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Chapter 16:
Lean Operations

Learning Objectives:

- Define Just-In-Time, TPS, and lean operations
- Define the Seven wastes
- Explain the 5Ss
- Define Kanban & Compute the # of Kanbans
- Understand the various Lean Tools

JIT, TPS and Lean Operations

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- Three approaches to continuous improvement that lead to world-class operations
  - Just-In-Time (JIT): continuous and *forced* problem solving via a focus on throughput and reduced inventory
  - Toyota Production System (TPS): focus on continuous improvement, respect for people and standard work practices
  - Lean operations: eliminates waste through continuous improvement and focus on exactly what the customer wants

- In practice, there is little difference, and the terms are often used *interchangeably*
  - Organizations use the approaches and techniques that make sense for them
  - In this class, we will use the term “lean” to encompass all of the related approaches and techniques

Three Fundamental Principles of Lean

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1. Elimination of waste
   - Waste: any activity that does not add value in the eyes of the customer

2. Reduce variability
   - Variability: is any deviation from the optimum process that delivers perfect product on time, every time

3. Improve throughput
   - Throughput: the rate at which units move through a production process

1. Elimination of Waste: Seven Categories of Waste

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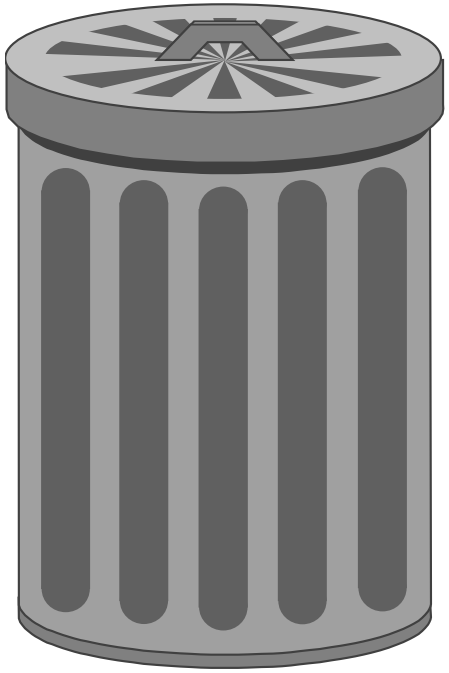
1. Overproduction: producing more than the customer orders or producing early
2. Queues: idle time, storage and waiting
3. Transportation: moving material between plants or between work centers
4. Inventory: unnecessary raw material, WIP, finished goods and excess operating supplies
5. Motion: movement of equipment or people that adds no value
6. Overprocessing: work performed on the product that adds no value
7. Defective Products: returns, warranty claims, rework and scrap



'Waste' in Japanese: 'muda'

Lean Improvement: Removing Motion/Transportation

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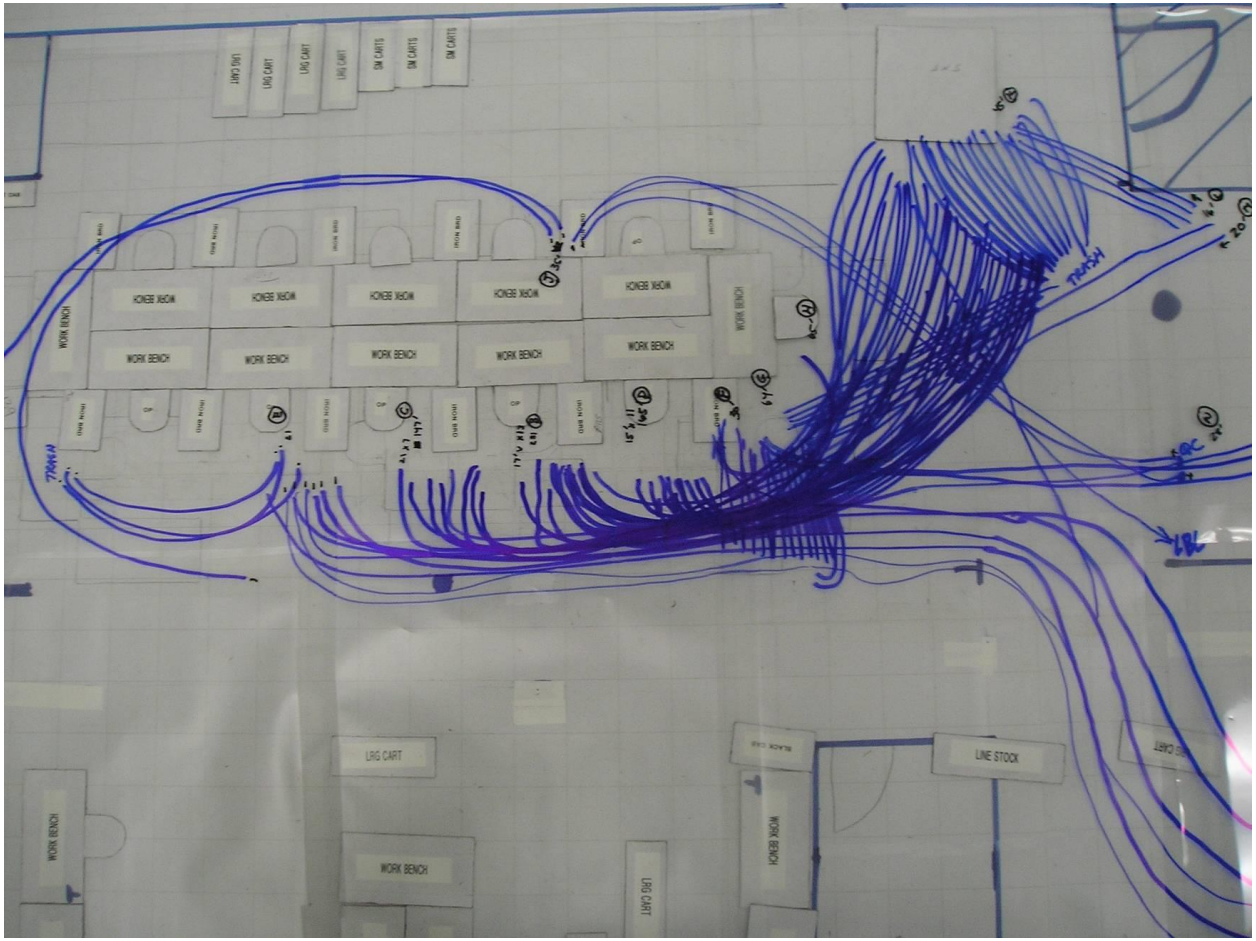

- Before Kaizen event = almost 1 mile walked per employee per day

Lean Improvement: Removing Motion/Transportation

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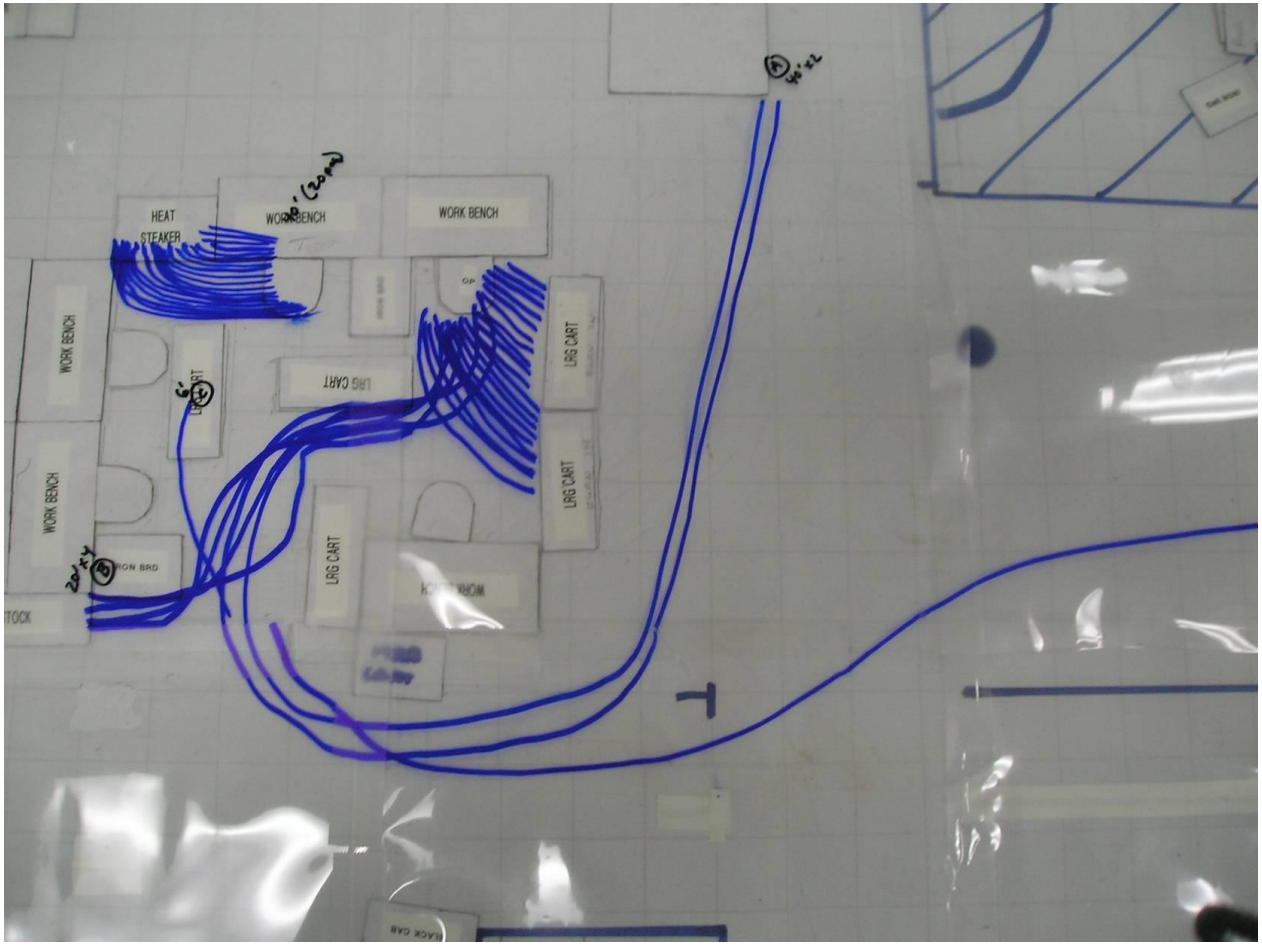

- After Kaizen event layout change = only 375 feet walked per day

Lean Improvement: Removing Queues

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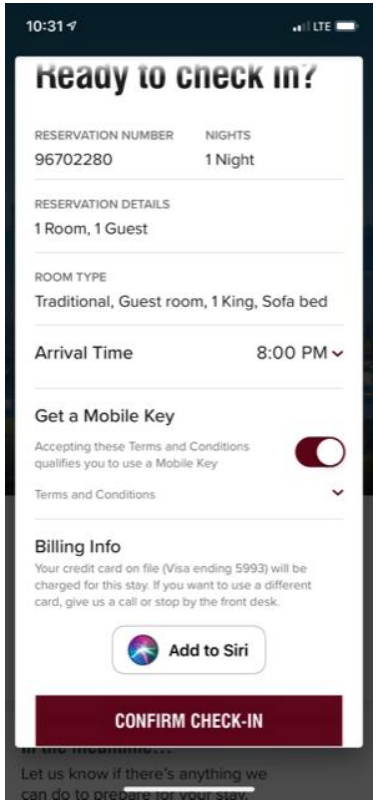
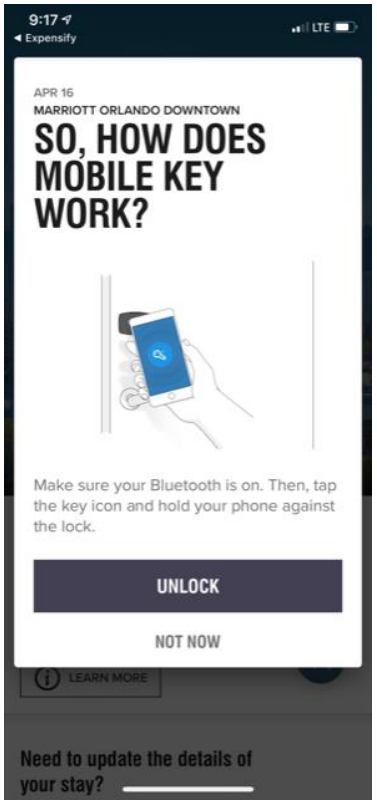
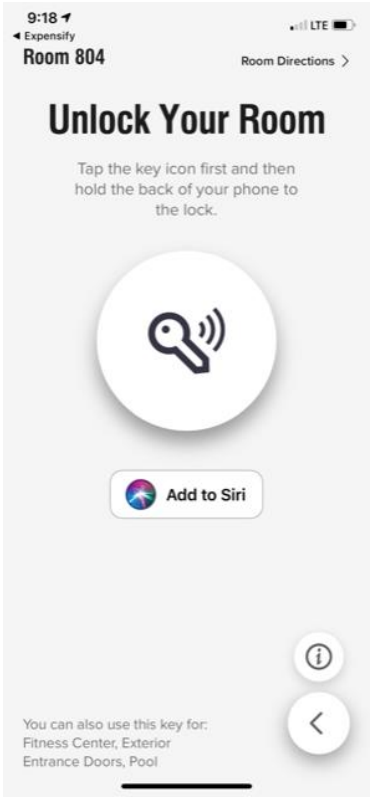
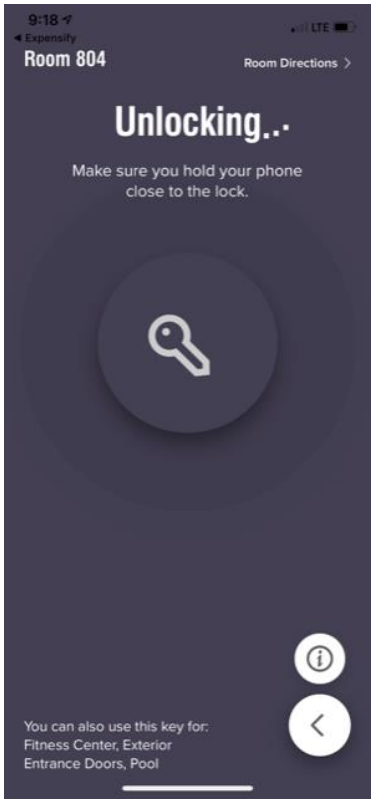
- Marriott Check in Process:









- Eliminates bottlenecks at Check-In counter!

Elimination of Waste: 5S Principles

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- 5S Principles are used to create a clean and well-organized work environment
- The 5S principles are as follows:
  - Sort: each item is in the proper place *[Japanese: seiri]*
  - Straighten: arrange materials so that they are easy to find and use *[Japanese: seiton]*
  - Shine: clean work area *[Japanese: seiso]*
  - Standardize: formalize procedures and practices *[Japanese: seiketsu]*
  - Sustain: keep the process going *[Japanese: shitsuke]*
- US Managers often add two additional S's
  - Safety: Build good safety practices into the above five activities
  - Support/Maintenance: reduce variability, unplanned downtime and costs

Lean Tools: 5s & Visual Controls

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Lean Tools: 5s & Visual Controls

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BEFORE

AFTER

Above: Shadow boxes

To the Right: Shadow boards

Lean Tools: 5s & Visual Controls

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- Visual controls: indicators for operating activities that are placed in plain sight of all employees so that everyone can quickly and easily understand the status and performance of the work system
  - Examples: electronic scoreboards in production processes, painted areas on the floor where certain boxes and pallets should be placed, employee pull cords to stop production, signal lights on machines, etc.

Lean Tools: 5s & Visual Controls

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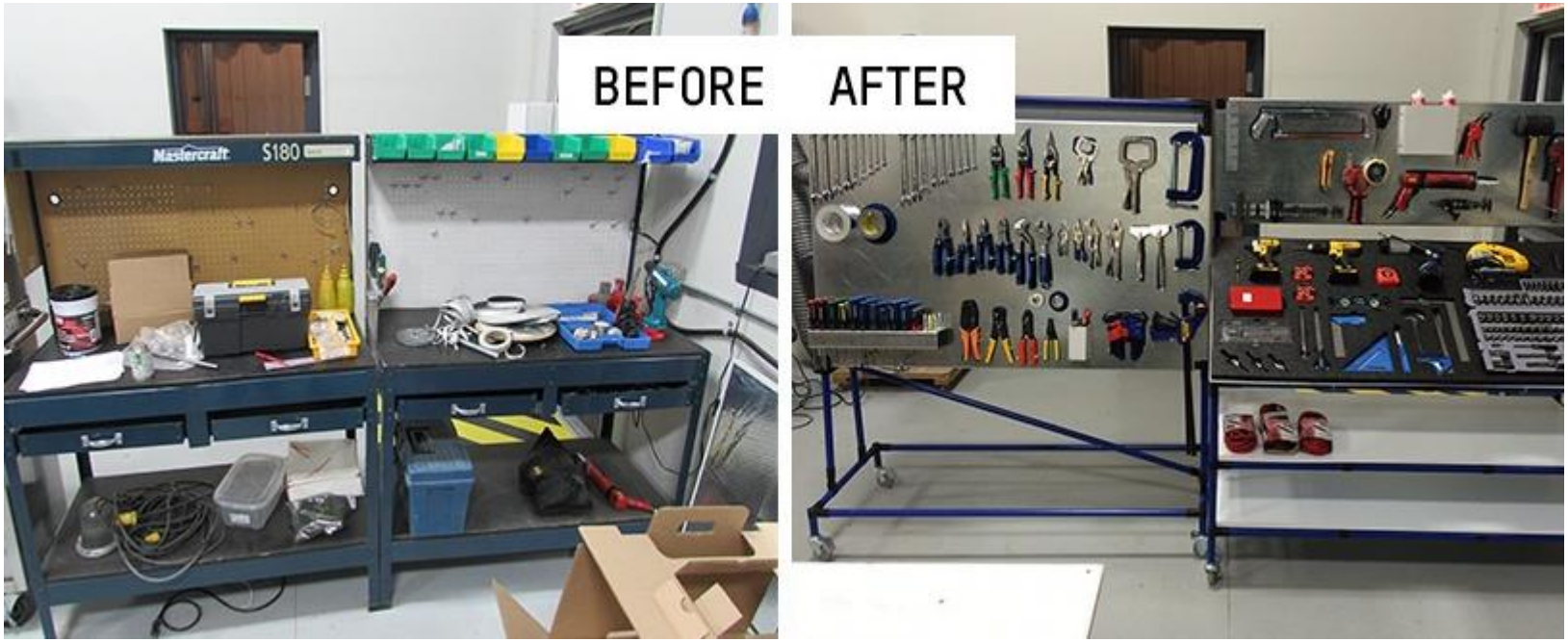

Lean Tools: 5s & Visual Controls

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Before/After 5S

Die Shop

5s your personal spaces too!

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2. Reduce Variability

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- Lean systems require managers to reduce variability caused by both internal and external factors
  - Variability: any deviation from the optimum process
    - Inventory hides variability
    - Less variability results in less waste

- Sources of variability
  - Poor production processes resulting in improper quantities, late, or non-conforming units
  - Unknown customer demands
  - Incomplete or inaccurate drawings, specifications, or bills of material

3. Improve Throughput

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- Throughput: the time it takes to move an order from receipt to delivery

- Manufacturing cycle time: the time between the arrival of raw materials and the shipping of the finished order

- Improving throughput
  - A "**Pull**" system increases throughput
  - Manufacturing cycle time is reduced
  - By pulling material in small lots, inventory cushions are removed, exposing problems and emphasizing continual improvement
  - In contrast, a "**Push**" systems dump orders on the downstream stations regardless of the need

Lean Tools: Pull Systems

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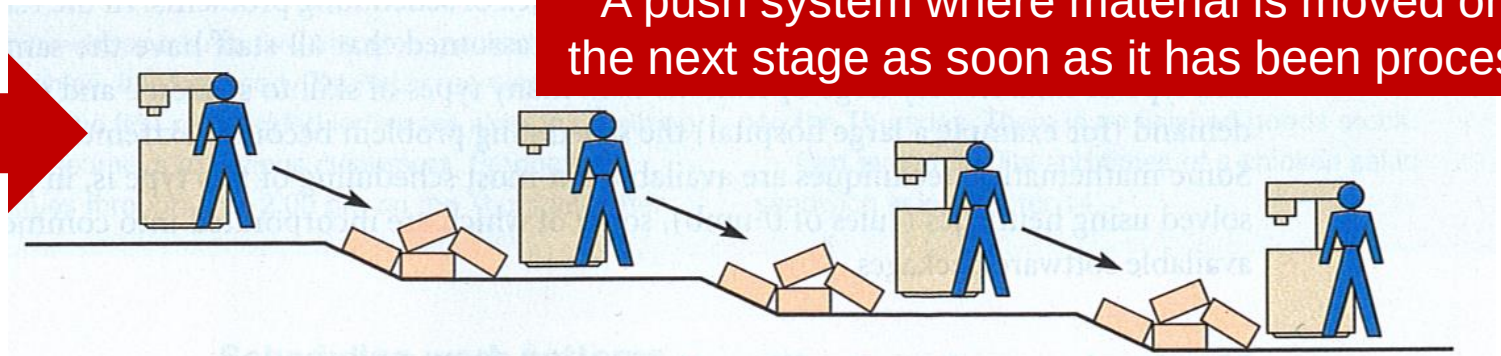
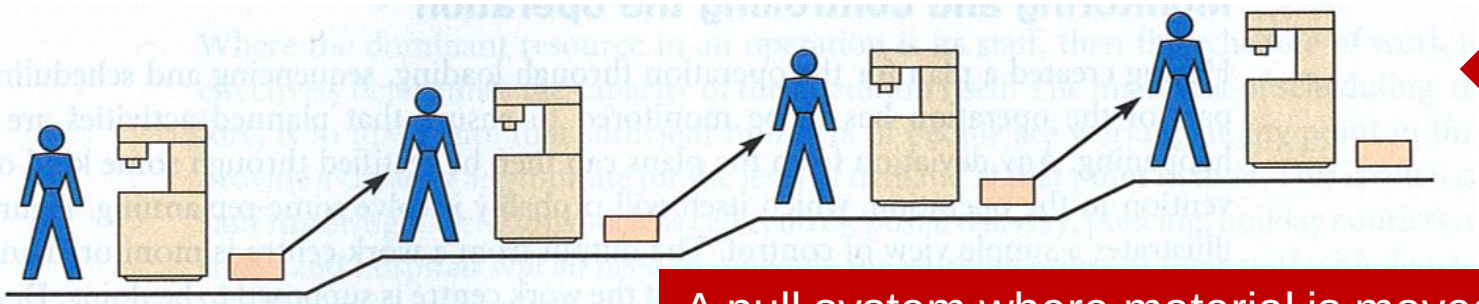
- Push system: produces finished goods inventory in advance of customer demand using a forecast of sales
- Pull system: employees at a given operation (work station) go to the source of the required parts, such as machining or subassembly, and withdraw the units as they need them

A push system where material is moved on to the next stage as soon as it has been processed

Push



Pull



A pull system where material is moved only when the next stage wants it

Example: Improve Throughput

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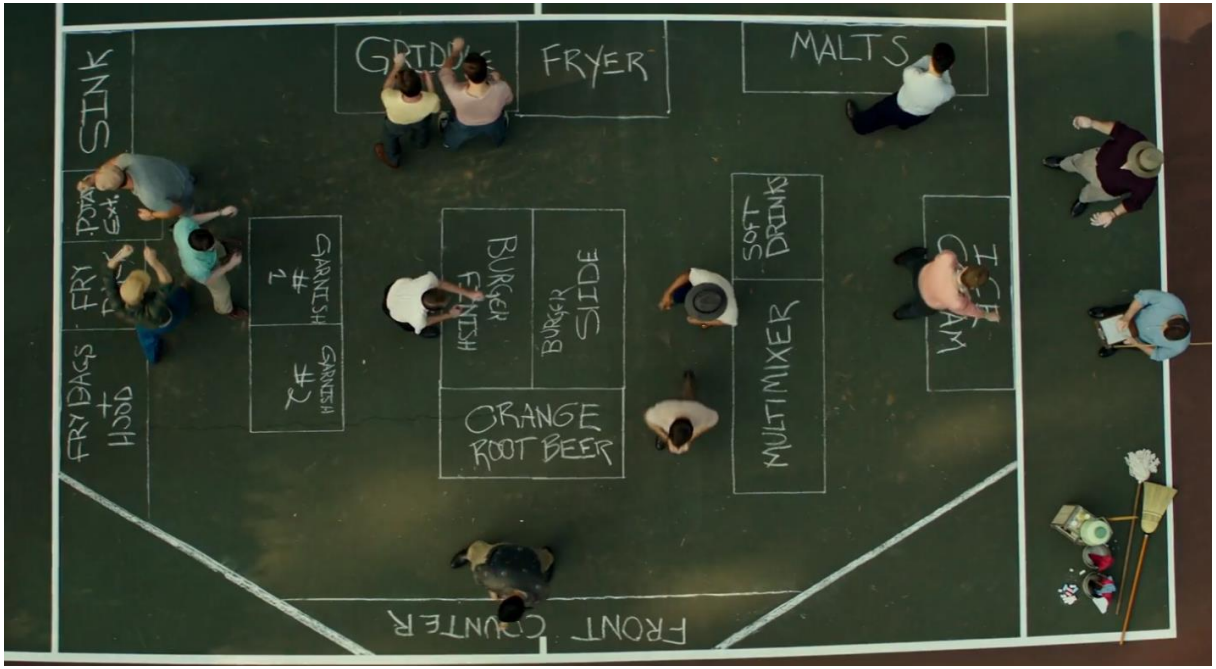
- Movie: **The Founder** (about Ray Kroc & McDonalds)

- This scene talks about how they brainstormed laying out the kitchen to improve throughput, years before anyone was incorporating lean principles into restaurants.



Lean and the Toyota Production System (TPS)

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1. Continuous improvement – process improvement is an integral part of every employee's job
   - Kaizen: a focus on continuous improvement
   - Kaizen event: members of a work cell or team meet to develop improvements in the process
2. Respect for people
   - People are treated as knowledge workers
   - Engage mental and physical capabilities
   - Empower employees
3. Processes and standard work practices
   - Work shall be completely specified as to content, sequence, timing, and outcome
   - Process improvements are made after rigorous analysis at the lowest level in the organization

Lean Tools: Kaizen Event

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Lean Tools: Gemba Walk & QDIP boards

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Left: Gemba Walk with QDIP boards. Gemba is defined as going to where the work is actually performed.

Below: QDIP board. Visual representation of daily performance for key metrics.

Lean and Traditional Systems: Key Differences & Benefits

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FACTOR	TRADITIONAL	LEAN
Inventory	Excess. Used to hide issues	Minimal necessary to operate
Deliveries	Few, large	Many, small
Lot sizes	Large	Small (ideal = 1)
Setup; runs	Few, long runs	Many, short runs
Vendors	Transactional	Partners
Workers	Necessary to do the work	Assets

Benefits of Lean:

- **Improved** Productivity, Equipment utilization, Higher quality, Flexibility, Good vendor relationships.
- **Reduced** Lead Times, Inventory levels, scrap and rework, space requirements, and need for indirect labor

Lean and Just-in-Time

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- Just-in-time (JIT) with it's focus on rapid throughput and reduced inventory, is a powerful component of Lean.
  - With the inclusion of JIT in Lean, materials arrive *where* they are needed, only *when* they are needed.
  - When goods *do not* arrive just as needed, a "problem" has been identified to be addressed.

- A well-defined Lean program requires a meaningful buyer-supplier partnership, which can then focus on
  - Supplier Partnerships
  - Lean Layouts
  - Lean Inventory

Supplier Partnerships

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- Supplier Partnerships: Partnerships of suppliers and purchasers that remove waste and drive down costs for mutual benefits.
- A successful Lean Supplier Partnership will achieve:
  - Removal of unnecessary activities
    - Receiving, incoming inspection, sourcing, invoicing
  - Removal of in-plant inventory
    - Delivery of small lots directly to production department
  - Improved quality & reliability
    - Through collaboration, communication, & commitments
  - Removal of in-transit inventory
    - By encouraging suppliers to locate nearby & use small lots

Consignment inventory: An arrangement where the supplier maintains title to the inventory until it is used by the buying firm

Lean Layouts

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- Lean Layouts reduce waste by reducing movement & motion

BENEFITS	LEAN LAYOUT TACTICS
Distance Reduction	• Build work cells for families of products • U-Shaped work centers • Group Technology
Increased Flexibility	• Moveable equipment and workstations • Single Minute Exchange of Dies (SMED) • Include multiple operations in small areas • Cross-Train workers to add flexibility
Employee Impact	• Empower employees to make suggestions/concerns • Close proximity increase communication • Implement poka-yoke processes to improve quality
Reduced Space & Inventory	• Design little space for inventory • Deliver directly to point of use location • Receive inventory Just-In-Time

Lean Layouts:
U-Shaped Work Cells

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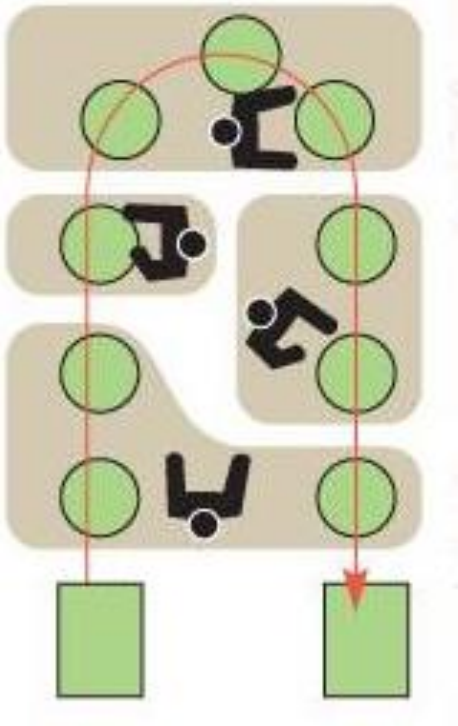
- Benefits of a U-Shaped work cell:
  - Allow better sharing of work
  - Less floor space required
  - Less waste of motion
  - Reduces transportation waste
  - Supports one piece flow
  - Improves communication



Lean Layouts: Group Technology

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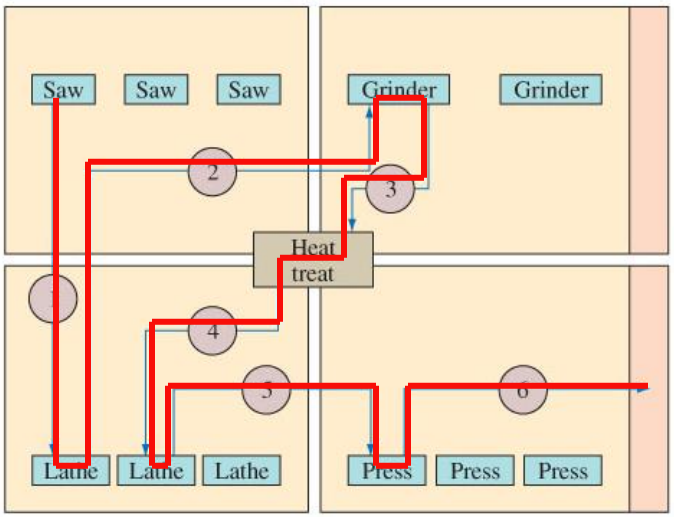
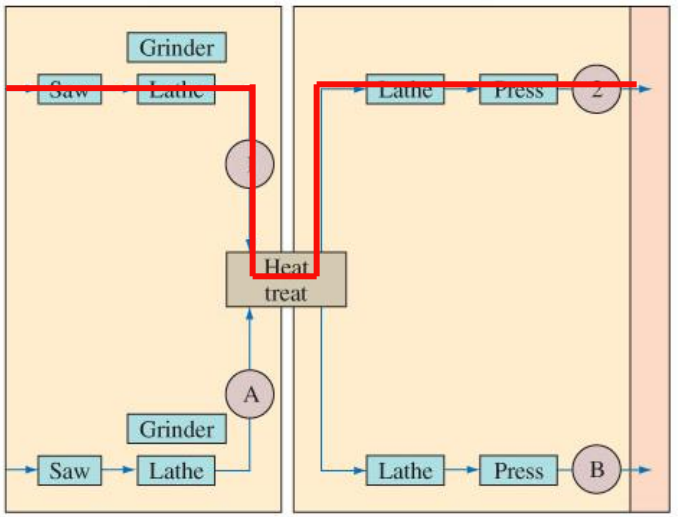
- Group Technology (GT): a philosophy in which similar parts are grouped into families and the processes required to make the parts are arranged in a manufacturing cell
- GT considers all operations to make a part and groups those machines together
- Eliminates movement, waiting time, reduces inventory and number of employees required

Specialized Work centers



Group Technology Cells



Lean Layouts:
Point of Use inventory

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- Point of Use Inventory: Inventory that is physically located at the manufacturing workstation.

Lean Inventory

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- Lean Inventory: The minimum inventory necessary to keep a perfect system running.

BENEFITS	LEAN INVENTORY TACTICS
Reduce Inventory & Variability	• Use a Pull System to move inventory • Supplier Partnerships & JIT • Consignment Inventory • Utilize level schedules
Reduce Lot Sizes	• Kanban • Produce small lots • Single Piece Flow
Reduce Set up Time & Costs	• Point of Use Inventory • Single Minute Exchange of Die (SMED) techniques • Use U-shaped work centers • Use Group Technology

Inventory Hides Problems

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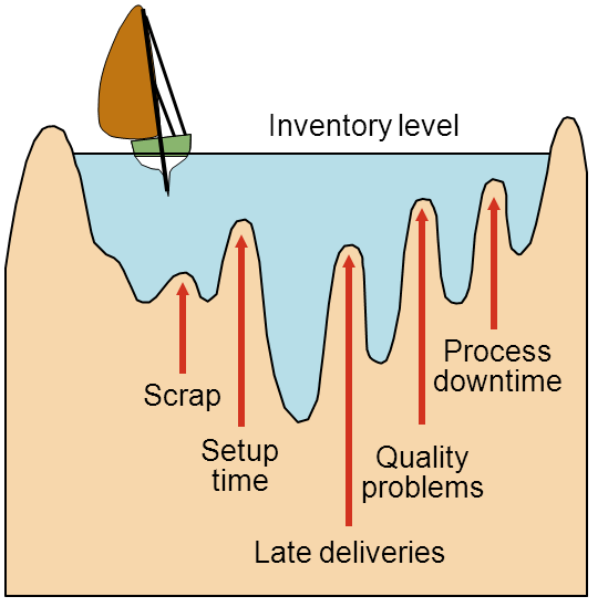
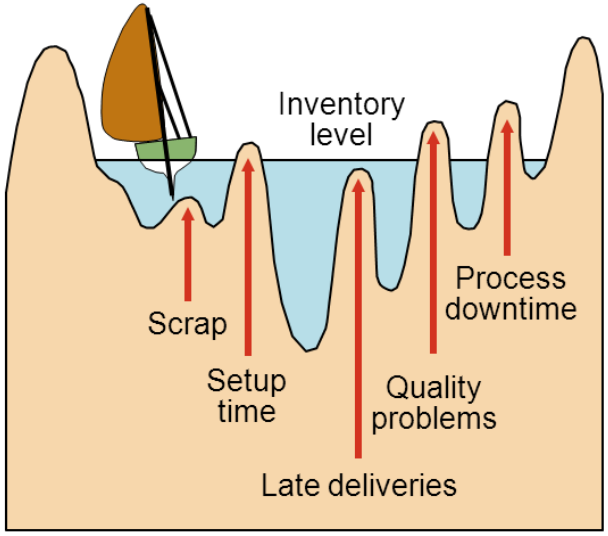
a) High levels of inventory hide problems

b) As we reduce inventory, problems are exposed

c) After reducing inventory and removing problems, we have lower inventory and lower costs



a)



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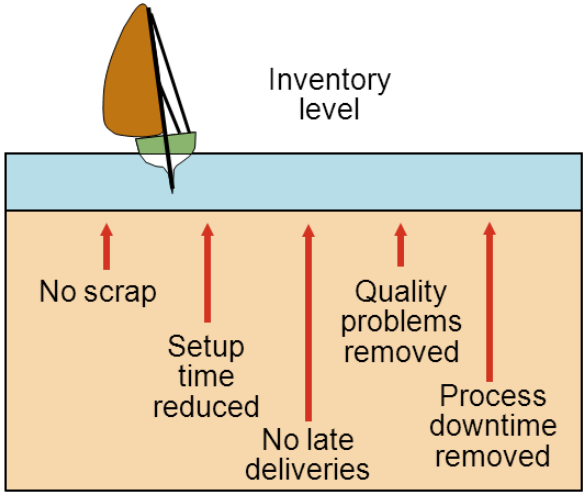

c)

Reduce Lot Sizes

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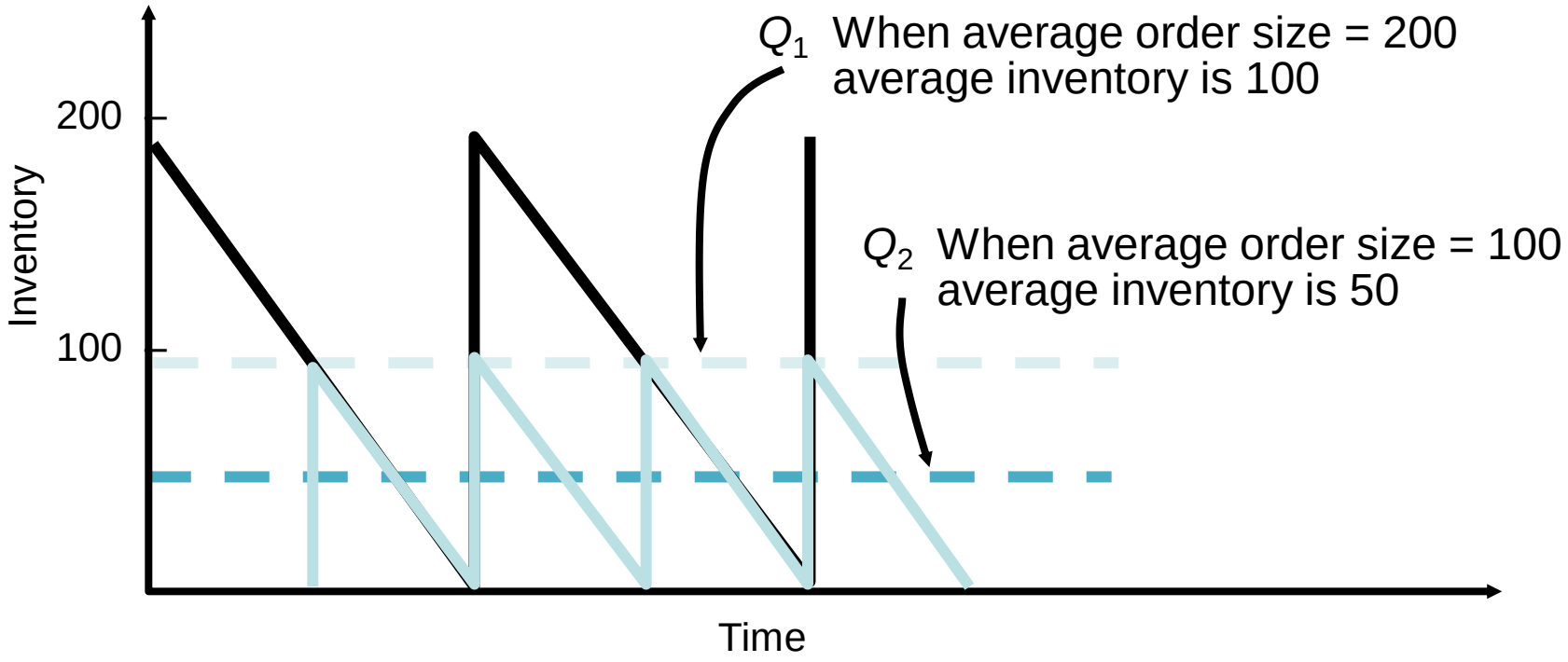

Lean Tools: Small Batches and Single-Piece Flow

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- Batching: the process of producing large quantities of items as a group before being transferred to the next operation
  - Lean operating systems seek to reduce batch sizes using single-piece flow

- Single-piece flow is the concept of ideally using batch sizes of **one**
  - It allows companies to better match production to customer demand, avoid large inventory buildups, and ensure uninterrupted movement of WIP through the production system

- To utilize single-piece flow, a company must be able to change between products quickly and inexpensively by reducing setup times

Batch versus Single-Piece Flow

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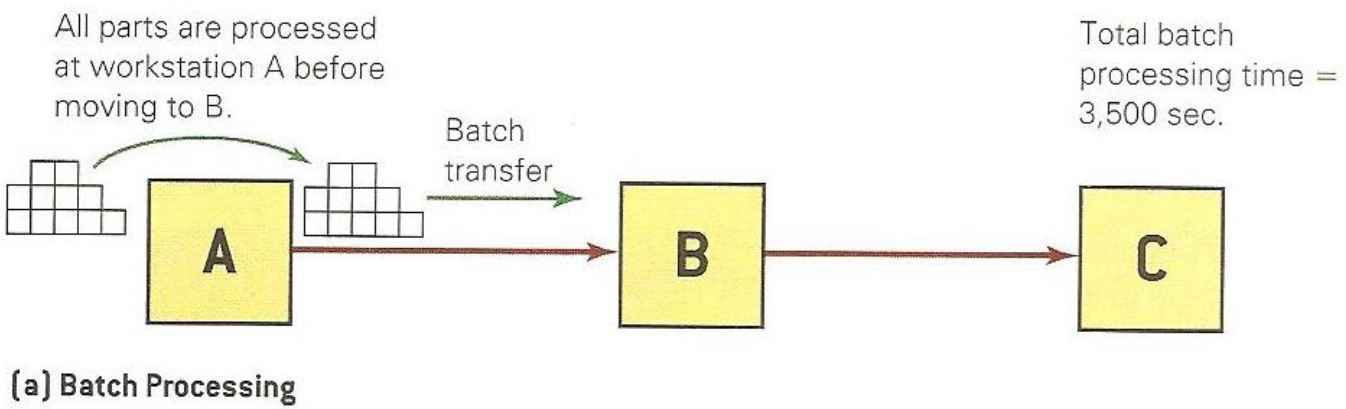
Batch Process.

Workstation	Batch Size (Q)	Processing Time per Item
A	100	5 seconds
B	100	20 seconds
C	100	10 seconds



(a) Batch Processing

A: 100 units x 5 seconds = 500 seconds

B: 100 units x 20 seconds = 2000 seconds

C: 100 units x 10 seconds = 1000 seconds

Total time for 100 units = 3500 seconds

Batch versus Single-Piece Flow

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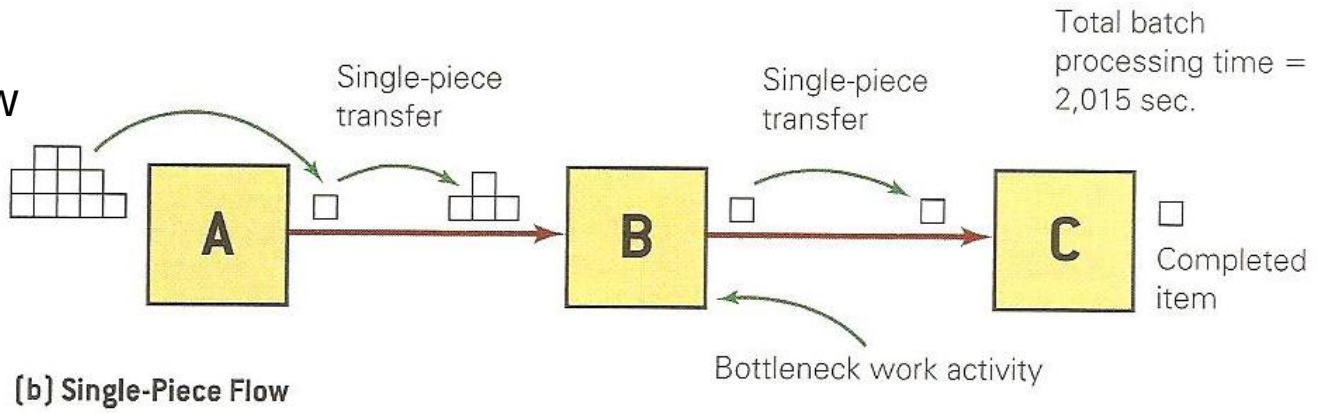
Workstation	Batch Size (Q)	Processing Time per Item
A	100	5 seconds
B	100	20 seconds
C	100	10 seconds

Single Piece Flow



Unit 1: A=5 sec x 1 = 5 seconds

Units 1-100: (B paces process = “bottleneck”) B=20 sec x 100 = 2000

Unit 100: (final step at C) C=10 sec x 1 = 10 seconds

Total time for 100 units = 2015 seconds

Batch versus Single-Piece Flow

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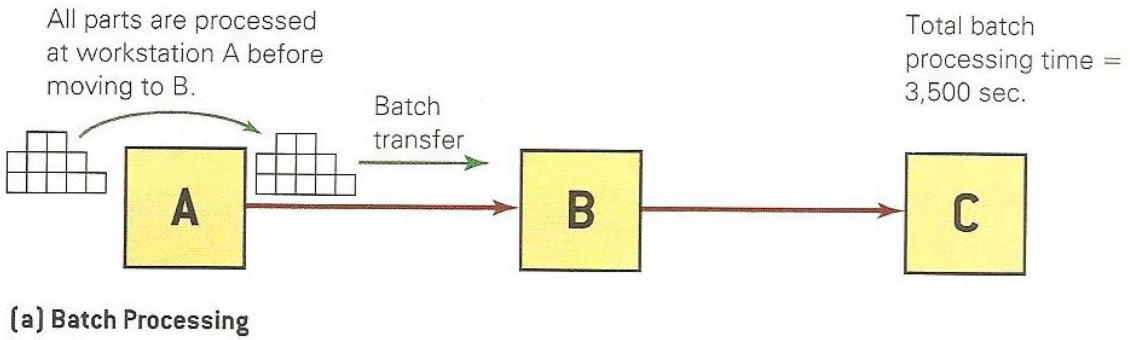
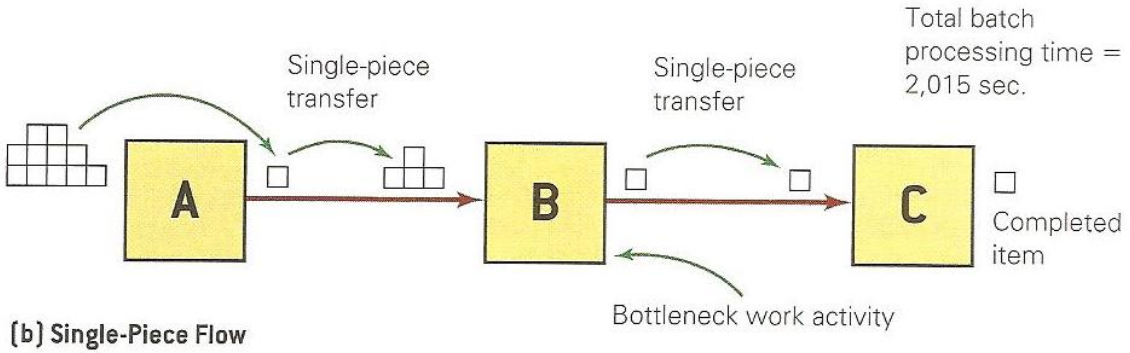
Workstation	Batch Size (Q)	Processing Time per Item
A	100	5 seconds
B	100	20 seconds
C	100	10 seconds



(a) Batch Processing

Batch Process: 3,500 sec.



(b) Single-Piece Flow

Single Piece Flow: 2015 sec. (42% reduction)

Lean Tools: Kanban

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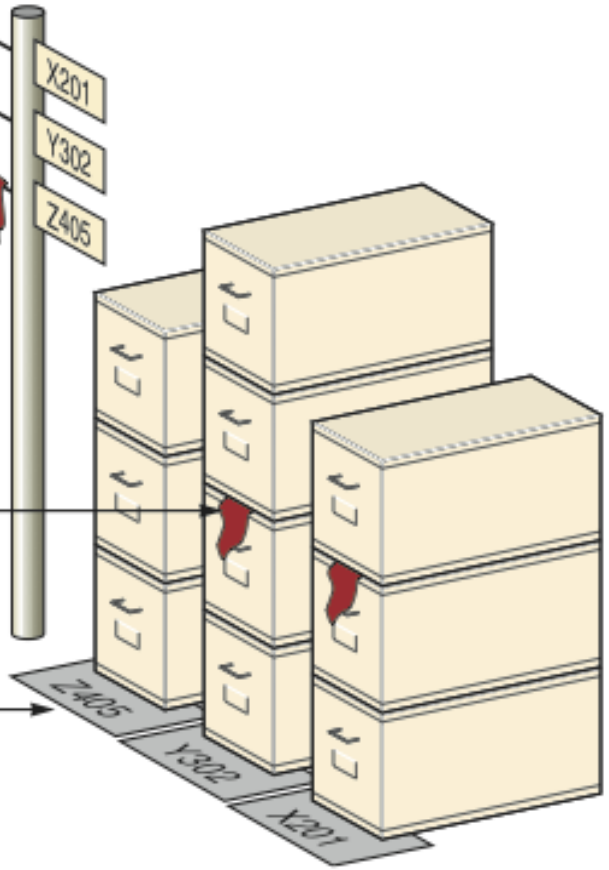
- Kanban: the Japanese word for *card*, which has come to mean “signal”
- Kanban System: moves parts through production via a “pull” from a signal

Signal marker hanging on post for part Z405 shows that production should start for that part. The post is located so that workers in normal locations can easily see it.

Signal marker on stack of boxes

Part numbers mark location of specific part



Lean Tools: Kanban

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Visual flags = empty bin

Lean Tools: Kanban Bins

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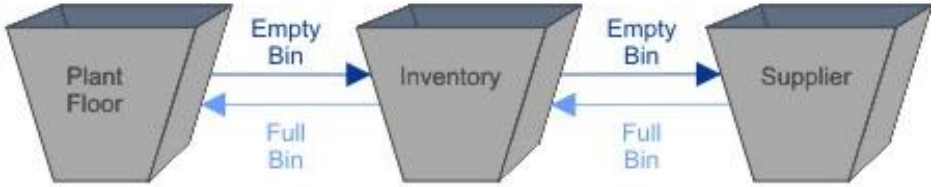
Manufacturing facility

Hospital Stockroom



Number of Kanban's Example

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- Kanban Bin(s) calculation: to calculate the quantity of Kanban bins for a given process, you need to know
  - The lead time needed to produce a container of parts
  - The amount of safety stock needed

$$\text{Number of Kanbans (bins/containers)} = \frac{\text{Demand during lead time} + \text{Safety stock}}{\text{Size of container}}$$

Number of Kanban's Example

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Daily demand	=	500 cakes
Production lead time (Wait time + Material handling time + Processing time)	=	2 days
Safety stock	=	1/2 day
Container size	=	250 cakes

Demand during lead time = 2 days x 500 cakes = 1,000

Safety stock = ½ x Daily demand = 250

$$\text{Number of Kanbans} = \frac{1{,}000 + 250}{250} = 5$$

Little's Law

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- Little's law: there is a long-term relationship between the inventory (WIP), throughput (R), and flow time (T) of a production system in steady state

$$\text{INVENTORY} = \text{THROUGHPUT} \times \text{FLOW TIME}$$

or

$$\boxed{\text{WIP} = \text{R} \times \text{T}}$$

  - Work-in-process inventory (WIP): inventory that is in process (no longer raw materials but yet to be finished goods inventory)
  - Throughput (R): the long-term average rate that items are flowing through the process
  - Flow time (T): the time that it takes a unit to move through the process from beginning to end
- If we know any two of the three variables, we can compute the third using Little's Law.

Little's Law Example # 1

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1. Suppose that a voting facility processes an average of 50 people per hour and that, on average, it takes 10 minutes for each person to complete the voting process. Compute the average number of voters in the process.

$WIP = R \times T$ R = throughput = 50 per hours
T = flow time = 10 minutes
WIP = R x T = 50 voters/hr * (10 min/60 min per hour) = 8.33 voters Therefore, on average, we would expect to find about 8 or 9 voters inside the facility

Little's Law Example # 2

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2. Suppose that the loan department of a bank takes an average of 6 days to process an application and that an internal audit found that about 100 applications are in various states of processing at any one time. Calculate the throughput of the department per month.

R = throughput = ?

T = flow time 6 days: 6 days/30 days per month = 0.2 month

WIP = 100 applications

WIP = R × T → R = WIP/T
= 100 applications / 0.2 month
= 500 applications per month