover from
1.5 hours to 20 minutes

Steelmill: Three 500 Ton presses completely changed over:
3 1/2 hours to 30 minutes

Automotive OEM injector molders: all molds and inserts changed, reduced from 1 1/2 hours to 9 minutes

Machine shop screw machine: tooling changed and new set-up, reduced from
1 hour to 8 minutes

The Wiremold Company
Reduced changeover from
2 hours to 10 minutes

Associated Spring
Reduced changeover from
3 hours to 20 minutes

Changeover times are usually measured from the last good piece of run A to the first good piece produced in run B.

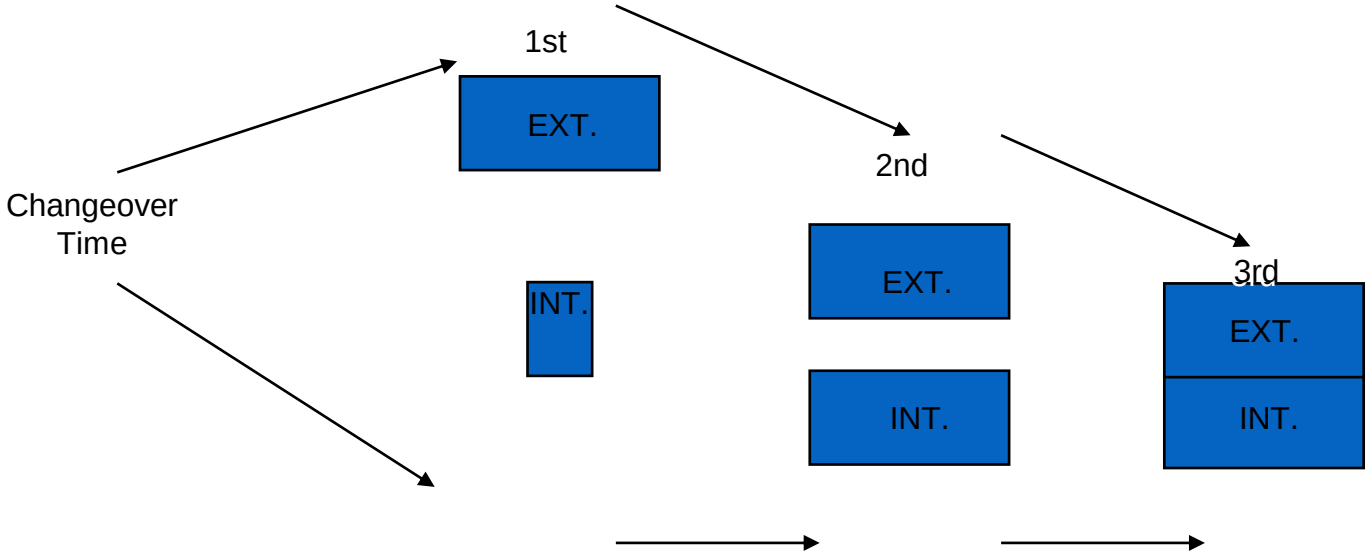
Powers and Sons
Reduced changeover from
8 hours to 2 hours

Changeover Work Allocation

Internal steps – These steps can only be performed with the equipment shut off

External steps – These steps can be performed while the machine is still in operation

Changeover time – The time from when the last good part comes off the machine until the first good part comes off after the changeover

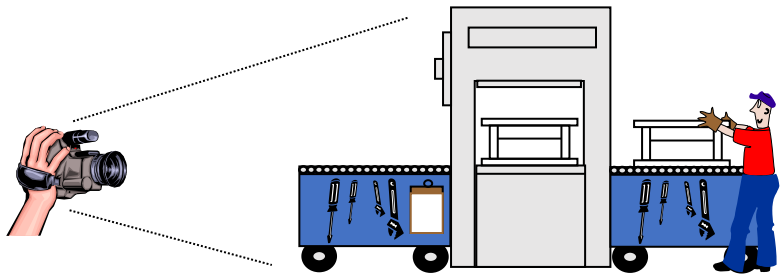


How will you know if there is a problem with changeover times?

Where do you start?

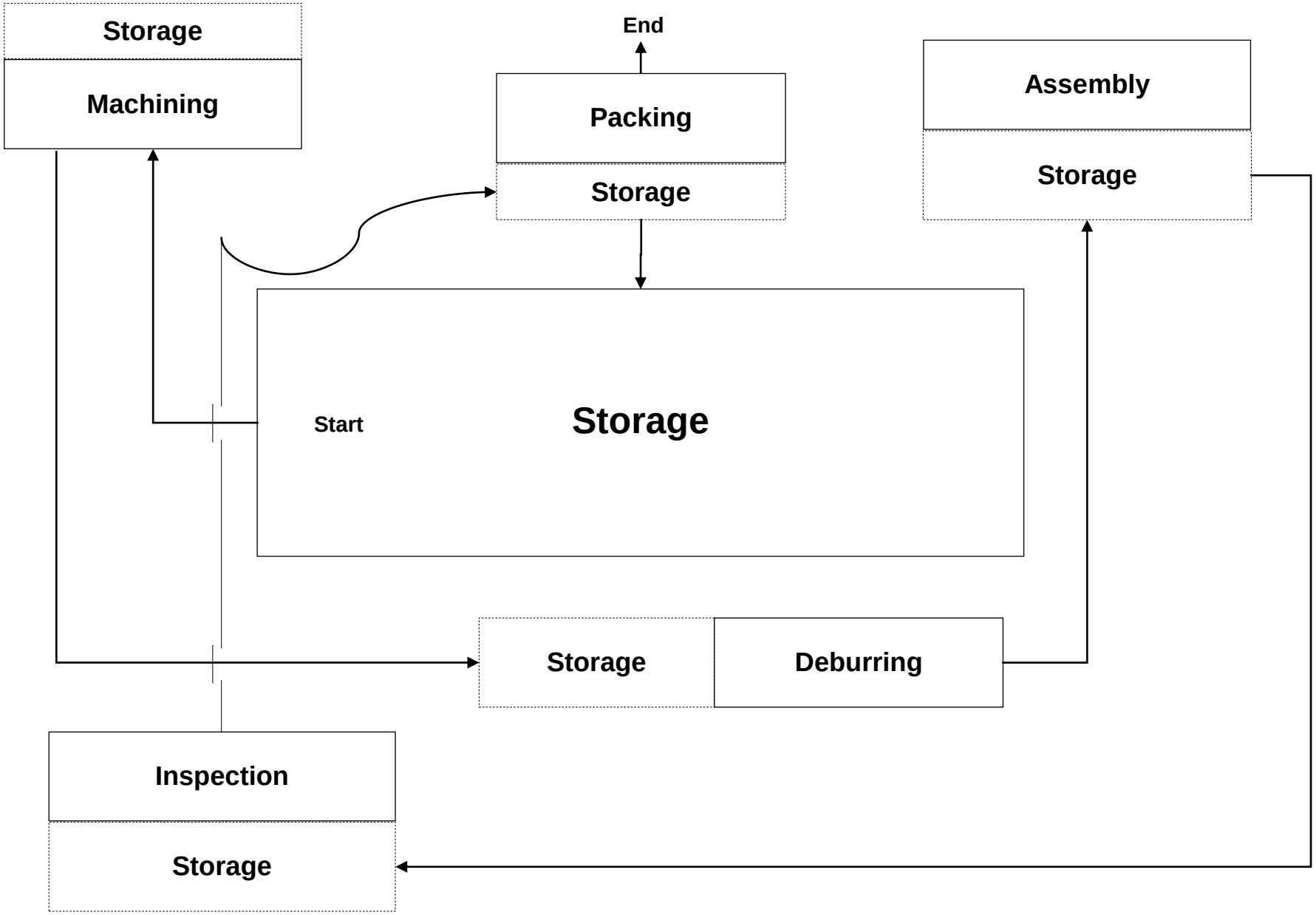
Breaking the Process Down

- Use a team of operators, tool makers, and engineers
- Observe and/or videotape the process as it is currently done
- Map the process and challenge each step. Is it required? Is there a better way? Eliminate or reduce whenever possible. Record problems that occur frequently
- Categorize each step as internal or external
- Wherever possible, convert internal steps to external steps
- Explore methods to reduce time for fastening and connecting (rapid connections), standardizing sizes and shapes, minimizing installation adjustments, etc
- Develop checklists, templates, and SOP's for setups and actions to be done



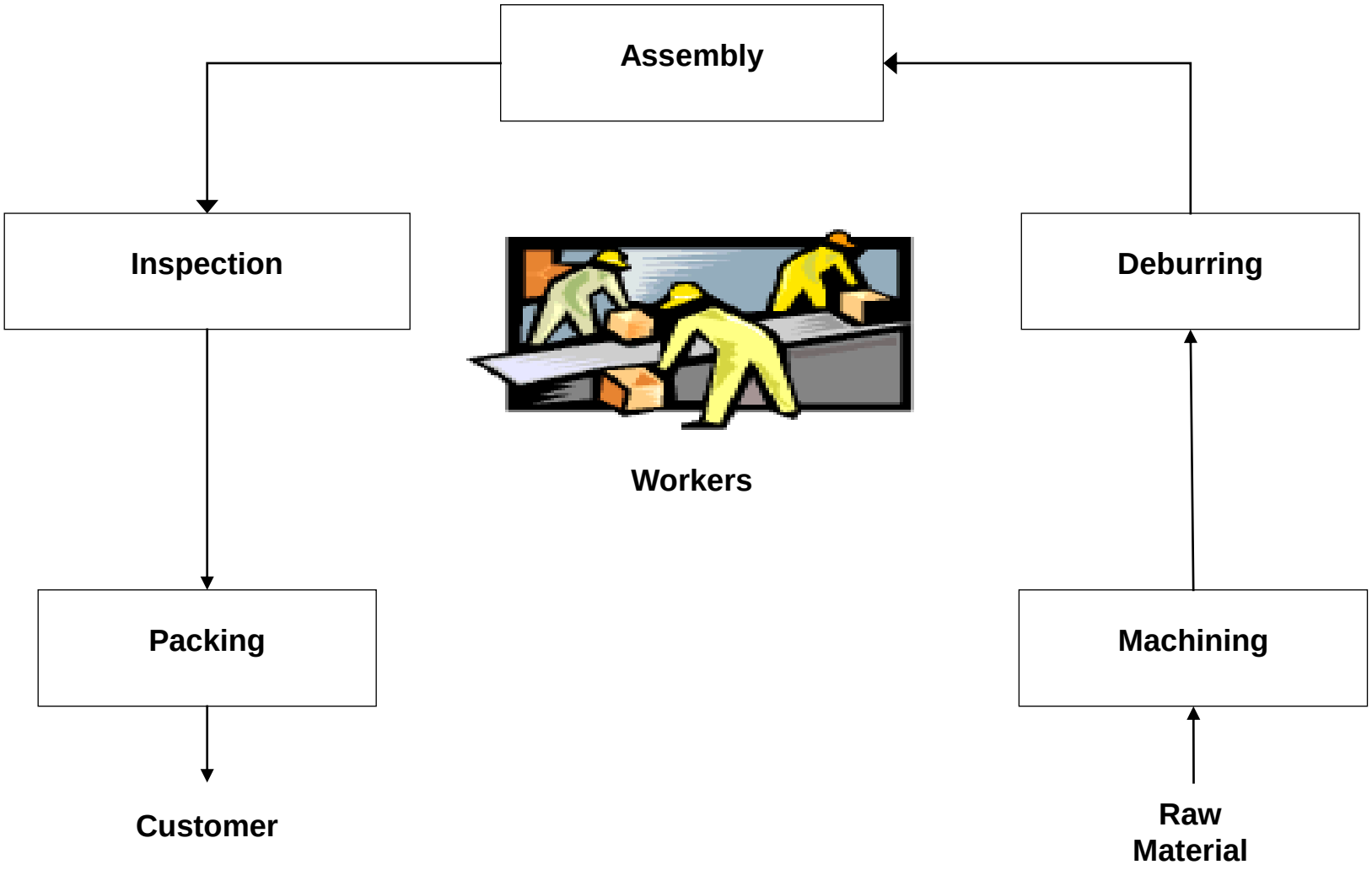
Batch and Queue

(Typical Physical Layout)



Single Piece Flow

(Improved Physical Layout)



Batch Production vs. Single Piece Flow

Lead Time = 30 Minutes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Machining	X	X	X	X	X	X																								
Deburring							X	X	X	X	X	X																		
Assembly													X	X	X	X	X	X												
Testing																			X	X	X	X	X	X						
Packing																									X	X	X	X	X	X

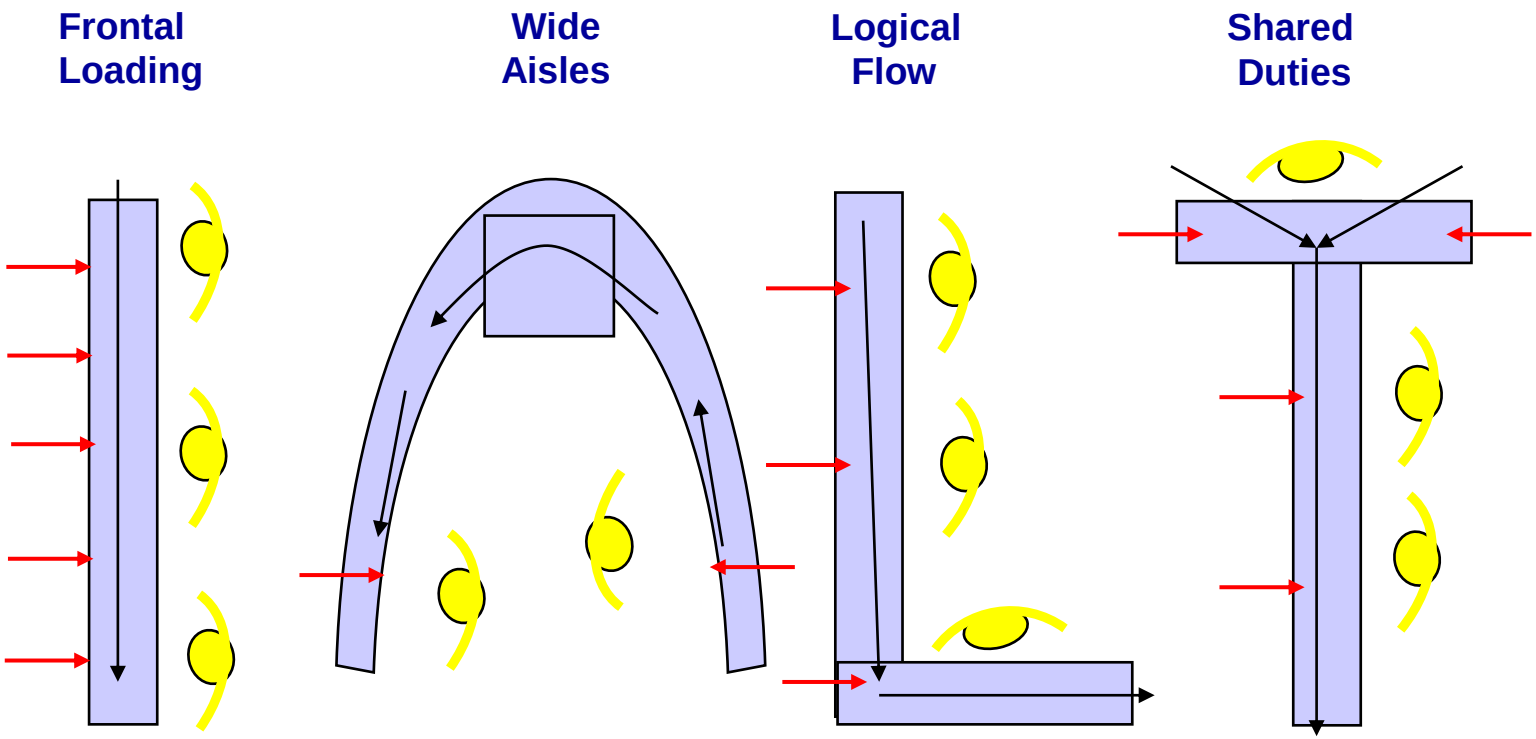
Lead Time = 10 Minutes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Machining	X	X	X	X	X	X																								
Deburring		X	X	X	X	X	X																							
Assembly			X	X	X	X	X	X																						
Testing				X	X	X	X	X	X																					
Packing					X	X	X	X	X	X																				

66% Reduction in Lead Time

Cellular Design

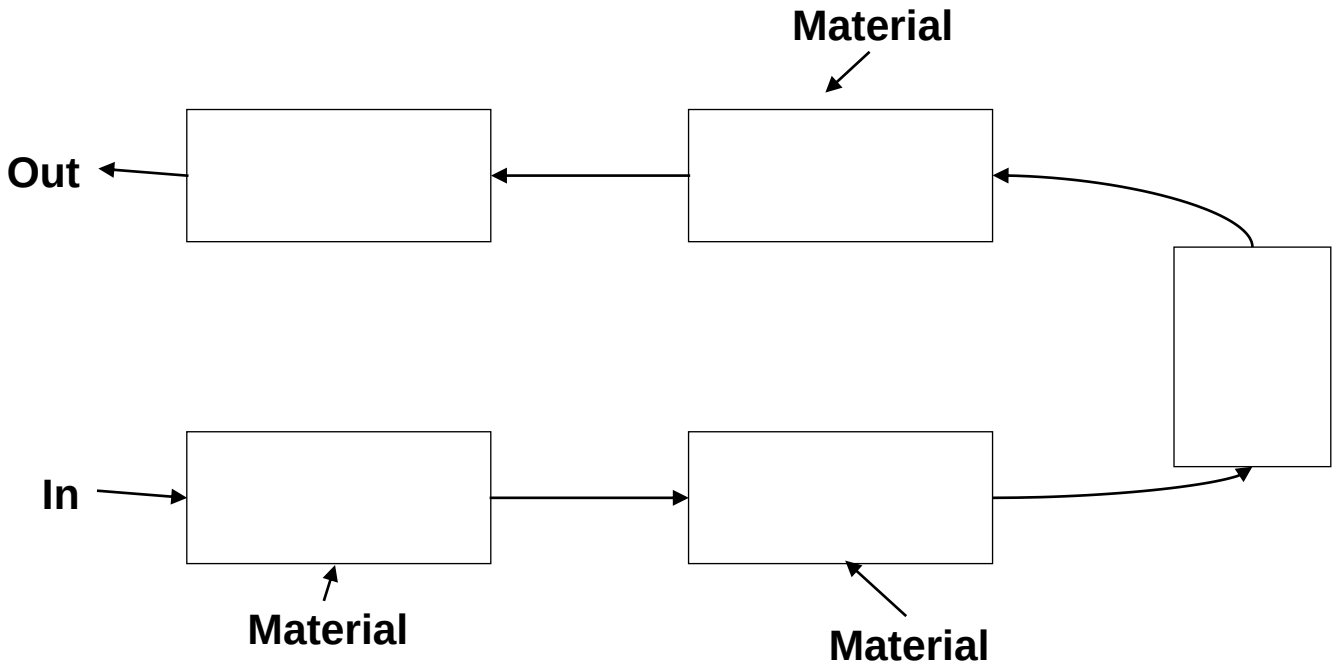
Desired properties of cellular designs.



The "best" layout is the layout that fits <u>your</u> application!

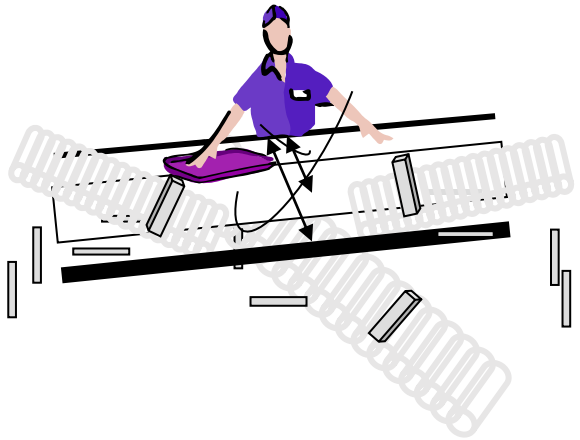
U-Shaped Cell Design

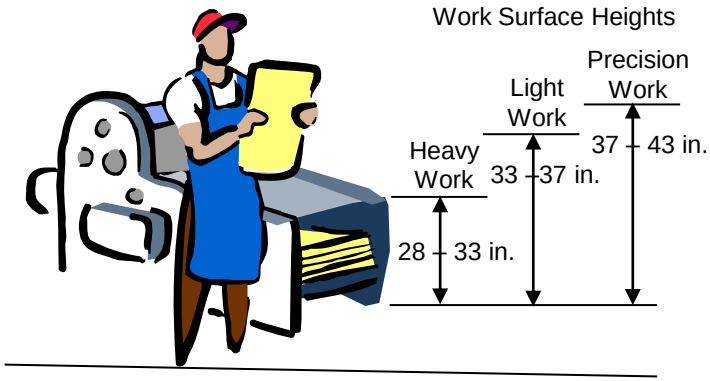
- The U-shaped design is a common organization for a cell
  - Parts return to the point of entry
  - Reduces walking time which reduces operator cycle time
  - Facilitates communication between operators
  - Visual controls can be seen by all operators
  - Water spiders (go-fers) facilitate material delivery



Creating Comfortable Work Areas

- All tools and equipment to be used by the operators should be within the Secondary work area (18-24 inches) away
- The Primary work area (14-18 inches) should be kept clear for handling the product
- The operator should not have to twist or turn to pick up materials or tools
- Assemblers or builders should have raw materials provided in front of them (frontal loading) and dispose of bins or totes under the work area in front of them (frontal discharge)
- Treat operators as if they are a surgeon in the Operating Room – make their job as easy as possible to perform without interruption!





What is a Kaizen Blitz?

- Kaizen is a Japanese word that means “Continuous Improvement”
  - Approach world class Japanese companies developed as a way of involving all workers and managers in continuous improvement efforts
  - Generates a better result, not necessarily the “best” result

- Typically a one week event
  - Results oriented
  - Involves cross functional teams
  - Make quick process improvements
  - Should focus on defined business objectives rather than pet peeves of individuals
  - Must be supported by management for:
    - Decision Making
    - Resource Prioritization

- Facilitated by a Black Belt or Master Black Belt
  - Requires experience in the technique
  - DMAIC and LSS expertise is needed for appropriate tool usage

Why Do A Kaizen Blitz?

- Objectives must be set and driven by upper management
  - Highlights the power of LSS tools and DMAIC methodology
  - Focus is on understanding and improving processes
  - If the “right” processes are chosen for improvement, the Kaizen process can have site wide implications
  - Objectives must be related to key metrics of the organization

- Encourages employee involvement in Lean Six Sigma
  - Cross functional teams increase employee exposure to DMAIC methodology
  - Allows for “just in time” training that will be applied immediately
  - Using tools immediately after learning the tool helps to foster future use of the same tools and techniques
  - Great opportunity to reinforce a continuous improvement culture
  - Improves morale as teams get to see the immediate results of their efforts
  - Helps facilitate communication between functional areas

Kaizen Blitz Typical Agenda

- Monday
  - Introduce team to the project chosen by site management
  - Train any needed tools
  - Collect data from the current process
  - Summary at the end of the day
- Tuesday
  - Analyze undesirable effects
  - Brainstorm alternative solutions
  - Summary at the end of the day
- Wednesday
  - Plan and Make the change
- Thursday
  - Plan and Make the change
  - Put changes into action/Confirm benefits
  - Summary of changes made
- Friday
  - Prepare Out-brief
  - List Outstanding Actions/Assign Action Items
  - Brief Team/Sponsors/Site Management

Total Productive Maintenance (TPM)

Preventive maintenance

+

Continuous improvement

+

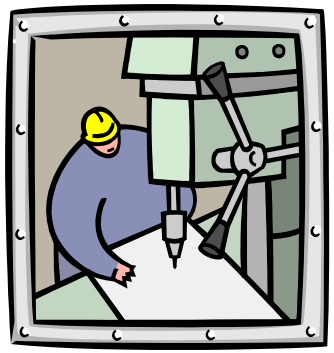
Operator involvement

+

Maintenance & Operator teams

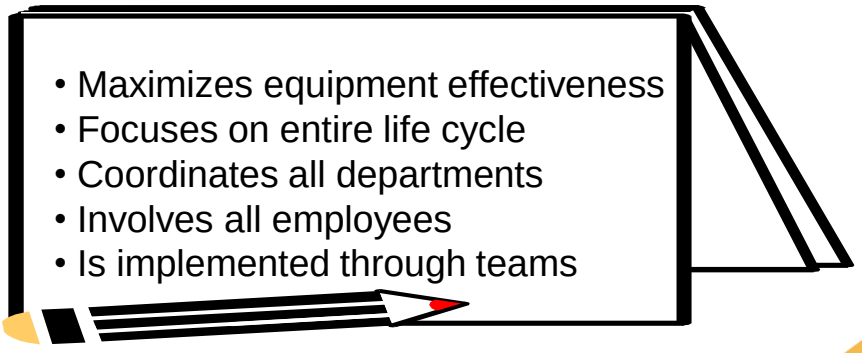
=

Total Productive Maintenance



Total Productive Maintenance (TPM) (cont.)

- Process for preventing equipment breakdowns that lead to unplanned down-time and line stoppages
- Goal is to maximize equipment effectiveness and availability
- Eliminate evils that cause breakdowns, such as inadequate lubrication, contamination, and misuse of equipment
- Company wide program that involves all operators, maintainers, schedulers, and engineers in a joint effort to prevent unscheduled downtime
- TPM is part of everyone's job.
  - Daily inspections
  - Repair and replacement of broken and worn components
  - Periodic inspections
  - Procedures and records



Shared TPM Tasks

OPERATORS	MAINTENANCE
• Become equipment focused	• Become equipment focused
• Daily/Shift inspections	• Daily review of discrepancies
• Routine cleaning	• Maintenance prevention
• Identifying problems early	• Predictive Maintenance
• Fixing minor problems	• Follow-up on major problems
• Accurately reporting problems as soon as discovered	• Educating/training operators when necessary
• Clean up after each shift	• Clean up after all maintenance
• See maintainers as teammates	• See operators as teammates

Understanding the Six Big Losses

OVERALL

EQUIPMENT

EFFECTIVENESS

- Availability losses
  - breakdowns/failures
  - setups/changeovers
- Performance losses
  - minor stoppages
  - reduced speed
- Quality losses
  - defects and rework
  - startup and yield loss

A mathematical score that indicates the overall effectiveness of an individual piece or group of machines. The score is driven by:

- the scheduled and unscheduled availability of the equipment
- the performance rate of the equipment
- the quality output from the equipment.

It can be tracked hourly, by shift, daily or weekly. Close attention paid to this score will indicate opportunities for increased performance and reduced downtime.

Components of OEE

OEE = Availability x Performance x Quality

- **Availability** is the % of the scheduled (available) time that the equipment operates
  - Example: The scheduled operating time for a piece of equipment is 420 minutes a day. It is down an average of 42 minutes a day for servicing and adjustments. Thus, its availability is 90% (378 minutes / 420 minutes)

- **Performance** relates to the efficiency (or speed) of the production rate
  - Example: We are expected to produce 100 units an hour during the scheduled (available) time and we only produce 80 units per hour. The performance rate % = 80/100 = 80%

- **Quality** is the first pass yield
  - Example: Of 560 units produced, 84 are defective (476 pass). Quality is 476/560 = 85%

- For our example above, OEE = 90% x 80% x 85% = 61.2%

- Spreadsheets, like on the next two pages, can be helpful for performing the calculations

Overall Equipment Effectiveness Calculations

Availability

A. Gross Available Time: _____ min.

B. Planned Downtime: (Scheduled downtime, Misc.) _____ min.

C. Total Available Time:
(Gross Available Time - Planned Downtime or A-B) _____ min.

D. Downtime Losses:

Taken from downtime log	#	Total time
# of Equipment Downtimes:(Breakdowns)	_____	_____ min.
# of Set-ups and adjustments	_____	_____ min.
(Includes servicing and minor maintenance)		_____ min.

E. Operating Time:
(Total Available Time - Downtime Losses or C-D) _____ min.

F. Percent Equipment Availability:
Operating Time ÷ Total Available Time x 100 or (E ÷ C) x 100 _____ %

Production Rate

G. Actual Parts Produced/Hr : _____ parts/hr
This includes both good and rejected production
(Total Available Hrs. = _____)(C/60)

H. Maximum Capability (Target) Parts/Hr _____ parts/hr
(Normal Conditions)

I. Performance Rate: Actual Parts/Hr ÷ Standard Parts/Hr x 100
G ÷ H x 100 _____ %

Overall Equipment Effectiveness Calculations (cont.)

Quality Rate

J. Defect Amounts or Total Rejects: _____ pieces _____ parts/hr

K. Quality Rate:
(Actual Parts/Hr - Defect Amount Parts/Hr ÷ Actual Parts/Hr x 100)
((G - J) ÷ G) x 100 _____ %

Overall Equipment Effectiveness: (calculate using proportions value for each)

(Equipment Availability X Performance Rate X Quality Rate X 100)

_____ %

OEE Exercise: Sample Data for OEE Calculations

Pause the video and work through this OEE exercise. You may use the spreadsheet found in the file named *OEE Template.*

OEE Template.xlsx

ABC manufacturing company produces 600 different parts as a supplier for the Computer hardware industry. Their "ABC Quality Systems" program helped them to become ISO 9000 certified last year and this year their final inspection rejection rate is below 0.5%. Everyone in the plant is quality conscious and motivated to produce the best parts possible.

Work is scheduled for three shifts per day covering 24 hours, 5 days a week for all employees. Each machine operator takes two 20 minute breaks and one hour for lunch. There is a 15-minute turnover period at the beginning and end of each shift for cleanup and changing of operators. There is only one operator assigned to each piece of equipment per shift. Bender #2 was designed to produce 100 parts per hour, but because of the tough quality requirements, and efforts to keep the old piece of equipment running, the press has been slowed to produce 85 parts per hour.

The following data was recorded for three shifts that were running Bender #2 on one day:

Downtime: Set-up and Adjustments: 45, 12, 59, 10, 22 minutes

Breakdowns requiring maintenance: 15, 37 minutes

Refilling oil reservoir: 7 minutes

Production: 1251 (total parts produced today)

Parts rejected for quality defects: 15

1. What is the OEE rate for Bender #2 for this one day?

2. How could TPM help improve the effectiveness?

Exercise: Overall Equipment Effectiveness Calculations

The final answer to this exercise is:

Overall Equipment Effectiveness: (calculate using proportions value for each)

(Equipment Availability X Performance Rate X Quality Rate X 100)

= 66.71 %

You may want to pause the video so that you may check your work by referring to the MS Excel file named *OEE Template – Approved Solution.*

OEE Template – Approved Solution.xlsx

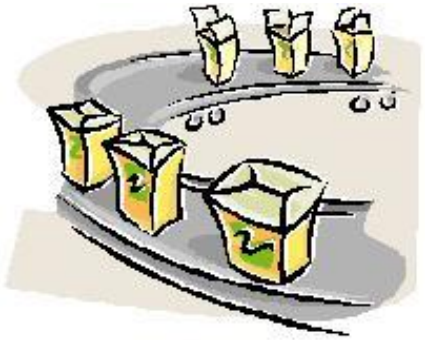
Flow

The continuous, progressive adding of value:

Starts at receipt of customer request
Ends at delivery to customer

Fewest number of steps with no interruptions:

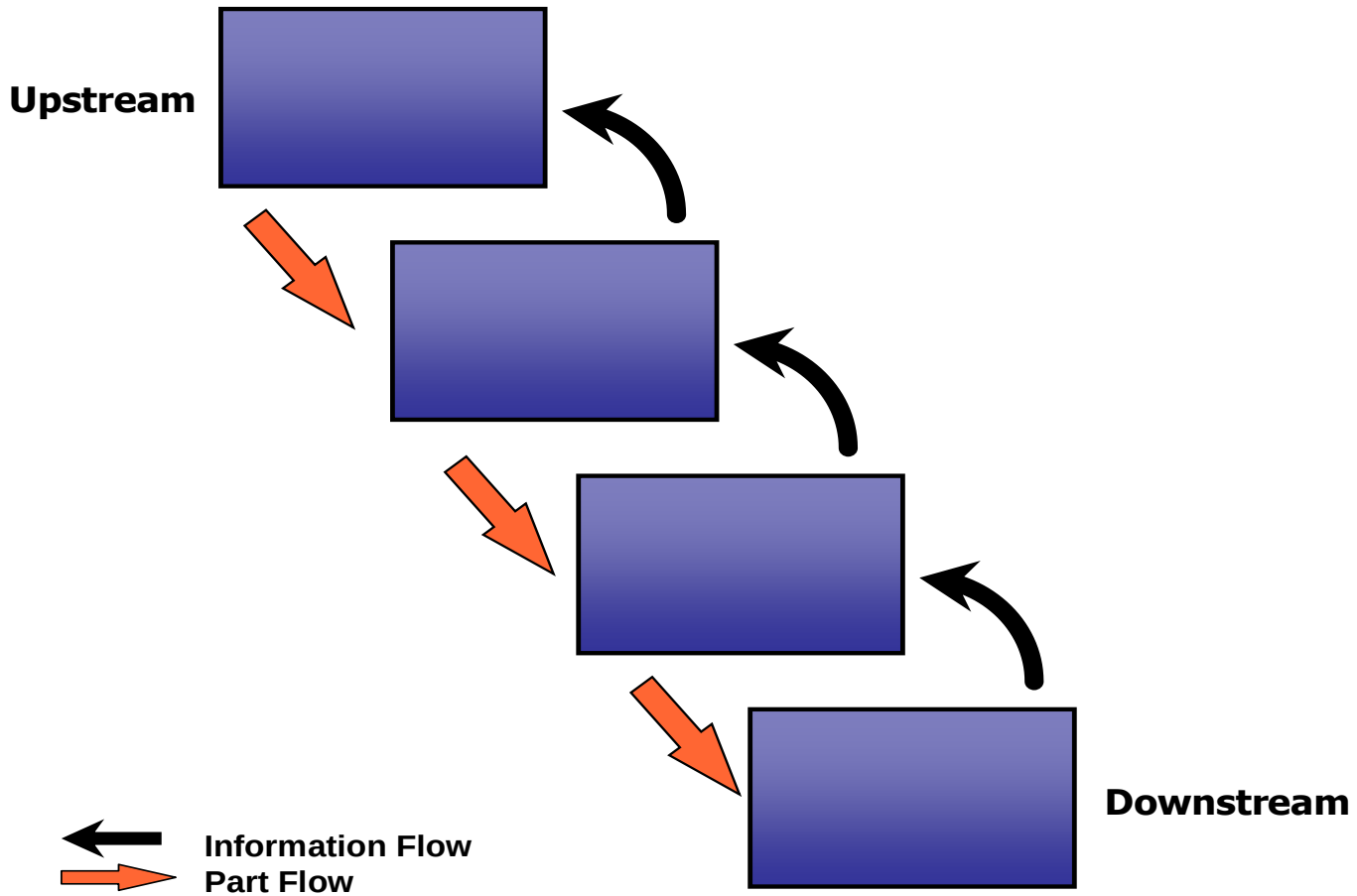
Waste eliminated



People always working on the product/service and the product/service always being worked on

Pull System

Pull means no one upstream should produce a good or service until the downstream customer asks for it



Pull Systems

- Pull systems are simplified visual information systems which are designed to respond to changes in demand simply, quickly and accurately

- Pull systems are information systems to achieve pull production

- Most utilize “Kanban” which is usually a tag-like card that communicates product information

- The “Kanban” is the vehicle to obtain a pull system linking subsequent operations

- Anticipated Usage
- Large Lots
- High Inventories
- Waste
- Management by Expediting
- Poor Communication

- Actual Consumption
- Small Lots
- Low Inventories
- Waste Reduction
- Management by Sight
- Better communication

Benefits of Pull Systems

- Increases employee involvement
- Allows decision-making at appropriate levels
- Only allows manufacturing based on replenishment of what has been consumed
- Improves communications of customer needs through visual controls
- Provides a common system for moving material through a plant
- Eliminates scheduling complexities
- Reduces lead time and work-in-process inventory
- Highlights quality issues quickly
- Organizes the workplace
- Leads to lower unit cost
- Supports continuous improvements
- Counts inventory by counting number of pull signals

Pull Production

- Producing Only What is Required for the Next Workstation
  - Not making parts or products ahead of when they are actually needed for the next stage in the process
  - Do not “push” parts to the next process
  - Pull what you need from the previous process
- Kanbans
  - Signal to communicate needs from workstation to workstation
  - Operators don’t start until Kanban is empty

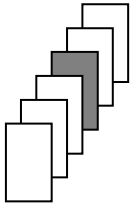
Kanban

- Japanese word for “card signal”
- Used to control the pace and flow of materials, transactions, and/or services; indicates the need for replenishment to create a “pull” process using visual signals
- “The right amount at the right time”
- Some Kanban examples
  - Empty containers (accompanied by a ticket that says “Fill me”)
  - Tickets attached to full containers that cause product to be moved
  - Marked “floor parking spaces” or shelf spaces to control over-production
- Where have you seen the principles of Kanban in action? (work related?, everyday life?)

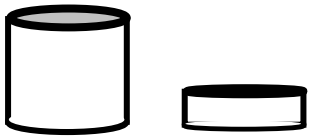
Simple, obvious flags

Some Methods for Implementing Kanban

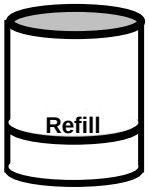
- Cards



- Two Bins

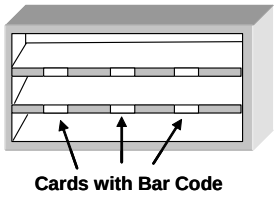


- Lines on Containers



- Bar Coding

- Specialized Containers



Two Common Categories of Kanban

- Production Kanban signals the supplier (internal or external) to produce a specific quantity

License to “Make”

- Withdrawal Kanban defines the quantity the customer may withdraw. The withdrawal of products by the customer creates a gap that indicates to production to provide more

License to “Take”

Parts Supermarket

Kanban Cards

- **Cards may contain data such as:**
  - What to produce?
  - When to produce it?
  - How much to produce?
  - How to transport it?
  - Where to store it?

In-Process Kanban Card

Item Number: 457-328

Item Name: Brake Arm, Forged

Tote Capacity	Tote Model	Date
3	B-3	3/16

From Process: Forging

Next Process: Painting

For internal use between processes.

Supplier Kanban Card

A B C Co.	Item Number: **321B4** Item Name: Hose, Type B Used In: Tractor type 532 w/320Engine Container Type: Grey 4 # In Container: 26	TO: XYZ **15** Stored **37C**
16	Date 3/17 Time 10:00 AM	

Part from ABC Co. to XYZ. Deliver to Dock 15 and will be stored in location 37C. The 16 is the Return-Call-Number used by ABC Co. for Container tracking purposes.

Inventory

- Inventory is a waste, but:
  - Without it, we could not respond to changes in the forecasted demands
  - Without it, we could not handle changes in our customer order patterns
  - Without it, we could not deal with our suppliers various lead times
- The trick is to calculate where and how much you need - not to guess at it

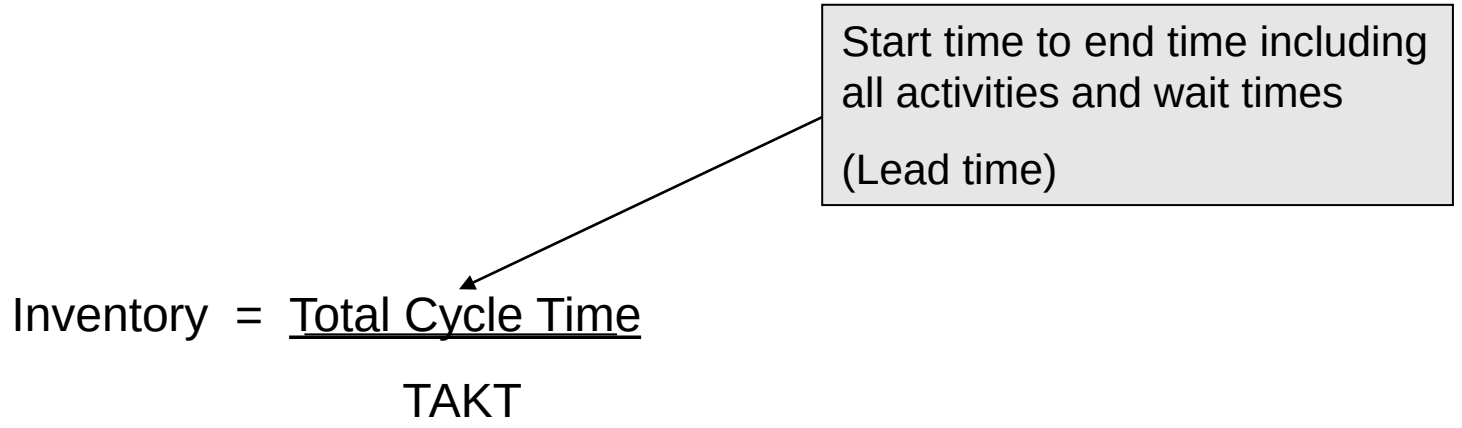
What Drives Inventory?

- The factors that drive inventory levels
  - Variability of production or demand rate
  - Long changeover times
  - Long Product Family Turnover Rate (“wheel time”)
  - Machine downtime
  - Schedule increases / decreases
  - Large process or transfer batch sizes
  - Process variability
  - Poor quality
  - Long cycle times
  - Bottleneck operations

= Long Replenishment Time

Inventory Levels

Using takt time and total cycle time, the minimum amount of inventory in the system can be calculated:



Example:
Total cycle time is 5 days, takt time is 2.1 min/unit

$$\text{Inventory (min)} = \frac{5 \text{ days} * 7 \text{hours/day} * 60 \text{ min/hour}}{2.1 \text{ min/unit}} = 1000 \text{ units}$$

Inventory Calculation

$$\text{Total Inventory} = (\text{ADD} \times \text{R}) + (\text{Service Factor} \times \sigma)$$

ADD = Average Daily Demand

R = Replenishment Time
(processing time + wait time + transport time)

Service Factor = Based on Service Level decision

σ = Calculated based on demand variability (ADD x R)

Strategic Inventory may be in a 'supermarket' or simply part of the Kanban calculation

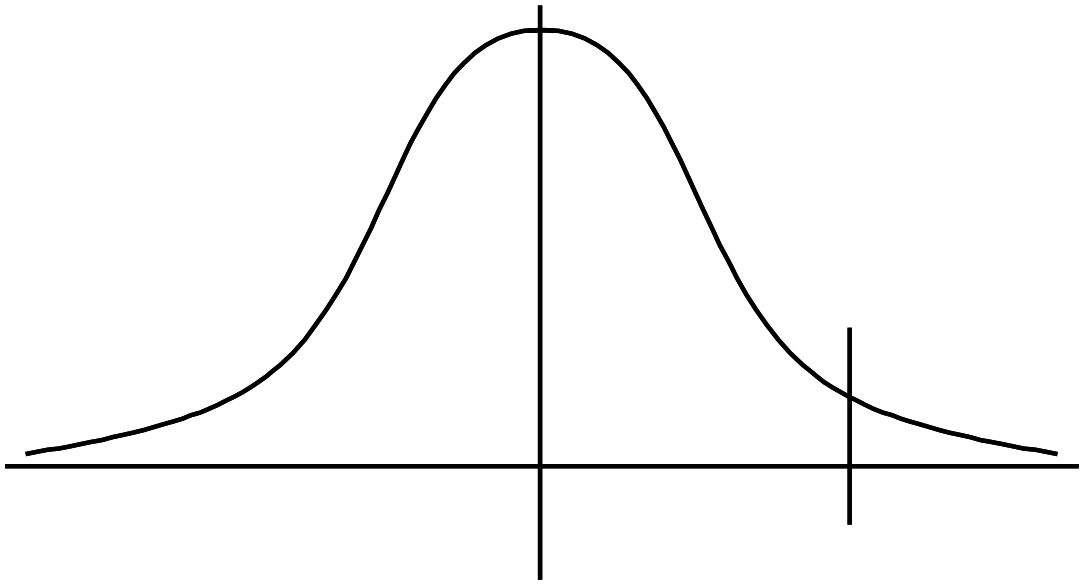
Service Factor

- A management decision about the acceptable level of exposure to stock-out

- The 'service level" determines the statistical likelihood of satisfying a typical pull from inventory on any given day

Service Factor

$$\text{Total Inventory} = (\text{ADD} \times \text{R}) + (\text{Service Factor} \times \sigma)$$



Average + Service Buffer

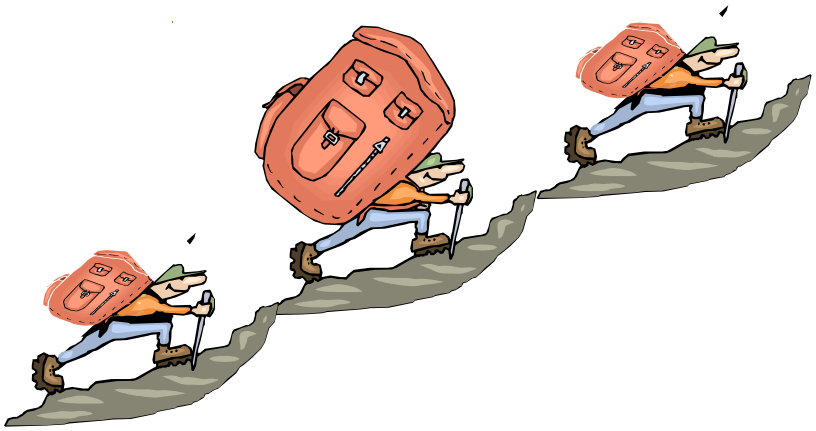
Service Level %	Service Factor
80	0.84
90	1.28
95	1.65
97.5	1.96
99	2.33
99.9	3.08

"Service Level" is statistical probability of meeting demand at any given point

Theory of Constraints

- Most processes do not exist in isolation - they are part of a system

- Every system has a “slowest” step or constraint
  - No more product will come out of your value stream than the slowest operation can produce
  - In knowledge processes, “gurus” are often constraints because every decision needs to pass through them
  - In administrative processes, reviews can be the constraints - occurring slower than the actual work steps



Generally, if you are not addressing the constraints, you are not improving the overall system

Theory of Constraints

Theory of Constraints (TOC) is an overall management philosophy that aims to find and remove the “slowest” or bottleneck constraint (from operations, plant type, supply, finance, project management or marketing /sales)

TOC consists of two main areas:

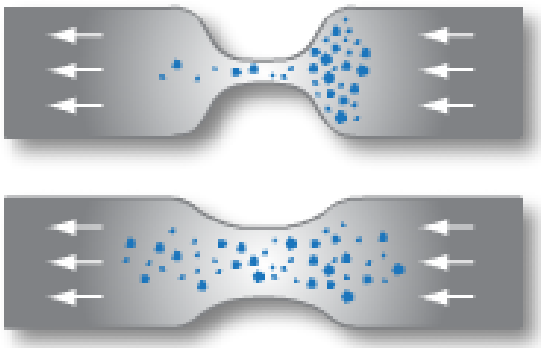
- The Thinking Process – a set of tools to help managers implement a project
- The Five Focusing Steps – a method to increase flow at the bottleneck
  - Identify the constraint
  - Decide how to exploit the constraint (make quick improvements to the throughput of the constraint using existing resources)
  - Subordinate and synchronize to the constraint (align and support the needs of the constraint)
  - Elevate the performance of the constraint (consider further actions, if need (capital equipment, etc.))
  - Repeat the process

Reference Cox, J & Goldratt, E.M. (1986). The goal: a process of ongoing improvement. New York, North River Press

Bottleneck Constraint Analysis

- When analyzing work, be on the lookout for bottlenecks (the slowest process steps in the product or service being provided)

- These limit the output capacity



- Bottlenecks impede work flow usually lead to delays, backups, and extra wait time (examples: turnaround times in the OR; approval process for capital equipment)

- Want to:
  - Make sure the “bottleneck” has capacity
  - Synchronize processes where possible
  - Simplify!

- Keep in mind that when the capacity of the bottleneck is increased, the process step with the next lowest capacity becomes the new bottleneck

Factory Floor Terms and Relationships*

Cycle Time (CT): The time from when a job is released into a routing to when it exits, e.g., time from “order entry” to “ship” – includes move time, queue time, setup time, and process time; the time a product spends as WIP

Throughput (TH): Quantity of good product produced in a process per unit time

Work in Process (WIP): Inventory between the start and end points of a product routing

Little’s Law: WIP = TH * CT

* Source: Factory Physics (2nd Ed.) by Hopp and Spearman

Uses of Little's Law*

Focus on Throughput / Ability to meet demand:

$$TH = WIP / CT$$

Focus on Cycle time reduction:

$$CT = WIP / TH$$

Focus on WIP:

$$WIP = CT * TH$$

*Source: Factory Physics (2nd Ed.) by Hopp and Spearman

Key Takeaways

- As a review, you may want to pause the video at this point and summarize the key learnings from this session, at least from a high-level view. When you are finished, resume the video.

Key Takeaways

1. 5S is a fundamental tool for workplace organization. Benefits of 5S:
   - improves moral
   - sets the groundwork for visual control
   - makes for a safer workplace, etc.
2. SMED is a process for reducing changeover times. Goal is for massive reduction, ideally down to times in the "single minute" range, but at least 50% or more reductions should be achievable
3. SMED is not about working faster, it is about working smarter. Trying to convert as many activities from internal to external as possible. Remember, as Yogi Berra once said, "You can learn a lot by just watching"!
4. Failure Mode and Effects Analysis; Used to see how a product or process fails and to identify ways to mistake proof or prevent these failures from happening….helps us prioritize our actions and points out critical process steps
5. RPN is calculated by taking the product of severity * occurrence * detection. RPN represents the risk of the process step or the product component.
6. Kaizen Blitz is a continuous improvement tool used to make quick but effective improvements to a process
   - Kaizen's must include senior management guidance
   - Should be focused on areas critical to the business
   - Kaizen's are usually accomplished within a single week

Key Takeaways (cont.)

7. Total Productive Maintenance can be applied on a factory floor and also in a transactional application
8. OEE or Overall Equipment Effectiveness is a great tool to help keep score for equipment. OEE takes into consideration equipment availability, production rate, and quality
9. Flow and Pull are key concepts of Lean. The theory of each will lead you to the concept of single piece flow
10. The Theory of Constraints (TOC) focuses on the bottleneck in processes. By focusing on bottlenecks you are focusing on the area of greatest pain
11. Kanbans are simple “signs” or signals to help “flow” and “pull” to work
12. Inventory should be minimized, but is caused mainly by long replenishment times
13. Strategic Inventory is the extra product that we have to make sure that we don’t run out when the customer wants the product/service. We can calculate how large our inventory needs to be so that we have a certain level of confidence that we will meet the needs of our customer
14. The WIP that we have in a value stream is inventory and is a function of TAKT time and cycle time
15. Little’s Law is a conceptual equation that relates throughput, cycle time, and WIP

Supplemental Material

- Suggested Reading:
  - ***Lean Six Sigma: A Tools Guide*** by Adams, Kiemele, Pollock and Quan (pp. 137 - 214)
  - Air Academy's app: ***Six Sigma Quick Tools***

- SPC XL™ software training tutorials:
  - https://airacad.com/our-insights/training-videos/spc-xl/

- The data files for this session can be downloaded from the site where you are accessing this course

Additional Practice / Review Questions

1. Hospital Patient Flow

   Average # patients = 102.5 (“WIP”)

   Discharge rate per day = 67.5 (“TH”)

   Cycle time (average time in hospital) = _____

2. Production Shop

   Daily output is 25 units/day

   Average cycle time is 2 days

   Average number of units in process (“WIP”) = _____

3. Coffee Shop

   Average number of customers in queue in the morning is 10

   Average time spent (“CT”) per customer is 3 minutes

   What is the expected throughput rate of customers?

   Customers per minute = _____

   Customers per hour = _____

   If customers spend on average $5, what is an estimate of the hourly revenue during this morning period? _____

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