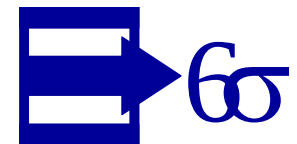
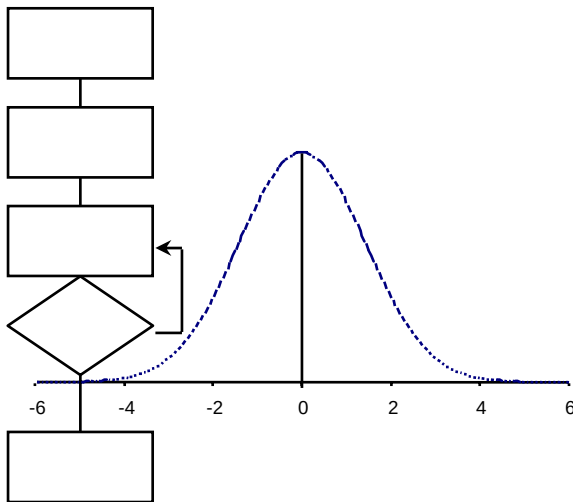


Lean Manufacturing



What is "Lean"

- "Lean" is a term used to refer to the processes, philosophy and improvement techniques that are proven to be the best in the world for delivering products and services.
- "Lean" enterprises:
 - are the most efficient (cost and working capital)
 - have the highest quality (defects/million)
 - are the most responsive to their customers (time, service and product development).

Principles of Lean

While there is several schools of Lean manufacturing, these principles seem to be the basis for all.

1. Identify Value Stream
2. One Piece Flow
3. Demand Pull
4. Perfection

The Value Stream

- Taiichi Ohno found the modern supermarket so stimulating that it inspired him in 1950 to invent the new system of flow management we now call Just in Time.
- Value stream:
 - activities necessary to create, order, and produce specific products. Those which can't be precisely identified, analyzed, and linked together cannot be challenged, improved and, eventually, perfected.
 - must manage the whole value stream for specific goods and services.

- Must define value stream in terms of the entire product not just one element of the product. Waste must be removed from the entire system in order to deliver the right product at the right time for the right price to the Customer better than the Competition.
- For example:
 - think of all the elements in different segments required to take a family vacation to another country.
 - where would the major costs and time be incurred in producing and delivering a can of a soft drink to the Consumer?

- Identifying every action required to design, order, the make a specific product is to sort these actions in three categories:
 1. those which clearly and unquestionably create value as perceived by the customer;
 2. those which create no value but are currently required by the product development, order filling, or production systems and cannot be eliminated;
 3. those actions which don't create value as perceived by the customer and can be eliminated immediately.

- An example given of the value stream is the life-cycle of a carton of cola. The cumulative days from mining the bauxite to making the aluminum can through consumption by the consumer, is 319 days. Total processing time is approximately three hours. Average consumption time is 5 minutes.

- The root cause of muda in the cola example is that all the apparatus used to make cola and get it to the customer is very large, very hard to changeover, and designed to operate efficiently at very high speeds. It is a mass production psychology. However, what appears to be efficient to individual companies, individual elements of the value chain, are far from efficient when viewed in terms of the total product and the total value stream.

- Tesco took the following steps to remodel this situation:
 - Point-of-sale bar code scanning system in checkout lanes of all stores
 - Transfer purchasing from individual stores to a centralized system to place combined orders from all stores with suppliers
 - Implement regional distribution centers (large trucks in, large trucks out)
 - Move to daily orders rather than weekly or monthly orders

Value Stream: Activities

There are three categories of activities generally associated with the Value Stream

- problem-solving task (design to launch)
- information management task (order taking to delivery)
- transformation task (raw material to finished product with Customer)

Some Advice...

- To hell with Competition; compete against perfection by identifying all activities that are muda and eliminating them.
- This is an absolute rather than a relative standard which can provide the essential North Star for any organization.
- However, to put this mission to work a company must master the key techniques for limiting muda.
- It all begins with flow.

One Piece Flow

- One Piece Flow is the elimination of batch and queue work flows or reduced elapsed cycle time in environments in which batching is required, for example, under FDA regulation
- Flow is counter intuitive.
- People naturally tend to think in terms of batch processes. However, the move to flow should be not only in special cases, like the Ford assembly line, but in a general case, like small lot production in modern automobile assembly plants.

One Piece Flow vs. Reengineering

- The reengineering movement has recognized that departmentalized thinking is suboptimal and has tried to shift focus from organizational categories (department) to value creating "processes".
- The problem is that the engineers haven't gone far enough conceptually. They are still dealing with disconnected and aggregated processes (for example, order taking for a whole range of products) rather than entire flow of value creating activities for specific products.
- Kaikaku: radical improvement
- Kaizen: continuous incremental improvement

One Piece Flow in Production

- Based on years of benchmarking, observation and implementation in organizations around world, we have developed the following simple conclusion about the application of these concepts and tools:
converting the classic batch and queue production system to continuous flow with effective pull by the customer will deliver double labor productivity while cutting production throughput times by 90 percent and reducing inventories in system by 90 percent as well.
Time to market for new products will be half and, within product families, a wider variety products can be offered at a very modest additional cost. What's more, the capital investment required will be minimal, even negative, the facilities equipment can be freed up and sold.

- Once Value is defined and the entire Value Stream is identified, we must simultaneously:
 1. Focus on the actual object (specific design, specific order, the product itself) from beginning to completion
 2. Ignore traditional boundaries of jobs, careers, functions
 3. Rethink specific work practices and tools to eliminate back flows, scrap, and stoppages of all sorts so that the design, order and production of the specific product proceeds continuously.

Demand Pull

- Demand is the Customer signal
- Pull is the material signal
- Then, Demand Pull, in the simplest terms, means that no one upstream should produce a good or service until the customer downstream tasks for it.
- In essence, Demand Pull is a permission system that prevents waste of resources and material while accelerating flow and simplifying control

Perfection

- Once the other three elements of Lean are deployed and implemented, then the idea of achieving Perfection becomes quite defined and practical.

Value stream identification

One Piece Flow

Demand Pull

Perfection

Exercise

- Do an exercise that demonstrates the reduction in WIP and lead time and defects.
- Start with a batching process
- Then go to one piece flow
- Then go to pull system.
- Measure WIP
- Lead time
- Defects

Lean Production Practices

- **Just in time techniques are used in the lean production environment, for example:**
 - Line leveling (heijunka)
 - Changeover reduction (leverage to smaller, much smaller, batches)
 - Reorganized operations into process related families
 - One piece flow
 - Right sized equipment (remember, determined in design process not just doing the best with what you have available)
 - Elimination of the muda of complexity (all the undue operational overhead)
 - Flexible and process trained workforce
 - Robust and repeatable processes
 - Dependable equipment (preventive maintenance, process capability)
 - Standard work
 - Mistake proofing (poka yoke)
 - Autonomation
 - Visual controls and the 5 Ss
 - Takt time and quick changeover
 - Demand pull system (permission system)
 - Pointed use delivery and storage of material
 - The location of production and support resources (don't get stuff from East Wherever because it is a to few cents a unit cheaper)

- **Muda:** the Japanese word for waste. It means any human activity which absorbs resources and creates no value.
- There are seven traditionally described forms of waste:
 1. Excess Production
 2. Waiting
 3. Conveyance
 4. Unnecessary processing
 5. Inventory
 6. Unnecessary Motion
 7. Producing Failures

Reason For the 5S's

- Process Driven Organization
- Elimination of Waste in the Process
 - Waiting
 - Conveyance
 - Unnecessary Motion
- Safer, High Quality Work Place Environment

1. Sort
2. Set in Order
3. Shine
4. Standardize
5. Sustain



1. Sort

- Remove from the Work Area All Items Not Required for Current Work Flow Activities
- When in doubt, throw it out!

1. Sort: Red Tag Process

In a Target Area:

- Identify Items of Questionable Need:
 - Is the Item Required?
 - Is the Item Required in the Quantity On Hand?
 - If Required, Must It Be Placed/Stored Here?
- Disposition Identified Items:
 - Hold
 - Relocate
 - Dispose
 - Leave in Place

1. Sort: Red Tag Process

1. Establish Red Tag Criteria:
 - Usefulness
 - Frequency of Use
 - Quantity
2. Tag All Questionable Items
 - Material/Equipment/Tooling
 - Space
3. Move to Hold Area:
 - Local
 - Central
4. Evaluate & Disposition Red Tag Items
5. Log & Report Results

2. Set In Order

- Identify, Label and Arrange Required Items so that They Are Easy to Retrieve and to Store as Part of Routine Work Flow Process
- When Set in Order Is Correctly Implemented, These Activities Can Be Performed by Anyone.

2. Set In Order: Method

Set In Order Uses a Two Step Method:

1. Determine Appropriate Locations for
 - Equipment
 - Fixtures & Tooling
 - Material
2. Label & Identify Locations

2. Set In Order: Method

1. Determine Appropriate Location:

Flow Map Current (Before) Work Flow (Spaghetti Diagram)

Determine Improved Flow

Detail Layout of Improved (After) Flow:

- Equipment
- Benches, tables
- Material & Space
- Tooling, fixtures
- etc...

2. Set In Order: Methods

2. Label and Identify Locations

Visual Controls Communicate Simply and Quickly to Anyone the Standards by which a Task or Activity Should Be Performed

Examples:

- Labeled and Outlined Tool Kit Boards & Tools
- Painting
- Sized Containers
- Color Codes
- Etc...

3. *Shine*

- Keep the Work Place Clean and Clutter Free
- Insure that Anything Needed Will Always Be Ready When it Is Needed
- Reinforce with Inspection

3. Shine: Methods

1. Identify Shine Targets:

Warehouse/Stockroom Items

Equipment

Space

2. Assign Shine Responsibilities & Schedule

3. Standardize/Document Methods & Measurements

4. Prepare Tools & Training

5. Implement & Follow-up

4. *Standardize*

- The Result that Exists When Sort, Set in Order and Shine Are Properly Maintained
- Standardization Insures that These Daily Work Habits Are Fostered and Maintained Completely, Fully and Productively

4. *Standardize: Methods*

1. Determine Responsibilities:

Operator

Supervision

Maintenance

Other

2. Integrate in Routine Work Activities

3. Follow-up and Track Routinely

4. *Standardize: Tools*

- Change Job Descriptions
- Visual Plant
- Charts
- Work Aide Sheets
- Checklists
- Etc...

4. *Standardization: Prevention*

- If the Standard Process Is Being Followed Correctly But Waste Continues:
 - Ask "Why" Until Root Cause is Identified (Ask Why 5 Times)
 - Ask "How" Can This Be Fixed
 - Implement Change to Standard

4. *Standardization: Prevention*

- Prevention Example:

Waste: Operators need to sweep floor in addition to cleaning machine table of chips and shavings from drill press operations

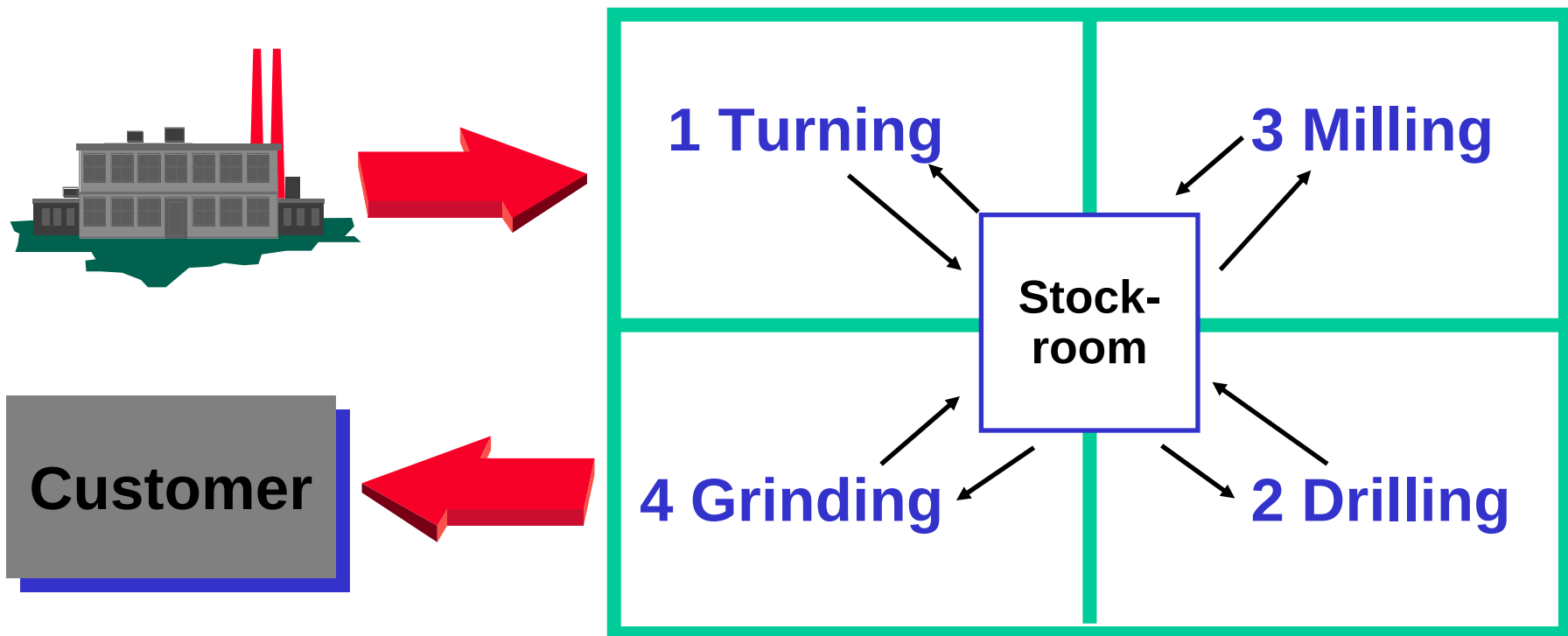
Prevention: Place metal and plexiglass panel to prevent chips and shavings from falling from machine table to floor.

5. Sustain

- Habit of Properly Maintaining Correct Procedures is Internalized by the Organization.
- Different from Standardize in that Sustain Can Not Be Measured or Are Results Visible -- it Is Changed Behavior
- Sustain Takes Leadership and Time to Achieve

Traditional manufacturing layout

MSCC
Six Sigma "Belt"

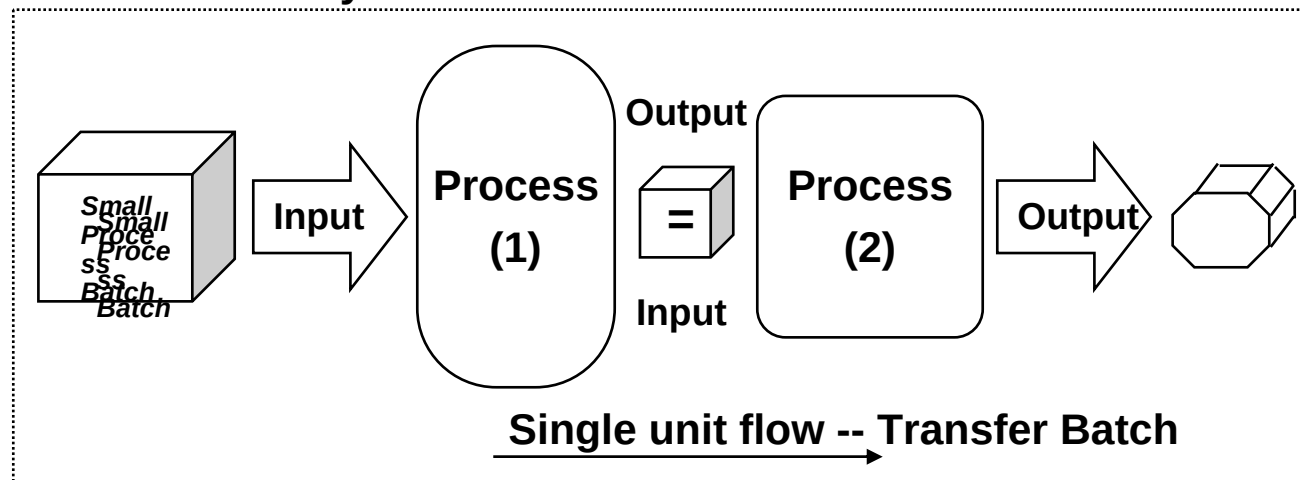


Why Redesign Process Flow?

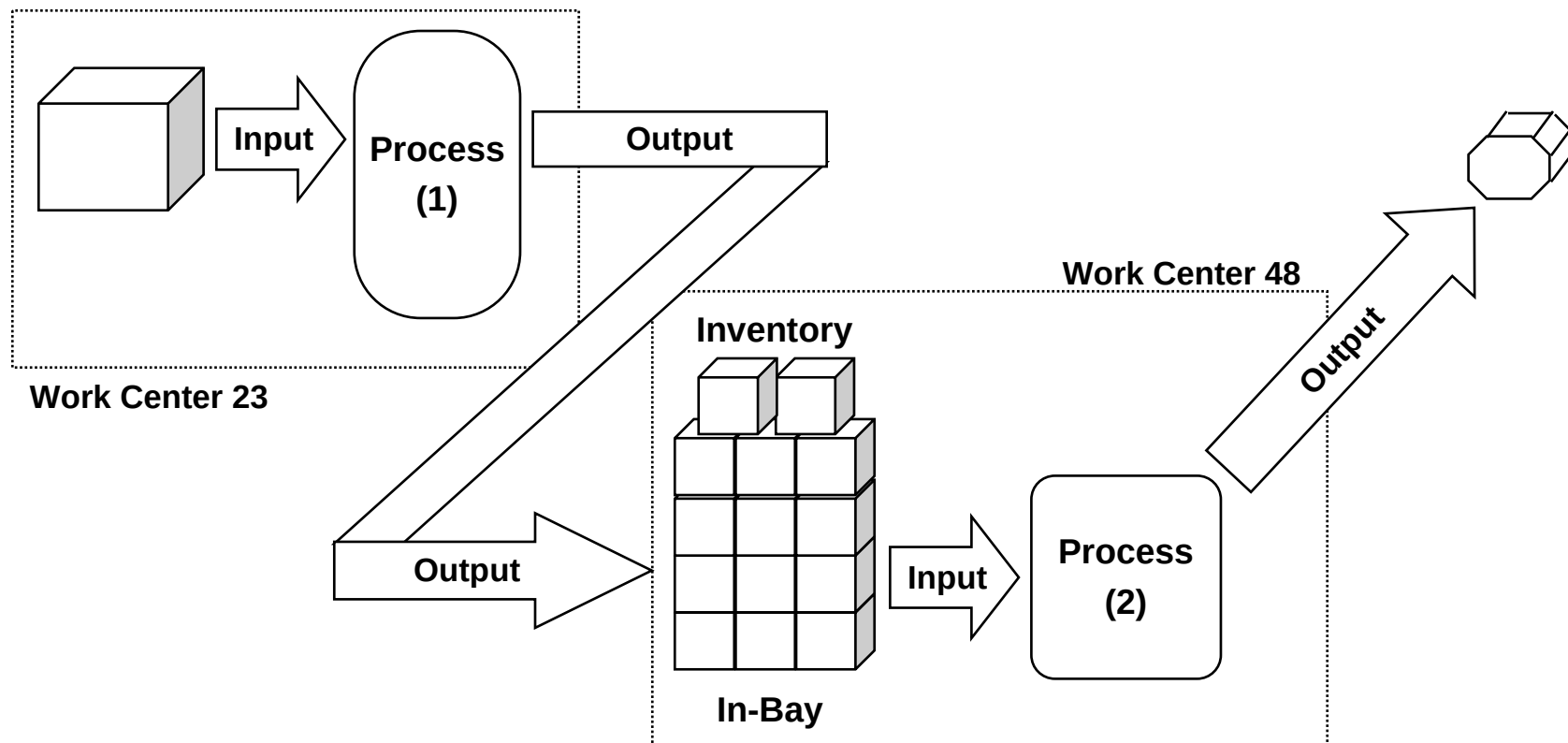
- As much as 60% of the total labor can be expended on non-value adding activities such as
 - Moving, counting and storing WIP
 - Unnecessary Inspection
 - Equipment attend
- To eliminate these non-value adding and wasted activities, redesign the process flow and organize the equipment into cells
 - Parts are moved and processed in small batches (ideally batch size of 1) uninterrupted from one operation to another
 - Having equipment in a linear flow forces problems to surface so that they can quickly be solved

- Organizing cells around families of similar products
- Organizing the equipment for each step to minimize part travel
- Eliminating any non-value added steps
- Collapsing the sequence of cell operations so that the output of one step feeds the next
- Avoiding barriers that prevent visibility of all cell operations
- Using the absolute minimum amount of space required for machines, tools, operators and inventory

Focused Factory Cell



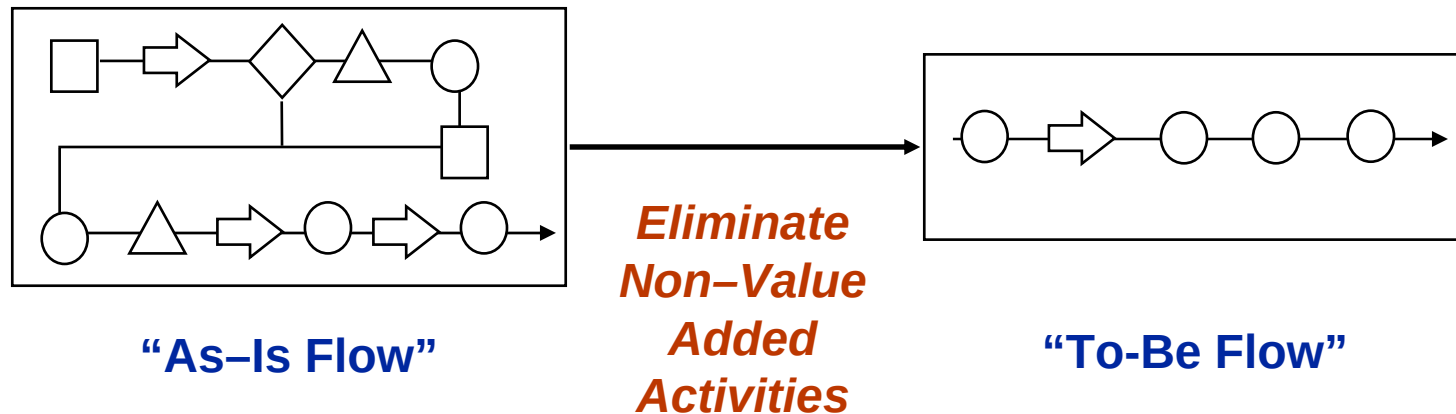
- Currently mfg and assy processes are organized in a functional layout
 - Organized by individual process step
 - Separated by long travel distances
 - Inventory storage locations prior to each step



Process Redesign Benefits

- Reduces Cycle Time
- Increases throughput (not more)
- Allows responsiveness to changes in demand
- Promotes high visibility of the process
- Gives operators immediate feedback
- Improves quality
- Minimizes travel distances, material handling, and space
- Anticipate equipment performance (i.e.. minimize unplanned downtime)
- Increase process ownership by operators

"To-Be" Process



Group product information process families when redesigning the process,

- Takt time
- Eliminate non-value added activities
- Increase organizational spans of control
- Reduce the number of decision points
- Increase yields
- Simplify and streamline the process
- Incorporate board room management
- Separate operator time from machine time
- Train "one-ups, one-down"

"To Be" Layout



- One-At-A-Time/First-In-First Out
- Synchronous To Demand (Demand Pull)
- One Operator-Multiple Machines
- Immediate Feedback
- Standard Work-in-Progress
- Small Lot Process Batch
- One Piece Transfer Batch

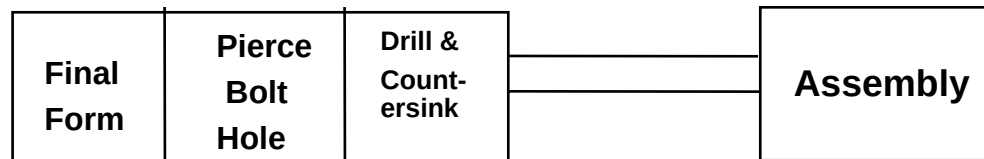
Challenge the Process

Fabricate Exit Device Cover



Simplify / Streamline Processes

Fabricate Governor Hsg

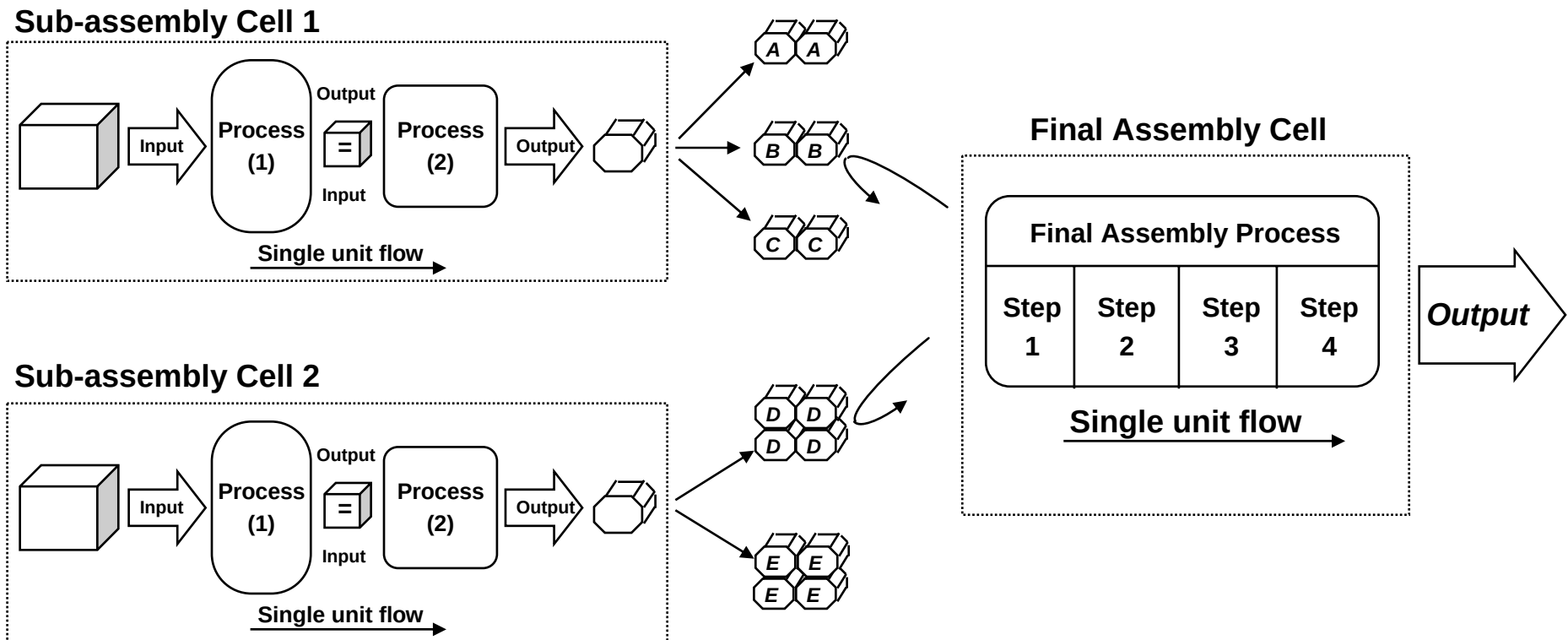


Flatten Bill of Materials

Cell Design Overview

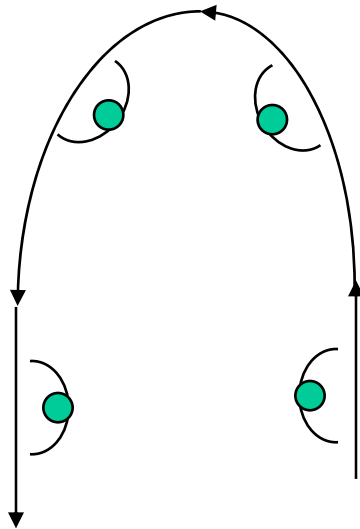
MSCC Six Sigma "Belt"

- In cases where multiple cells feed one another, the design layout must include visible storage area for kanban inventory and pull signal communication

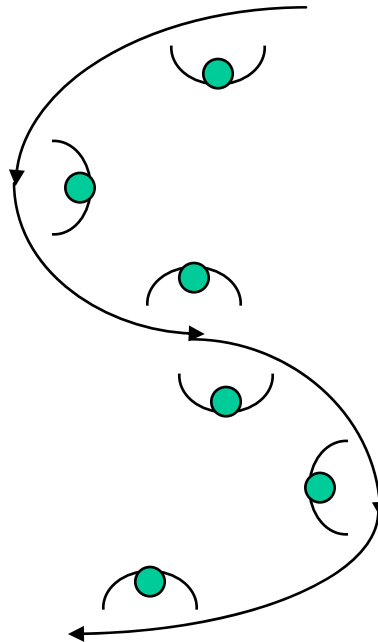


Examples of cell layouts

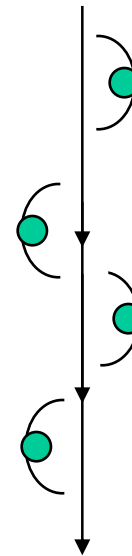
U - shaped



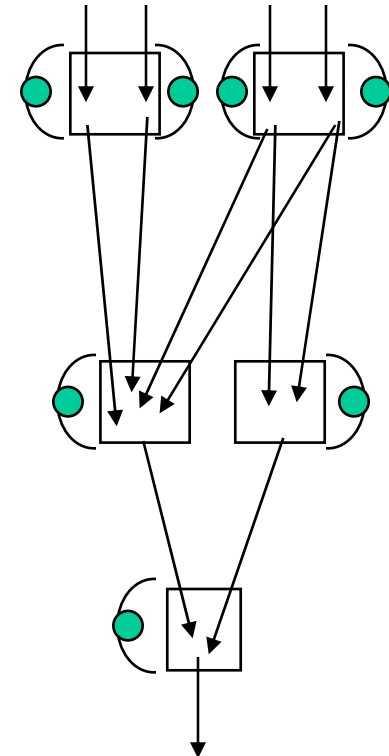
S - shaped



Line

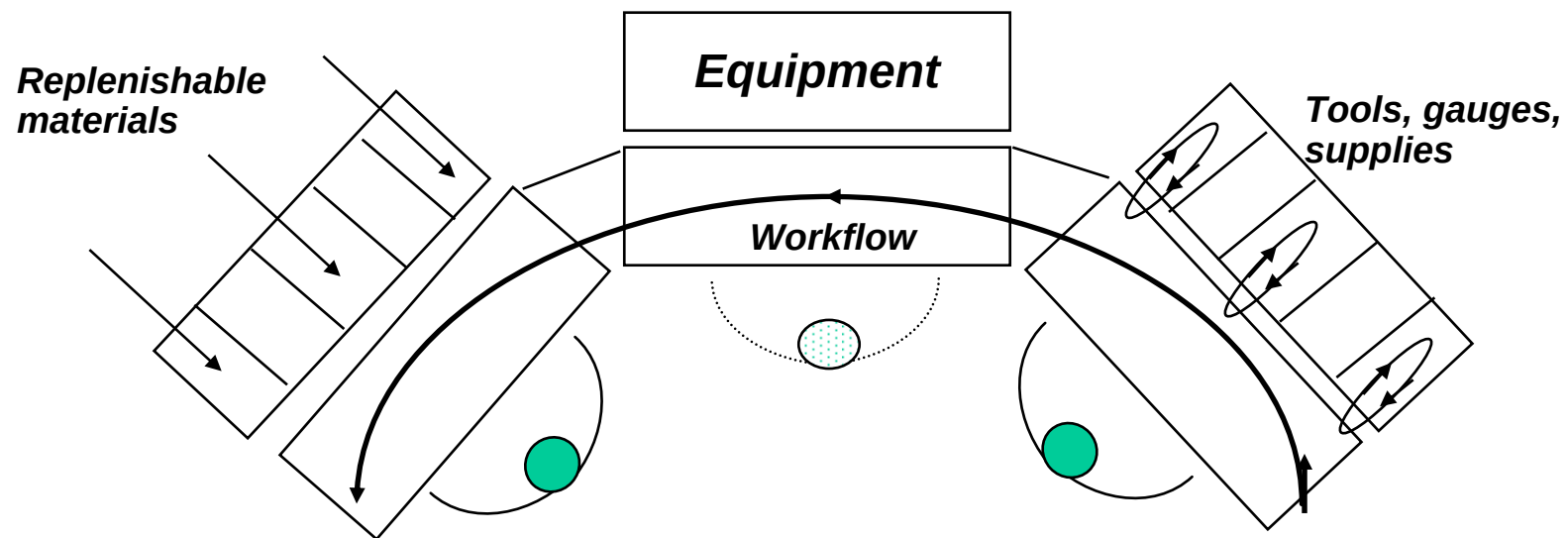


Mixed



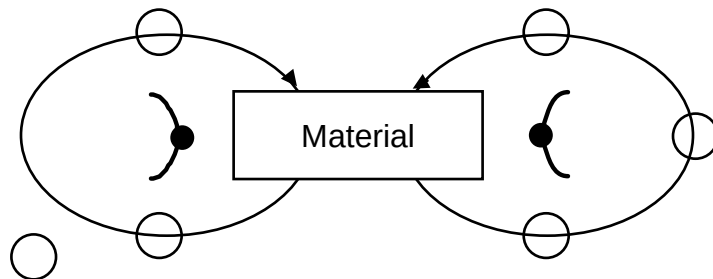
Desirable Characteristics of Cells

- Material passed right-to-left
- No conveyers, belts, rollers
- Visibility and feedback are maximized
- Standard WIP
- Set inspect points
- Staffing flexibility and satisfaction maximized

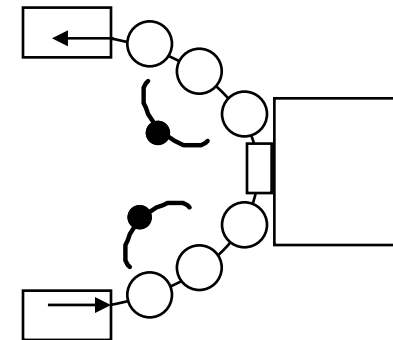


Principles of Cell Design - operators

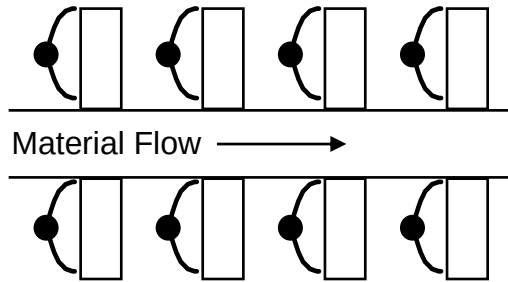
- Keep the operator inside the cell, with benches, machines, and material presentation on the outside
- Place operators close together
- Keep the distance between an operator and part travel to a minimum
- Don't isolate operators
- Separate operator time from machine time



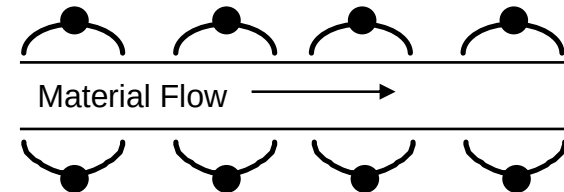
BAD: Operators bird caged. No chance to increase output with a third operator.



Better: Operators can help each other. Might increase output with third operator.



BAD: Operators caged. No chance to trade elements of work between them.
(Subassembly line layout common in American plants)



Better: Operators can trade elements of work. Can add and subtract operators. Trained ones can neatly self-balance at different output rates.

- Don't isolate equipment
- Make machines movable where practical
 - Have machines on wheels (on air pallets) for ease of maintenance and cell fine tuning
- Don't be trapped by “machine utilization”
- Make waste visible
- The operators and the part do not have to travel the same path
- Place functionality above appearance; cell designs can be “ugly”

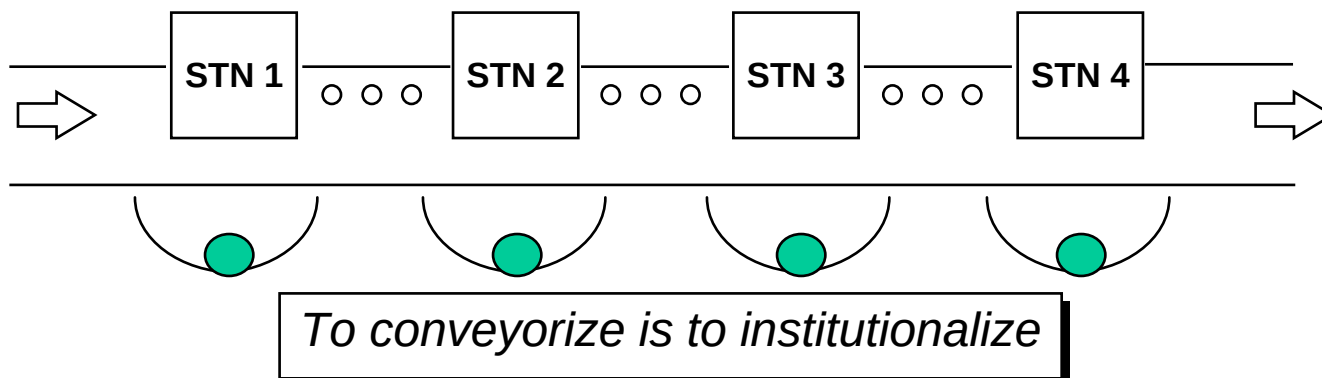
- Make working conditions easy, avoid ladders, use platforms or cut holes in the floor for easy access to equipment or product
- Standardize table/work station height
- Avoid unloading an operation to a table then reloading to the second operation

Feed the output of one operation directly to the second operation

Have the operator unload the previous operation

Automate unload

- Eliminate conveyors

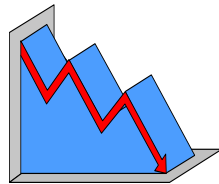


- Make housekeeping an easy part of maintaining cell operations
- A place for everything and everything in its place
- Push responsibility throughout the organization
- Provide guidelines
- Specific areas include:
 - scrap area / disposal procedures
 - tool storage on outlined peg boards
 - machines cleaned / painted
 - lines labeled
 - storage designated

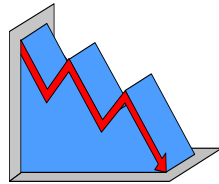
- Stop the line when imbalances occur
- If a cell stops—solve the problem, don't keep people busy making inventory
- First, eliminate the cost (non-value) adds, then streamline the value adds
- Stress the cell! When shift production is regularly completed before shift end, reassign an employee and rebalance the cell

Good cell layout and process discipline form the foundation of performance improvement

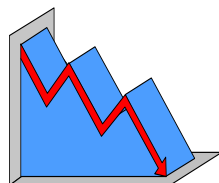
- *Cycle Time*



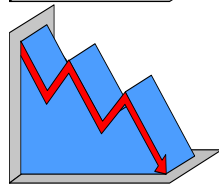
- *Inventory*



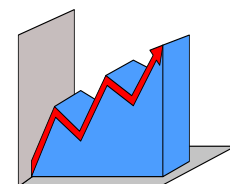
- *Product Cost*



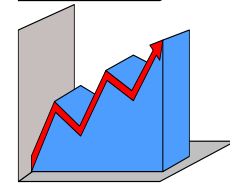
- *Process Variability*



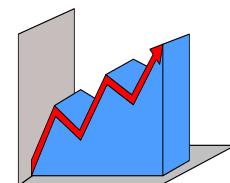
- *Housekeeping*



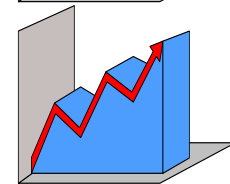
- *Quality*



- *Operator Satisfaction*



- *Machine Reliability*



Visual Controls

- Visual Controls Communicate Simply and Quickly to Anyone the Standards by which a Task or Activity Should Be Performed in any Work Flow Environment

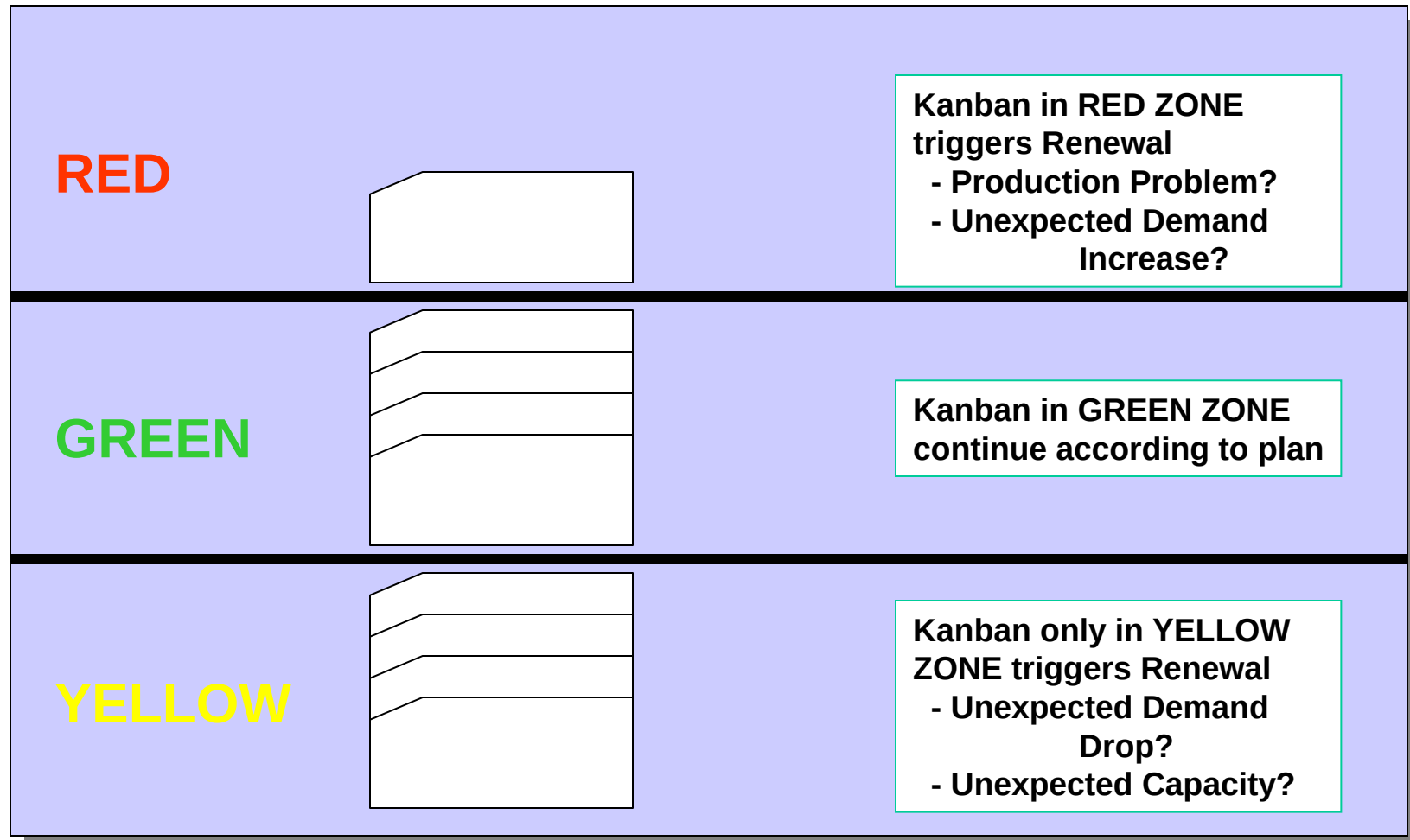
Visual Controls

- A well implemented Visual Control System:
 - passes decision-making to the point of operation
 - prevents mistakes
 - quickly highlights mistakes or variances that have occurred

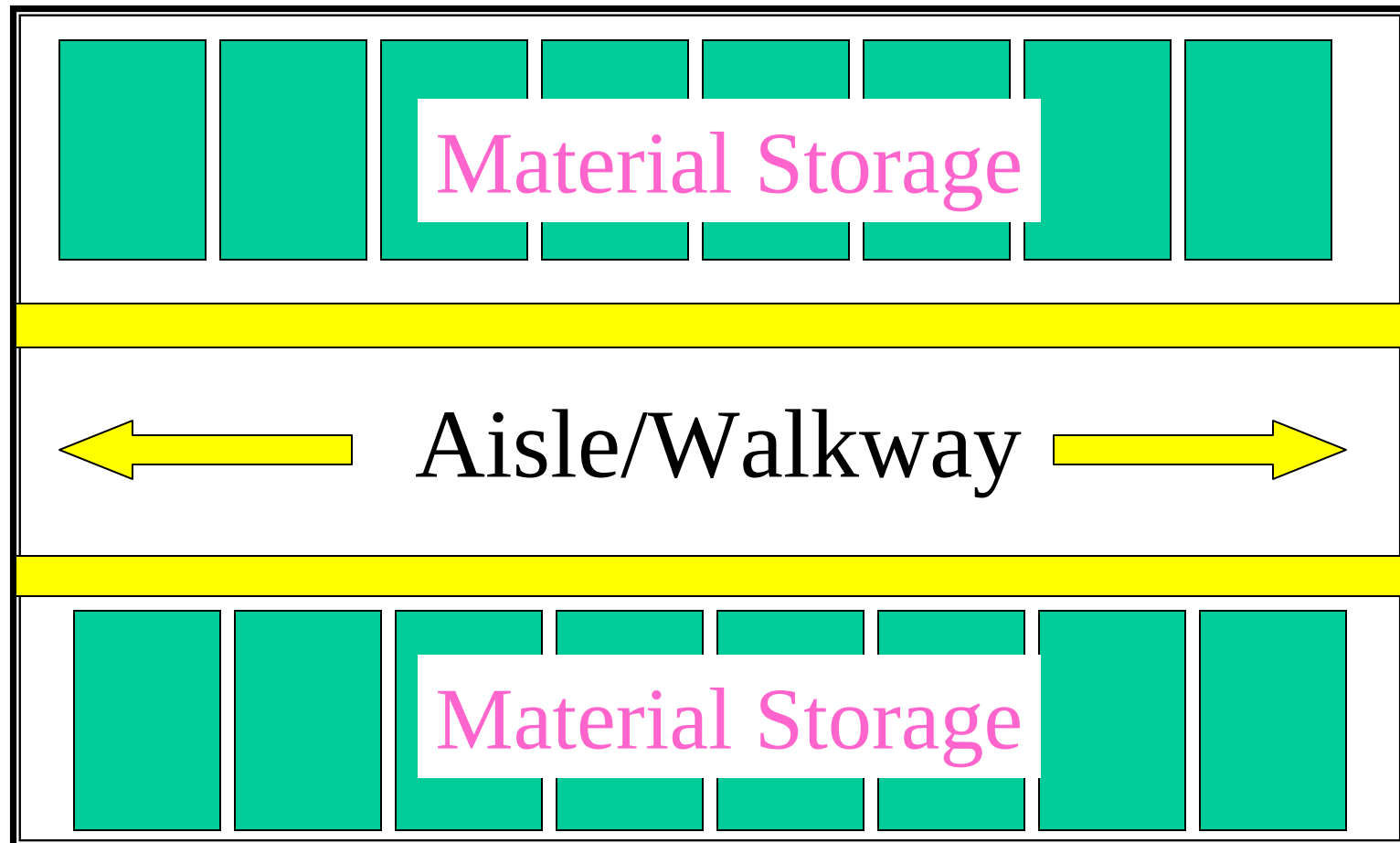
Visual Controls

- Examples of Common Visual Controls Systems are:
 - Kanbans Cards and Kanban Squares
 - Schedule Boards
 - Labeled and Outlined Tools & Tool Kit Boards
 - Painting
 - First-in-First-Out Queues
 - Dedicated, Sized Containers
 - Color Codes
 - Etc...

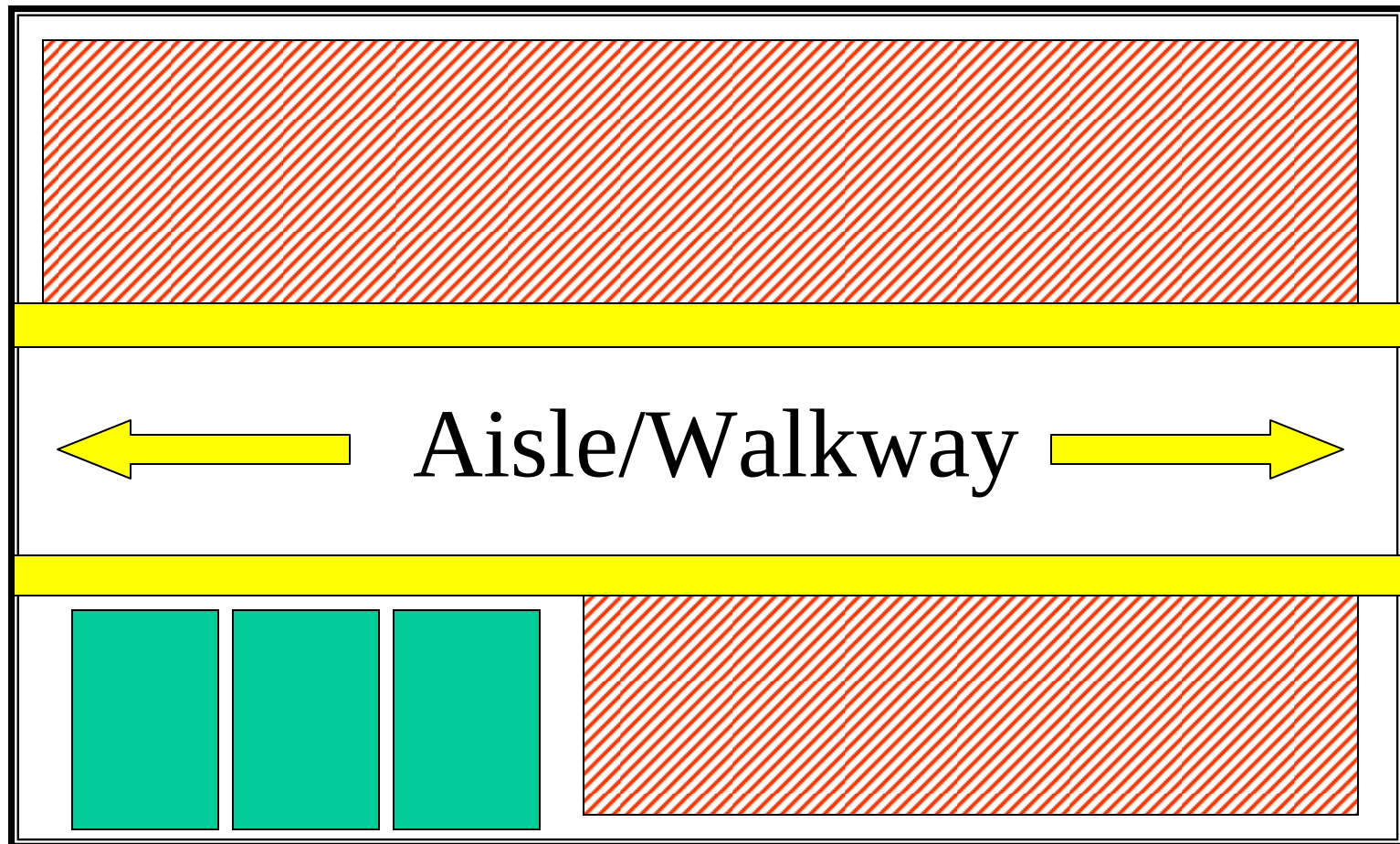
Finished Goods Replenishment Unit Kanban Board



Before



After



Schedule Board

Part	Hour	Plan	Actual	Dif	Comment
772025	1	1350			
772025	2	1500			
812130	3	1350			
812194	4	1350			
772053	5	1350			
772111	6	1350			
812290	7	1350			
812600	8	1350			

Set-Up Time Reduction Benefits

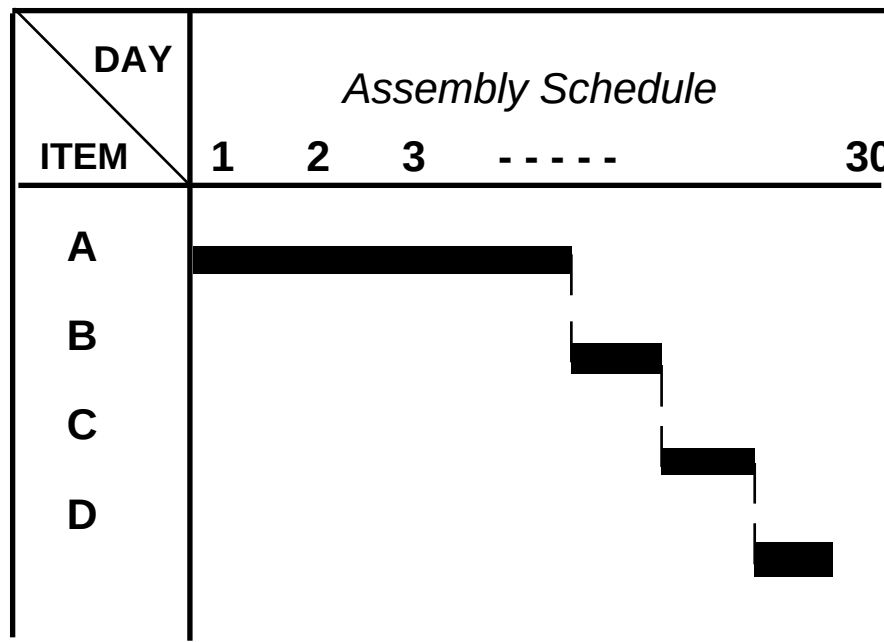
Decreased set-up time provides a stream of benefits . . .

- More frequent changes . . . allow
- Shorter production cycles . . . which
- Lower inventories . . . and offer
- More flexibility . . . to deliver
- Faster customer response . . . with
- Better quality . . . resulting in
- Higher controllable earnings

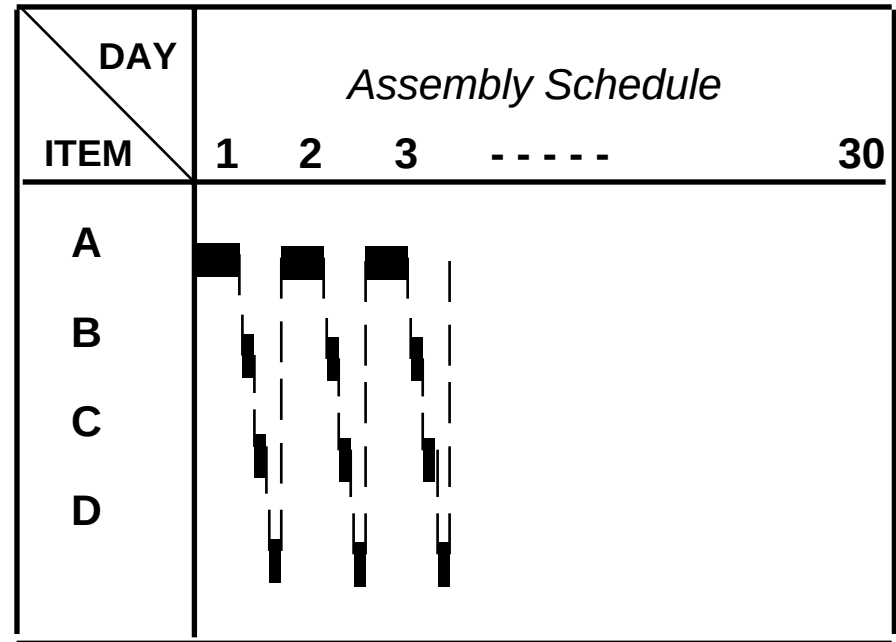
Set Up Time = One Piece Flow

Reducing Lot Sizes is Critical to Being Able to Produce to Customer Demand and Respond Flexibly

Old Batched Lots



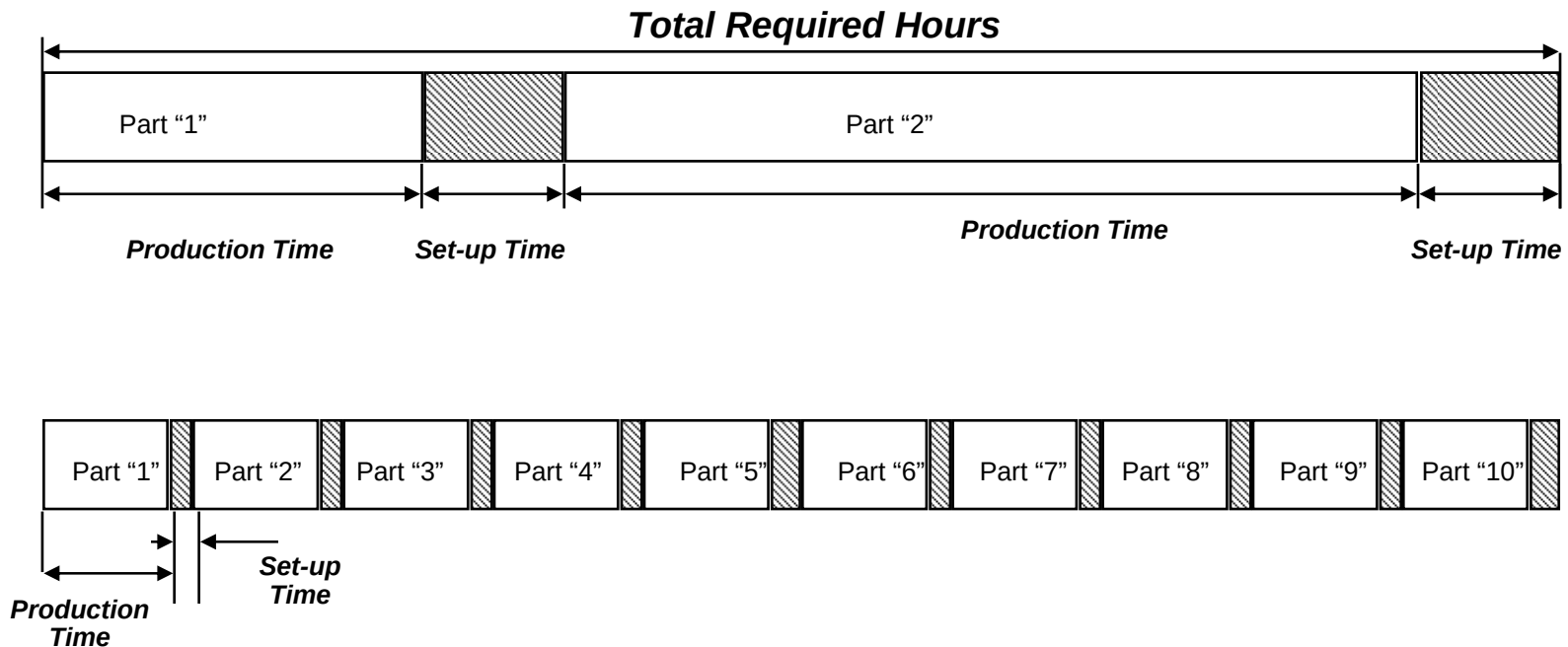
New Small Lots



Sell Daily? Build Daily!

Set Up Time Reduction

Greatly Increase Flexibility By Affording the Opportunity to Reduce Lot Sizes



The number of different lots produced is increased in direct relation to shortening set-up time (e.g., 5 times as many different parts produced equates to the individual set-up being allowed 1/5 the time.)

Set-up Time Reduction 12-Step Process

1. Create Team
2. Select Set-up Project
3. Determine Set-up Time Reduction Goal
4. Videotape Set-up Activity
5. Document Activities
6. Identify Internal vs. External Elements
7. Housekeeping/Organization
8. Shift Internal to External
9. Improve Elemental Operations
10. Standardize and Document New Methods
11. Analyze New Method & Videotape
12. Goal Attained

Overview: Mistake Proofing (Poka-Yoke)

- A Lean Enterprise is a process driven enterprise that is always striving to eliminate waste
- Processes should support the perfect satisfaction of Customer requirements when followed correctly
- Mistake Proofing is a method for insuring that the process is necessarily followed

Overview: Defect Causes

Most defects are caused by Human Error, such as (in order of importance):

1. Omitted Processing
2. Processing Errors
3. Errors Setting Up Workpieces
4. Missing Parts
5. Wrong Parts
6. Processing Wrong Workpiece
7. Misoperation
8. Adjustment Error
9. Equipment Not Set Up Properly
10. Tools and Jigs Improperly Prepared

Overview: Poka-Yoke

- Poka-Yoke: loosely translated means “mistake proofing”. It is from Japanese:
 - yokeru: to avoid
 - poka: inadvertent errors
- Key Attributes:
 - Respect for Worker Intelligence
 - Focus on Repetitive Activities that Rely on Vigilance and Memory
 - Free Worker to Pursue Creative, Value-Added Activities

Quality Control Techniques

There are three categories of inspection approaches:

1. Judgement Inspection
2. Informative Inspection
3. Source Inspection

Judgement Inspection

- Approach: Focus on preventing "escape" defects from getting to the Customer by inspection and separation of good product from bad product after processing
- Result: Escapes are prevented but Defect Rate is not reduced.

Informative Inspection

- Approach: Investigate "cause" of defect and reports this information so that the process can be improved to further reduce defects
- Result: Tolerates, a priori, existence of defects

Source Inspection

- Approach: 100% Inspection at Source Activity so that simple "mistakes" can be prevented prior to generating a defect
- Result: Mistakes are prevented through Mistake Proofing (Poka-Yoke) providing Zero Quality Control

Zero Quality Control

Three Components:

- 1 Source Inspection: errors, not defects
- 2 100% Inspection: inspection simple, inexpensive and automatic part of process
- 3 Immediate Action: stop the process

Zero Quality Control

- Strategies for Zero Defects:
 1. Don't make it if it isn't needed
 2. Make it to withstand any use (don't let the Customer be your inspector)
 3. Make it, use it immediately (small lot/continuous flow production)

Mistake Proofing

- Defects occur when there is a breakdown in one or more of the Five Elements of Work Flow:
 1. Associate/Operator
 2. Material
 3. Equipment
 4. Method(s)
 5. Information

Mistake Proofing: Defects

- Defects can exist in one of two states:
 - Defect has occurred
 - Defect is about to occur

Mistake Proofing: Defects

- Mistake Proofing has three functions used when Defects are Predicted or Detected:
 - Shutdown
 - Control
 - Warning

Mistake Proofing

- Mistake Proofing, in general, is:
 - Simple
 - Quick to Implement
 - Inexpensive or free

Mistake Proofing: Eight Principles

1. Build quality into the process
2. All inadvertent errors can be eliminated
3. Stop doing it wrong, Start doing it right-now
4. Don't think "Why I can't do it right", think "How can I do it right?"
5. Go for a 60% chance of success
6. Team work can reduce mistakes and defects to zero
7. Ten heads are better than one
8. Ask "Why" 5 times and "How" once (5W's & 1H) to isolate root cause.

Common Mistake Proofing

Several of the most common methods used for mistake proofing are:

- Guide pins of different sizes: interference fits

- Error detection and alarms

- Limit switches

- Counters

- Checklists