UCL
SCHOOL OF
MANAGEMENT

MSIN0095: Operations Analytics

Class 1-4: Process Analysis
Class 5,7: Waiting Time Analysis
Class 6: Inventory Management – Newsvendor Model
Class 8: Inventory Management – Newsvendor, Periodic Review
Class 9: Inventory Management – EOQ
Class 10: Inventory Management – Amazon Distribution Strategy
Class 11: Supply Chain Management I: Beer Game
Class 12: Supply Chain Management II
Class 13: Supply Chain Management III: Strategic Sourcing, Sustainable Supply Chains
Class 14: Demand Forecasting I
Class 15: Demand Forecasting II – Caesars Entertainment
Class 16-17: Revenue Management I

Class 18: Quality Management: Toyota Production System, Six Sigma

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Learning Objectives

- **Lean Production and the Toyota Production System (TPS)**
- Quality
  - What is it?
  - How to measure it?
  - Six sigma process

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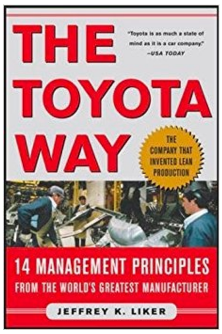
The Seven Deadly Wastes (*Muda*)

1. Overproduction
2. Defects
3. Inventory (> need)
4. Waiting (workers, products)
5. Processing (not value-adding)
6. Motion (unnecessary movement of worker and equipment)
7. Handling (unnecessary transportation)

What is Lean?

- Eliminate Waste (Muda)
  - Anything that does not add value
  - Anything that does not help meet customer requirements
  - Anything customers would not be willing to pay for




Taiichi Ohno

Toyota Production System (TPS)

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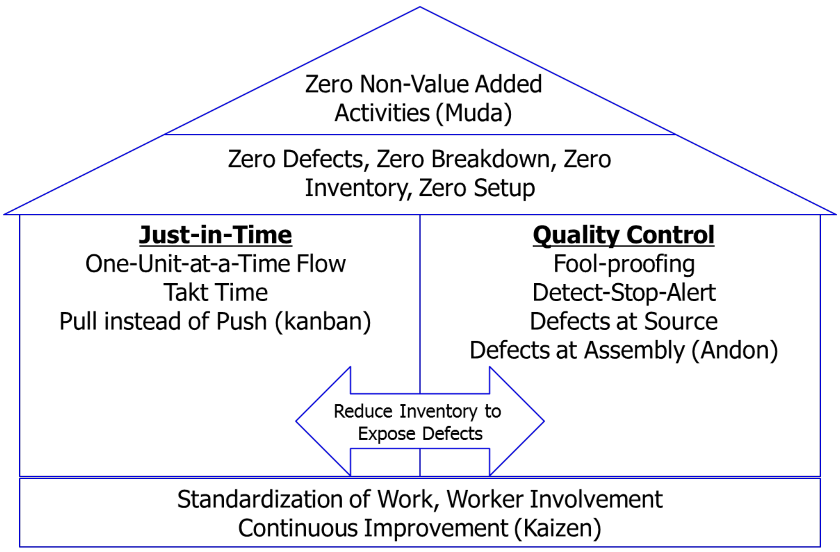
Toyota Production System (TPS)



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The Machine That Changed The World

International Motor Vehicle Program (IMVP)
- Global Benchmarking of automotive plants. 1980

	GM Framingham	Toyota Takaoka
Gross Assembly Hours per Car	40.7	Speed
Assembly Space per Car (sq. ft.)	8.1	
Assembly Defects per 100 Cars	130	Quality
Average inventory of parts	2 weeks	Cost

Toyota Production System, aka Lean

Lean Healthcare

Combining World-Class Lean Healthcare Training Expertise with Hands-On Experience

Our team of Lean Healthcare experts from the world-class University of Michigan Health System enables you to see and think differently and gain essential skills to lead a Lean initiative in your organization. Through a hands-on simulation and case studies, you also have the opportunity to practice instrumental tools and techniques such as value

Lean Government

Wisconsin "Lean Government" Initiative

In order to create jobs and promote economic growth state government must operate with business-like efficiency. Becoming more efficient and continuously improving government will both improve services and control its cost to taxpayers.
In keeping with this philosophy, Governor Walker signed Executive Order #66. This order requires state agencies to implement a lean government initiative. This initiative must engage staff and agency leaders in order to eliminate waste, save time and cost, and improve government services to the benefit of both state residents and employers and annually report their progress to the Governor at the beginning of each year.

What is Lean? Lean is a continuous improvement philosophy. Customers, employees, suppliers, managers, and executives work together in events commonly called value stream mapping, designed to improve operational efficiencies and maximize financial savings. By mapping the status quo, everyone works in cooperation to identify and eliminate the non-value added processes. The result of Lean is increased efficiencies in services for the customers of state government and a safer, more streamlined workplace for employees.

Wisconsin government should always be looking for ways to improve operations and services. Lean initiatives provide a framework for continuous improvement. These processes save taxpayer money, improve workplace safety, and allow government to better serve the public.

Lean Agriculture and Food

Take it from Toyota – lean and green can cut costs

By David Burrows
25-May-2017 - Last updated on 26-May-2017 at 12:56 GMT

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The first step is to identify different kinds of existing waste in the food production process, before classifying them and assessing how to eliminate them. ©iStock/TeamOktopus

Food processors could drive down costs by following the model designed by car manufacturer Toyota in the 1950s, according to a leading supply chain expert.

Lean Insurance

MANAGE

Nationwide CIO: A new Lean management system saves $28 million

by
Nicole Laskowski
Senior News Writer

Guru Vasudeva describes how Nationwide IT is scaling its Lean practice to drive major cultural changes and big savings.

Not just manufacturing…

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Not just manufacturing… The Founder (2016)

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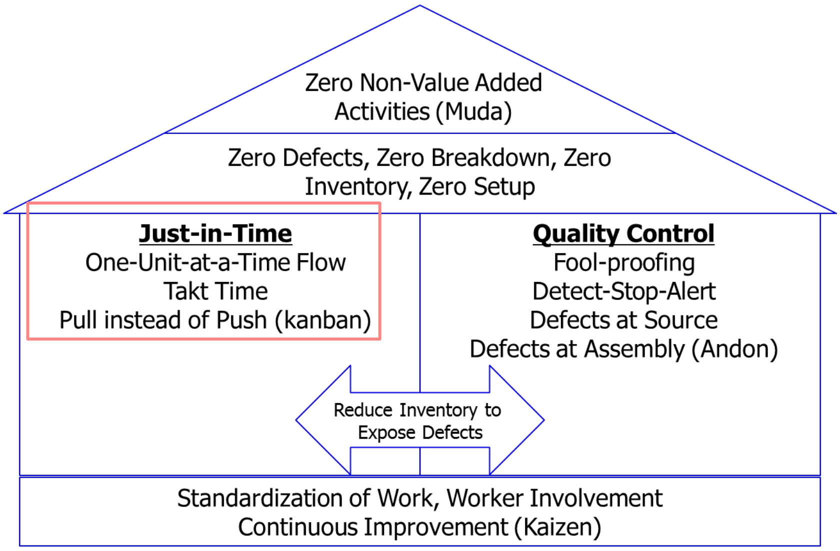
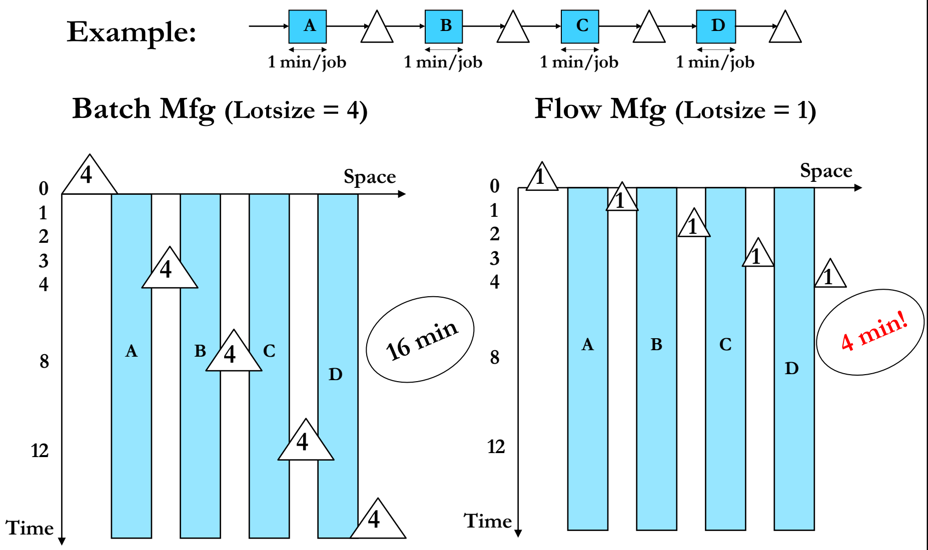
Toyota Production System (TPS)



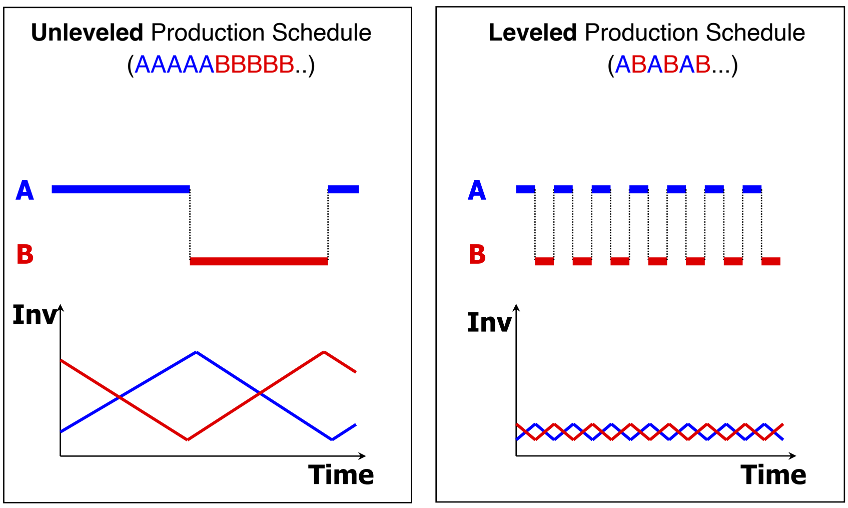
Just-in-Time

- Takt Time (Cycle Time)
  - Pace of demand
  - Work-cycle synchronized with demand cycle
- Leveled production: One-Unit-at-a-Time flow, Heijunka
- Kanban (Pull production)

Leveled Production: One Unit At A Time



Leveled Production: One Unit At A Time

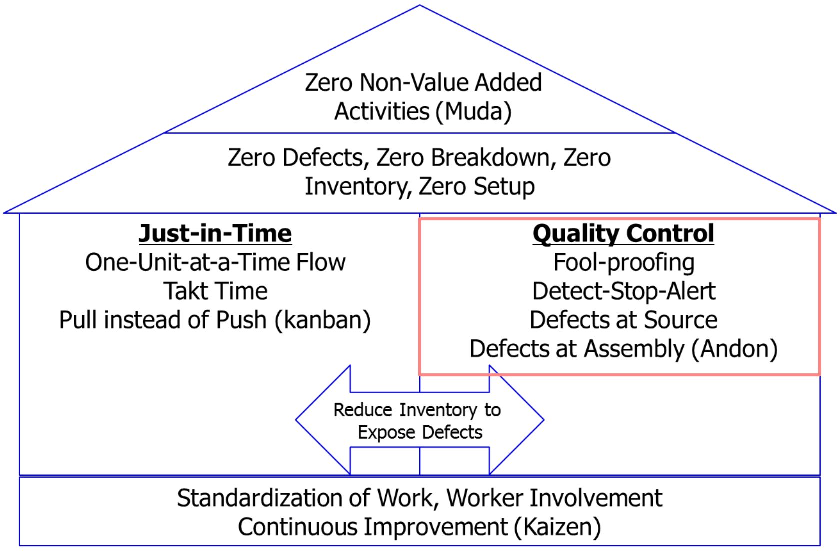


Achieving JIT: Kanban (pull) system

An example of a physical Kanban card.

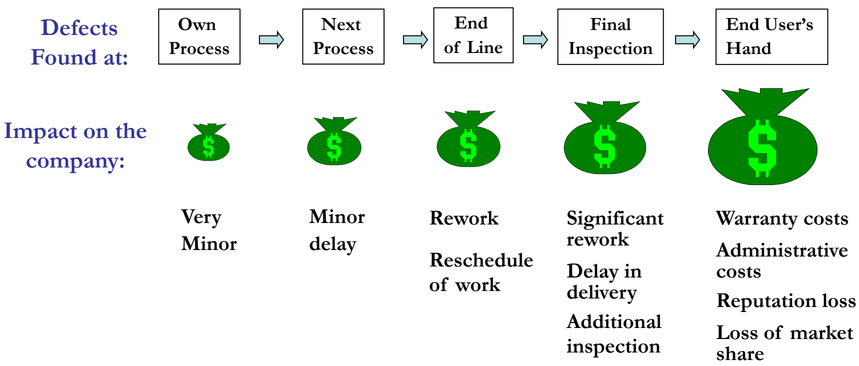
Achieving JIT: Kanban (pull) system

Toyota Production System (TPS)



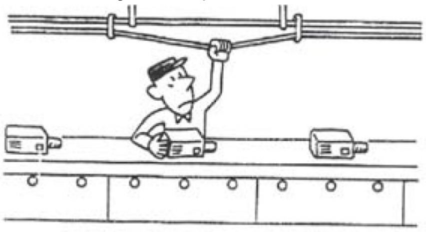
Quality Control: *Jidoka*

- Principle:
  - Control quality **when and where problems occur**

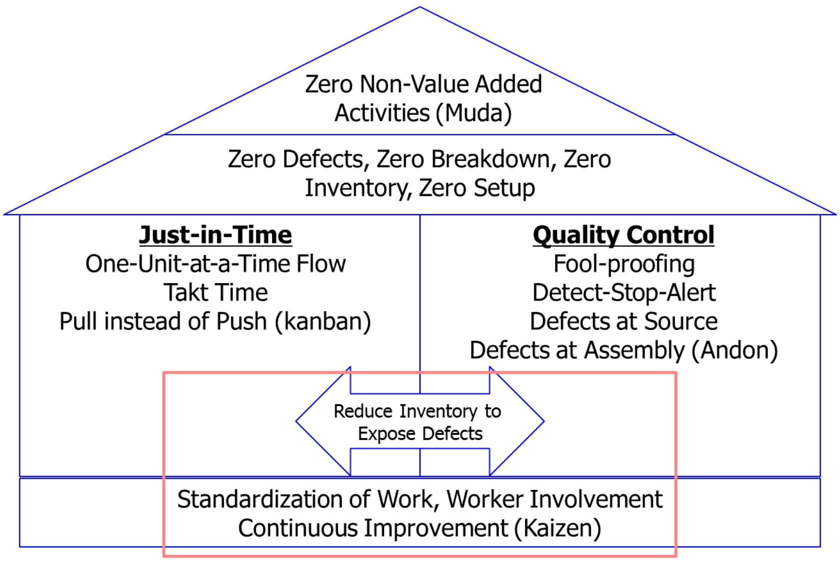


Quality Control: *Jidoka*

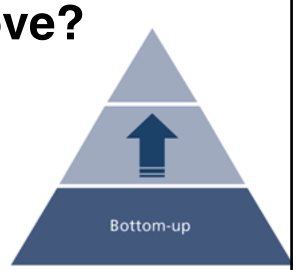
- Principle:
  - Control quality **when and where problems occur**
- Methods:
  - Fool-proof/Failsafe Design (*Poka-Yoke*)
  - Automated Inspection at source (Mechanical *Jidoka*)
  - Line-Stopping Empowerment (Human *Jidoka*, *Andon* System)



Toyota Production System (TPS)



How do Organizations Improve?



Top Down?

No – no one fully understands a complex organization and so no one can dictate practices

Bottom Up?

Yes – ultimately, it is an organization's culture that enables it to learn and change

Management can definitely influence culture…

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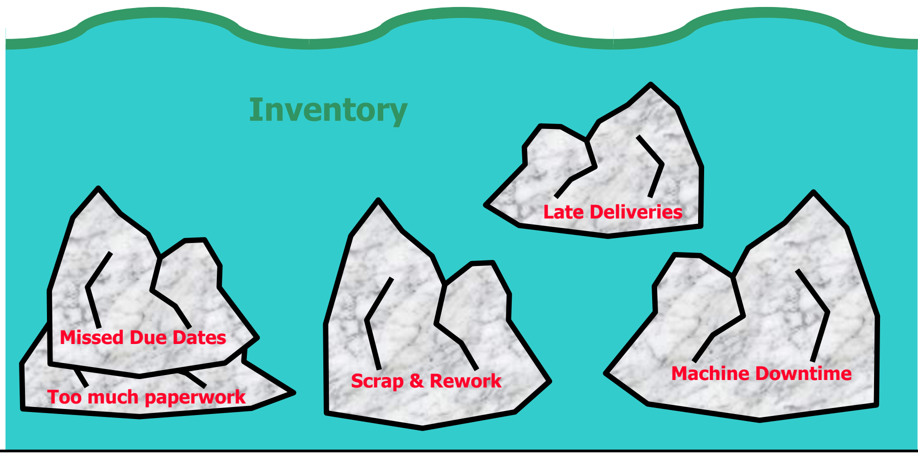
Continuous Improvement: *Kaizen* (改善)



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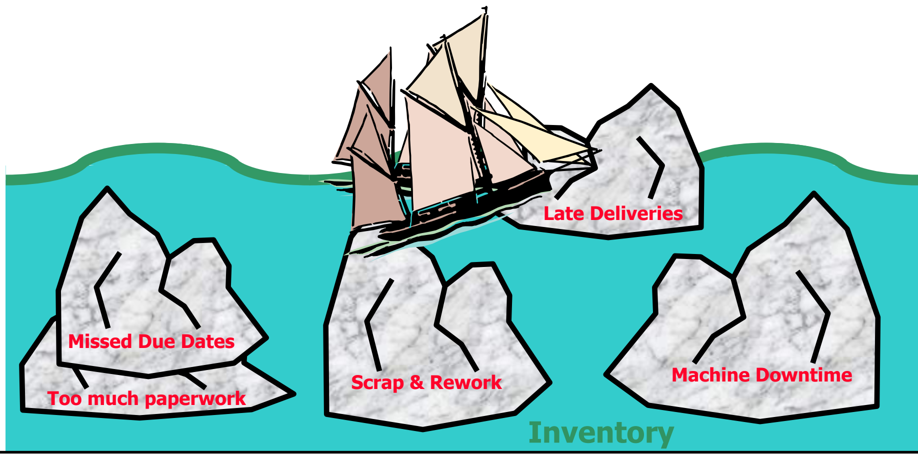
Continuous Improvement: *Kaizen* (改善)



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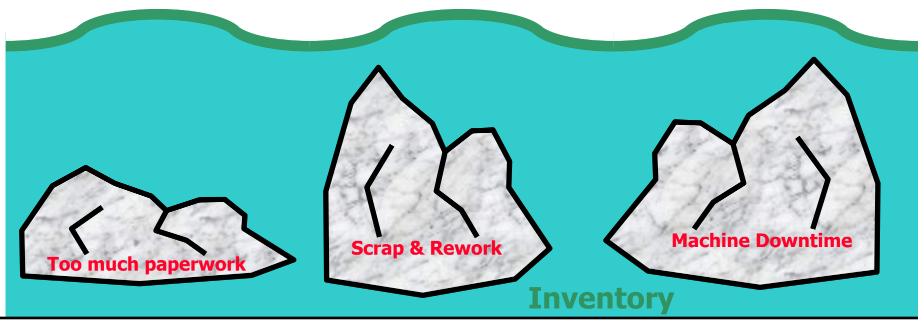
Continuous Improvement: *Kaizen* (改善)

- Reduce inventory to increase visibility of waste



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Learning Objectives

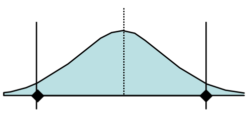
- Lean Production and the Toyota Production System (TPS)
- **Quality**
  - **What is it?**
  - **How to measure it?**
  - **Six Sigma process**

Design Quality

0.995 in 1.005 in

Wood thickness

Conformance Quality



0.995 in 1.005 in

The conformance quality is the ability of the process to meet the design specifications.

Two categories of Quality

- Design Quality
  - Target niche of the product in the marketplace ← A strategic decision for the firm
  - Performance, Features, Reliability/durability, Serviceability, Aesthetics
  - Good Quality ≠ Luxury. A firm designs a product or service to address the need of a particular market
- Conformance Quality
  - Degree to which the product or service design specifications are met

What is the quality of a guitar string?

How do we measure quality

- The guitar string has several quality dimensions:
  - Diameter (gauge)
  - Stability under tension (load + extension)
  - Strength and elasticity (number of twists)
- Tolerance limits specify how much dimension can vary yet still meeting the design specifications
- For the extension:
  - LTL = 6.50 in
  - UTL = 7.50 in
- Anything beyond the tolerance limits is considered a defect (i.e., inconsistent with design specifications).

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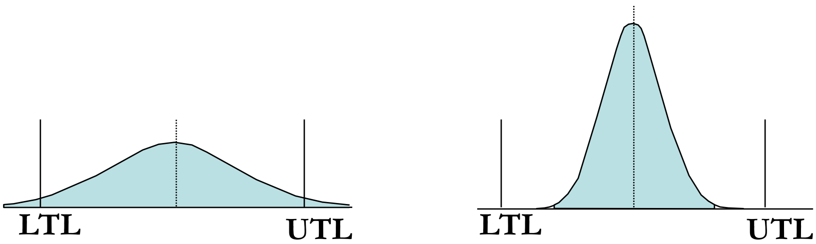
Which process has higher quality?

Probability of defect: Probability that the string extension falls below LTL or above UTL



Smaller Variability = Higher Quality

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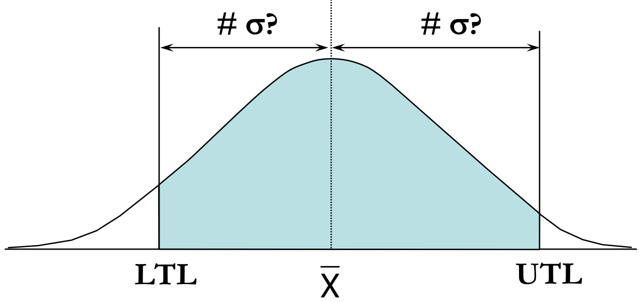
Quality measure I: sigma capability

How many standard deviations the process mean is away from the closer tolerance limit?

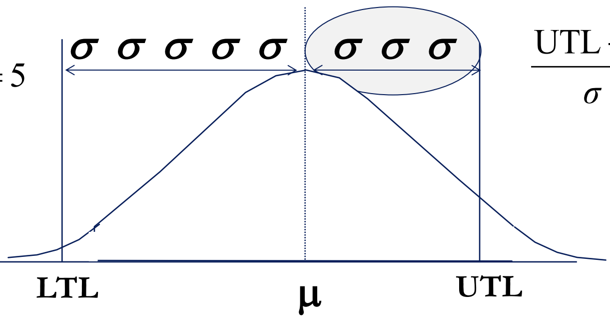


$$z = \min(z_L, z_U) = \min\left(\frac{\bar{X} - LTL}{\sigma}, \frac{UTL - \bar{X}}{\sigma}\right)$$

Higher z means higher process quality

Sigma capability example

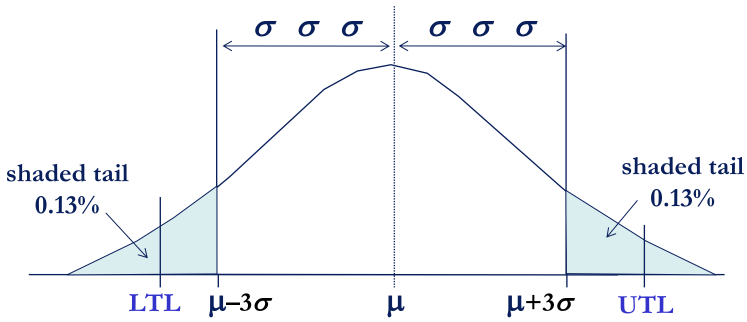
$$\frac{\mu - LTL}{\sigma} = 5$$



$$\frac{UTL - \mu}{\sigma} = 3$$

This diagram depicts 3-Sigma Capability

Sigma capability example



If Sigma Capability $z \geq 3 \Rightarrow$ Probability of defect $\leq 0.26\%$

Quality measure II: capability index

- **Capability Index C_{pk} = Sigma Capability z / 3**

$$C_{pk} = \frac{z}{3} = \min\left(\frac{\overline{X} - LTL}{3\sigma}, \frac{UTL - \overline{X}}{3\sigma}\right)$$

Quality measures: example

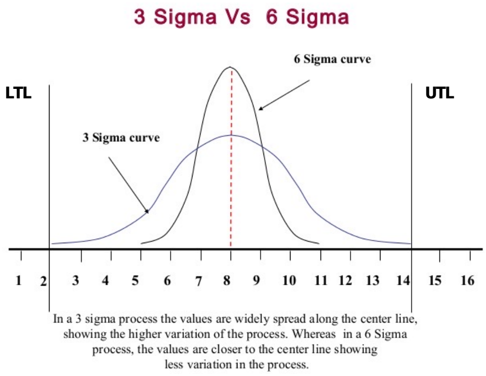
$$C_{pk} = \frac{z}{3} = \min\left(\frac{\bar{X}-LTL}{3\sigma}, \frac{UTL-\bar{X}}{3\sigma}\right)$$

- LTL = 6.50, UTL = 7.50, $\bar{X}$ = 7, σ = 0.125
  Sigma Capability=___4___ C_{pk} = _1.333__
- What if $\bar{X}$ shifts to 7.4?
  Sigma Capability = _0.8__ C_{pk} = _0.267__

Capability Index

$$\boxed{C_{pk} = \frac{z}{3} = \min\left(\frac{\bar{X}-LTL}{3\sigma}, \frac{UTL-\bar{X}}{3\sigma}\right)}$$

- Traditionally, recommended to be at least 1.33
- Motorola recommended 2→ UTL and LTL are "6 sigma" apart from the mean



Isn't 99.9% Quality of Service Enough?!

- No electricity, water or heat for 8.8 hours each year
- No telephone service or TV transmission for 10 minutes each week
- Two short (or long) landings at DTW each week
- At least 20,000 wrong prescriptions per year
- 4,220 newborn infants dropped by doctors or nurses onto hospital floors

Six-Sigma wants 99.9999998%

Six Sigma

- A philosophy and set of methods to eliminate defects in product/service processes
- Implements DMAIC (Define, Measure, Analyze, Improve, Control (Statistical Process Control))
- A six sigma process produces two defects every billion products (practically zero defects)

MOTOROLA

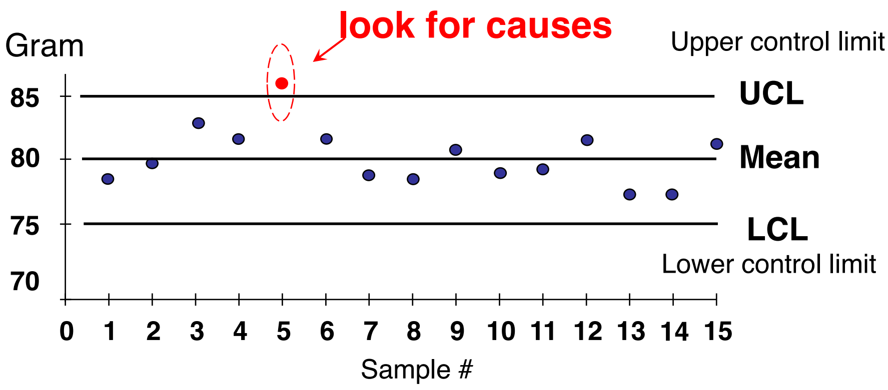
Honeywell

AMERICAN EXPRESS

FedEx

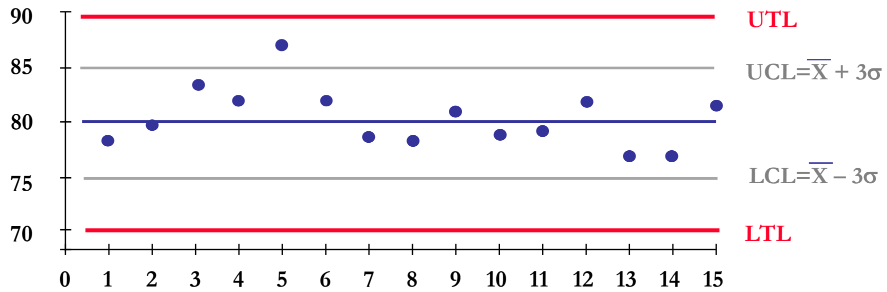
Process control charts

Used to monitor process over time to ensure it remains stable and is operating normally.



Control limits vs. tolerance limits

- Control limits:
  - Whether the process is performing predictably
- Tolerance limits (specification limits):
  - Whether the process is performing acceptably (by customers)
- "voice of the process" vs. "voice of the customer"
- Control limits should fall within the tolerance limits



Control limits vs. tolerance limits

	Tolerance Limits	Control Limits
Who determines?	Customers Designers	Producers, Quality Controllers
What happens beyond limits?	Defects	Actions need to be taken

Practice Problem 1

Service quality control at Sigma Auto Wash requires the length of its service to 30 ± 3 min. A current report indicates that the current average service time is 31 min with a standard deviation of 1 min.

a) Calculate the sigma capability for this example

$$z = \mathrm{Min}\left\{\frac{\overline{X}-\mathrm{LTL}}{\sigma}, \frac{\mathrm{UTL}-\overline{X}}{\sigma}\right\} = \mathrm{Min}\left\{\frac{31-27}{1}, \frac{33-31}{1}\right\} = \mathrm{Min}\{4,\ 2\} = 2$$

b) What SD would you need to achieve 1 defect per 100?

defects too short: 100*NORMSDIST (-4) = 0.00317
defects too long: 100*(1 – NORMSDIST (2)) = 2.27
Need z_U = NORMSINV(0.99) = 2.3265
z_U = (33 – 31)/σ = 2.3265
σ = 0.86min

Practice Problem 2

At a McDonald's restaurant, it is specified that any regular order must be "assembled" within 30 ± 10 sec. A quality inspector takes several sample measurements over time and determines the sample average assembly time is 32 sec. with a standard deviation of 3 sec.

a) Calculate the process capability index

$$C_{pk} = \mathrm{Min}\left\{\frac{\overline{X}-LTL}{3\sigma}, \frac{UTL-\overline{X}}{3\sigma}\right\} = \mathrm{Min}\left\{\frac{32-20}{9}, \frac{40-32}{9}\right\} = \mathrm{Min}\{1.333, 0.889\} = 0.889$$

b) If McDonald's wants to achieve 3-sigma service, is this process capable of delivering desired service quality? How can the process be improved?

It is not capable at present. Improvement: 1) adjust the process mean closer to 30, and 2) reduce variability.

Process Capability Example 1

Sigma a 3 ± 0.02 cm specification. A machine operator takes several sample measurements over time and determines the sample mean outer diameter to be 3.006 cms with a standard deviation of 0.005 cms.

a) Calculate the sigma capability for this example

$$z = \mathrm{Min}\left\{\frac{\overline{X}-LTL}{\sigma}, \frac{UTL-\overline{X}}{\sigma}\right\} = \mathrm{Min}\left\{\frac{3.006-2.98}{.005}, \frac{3.02-3.006}{.005}\right\} = \mathrm{Min}\{5.2,\ 2.8\} = 2.8$$

b) What SD would you need to achieve 1 defect per 1000?

defects too small: 1000*NORMSDIST (-5.2) = 0.0001

defects too large: 1000*(1 – NORMSDIST (2.8)) = 2.55

Need z_U = NORMSINV(0.999) = 3.09

$z_U = (3.02 - 3.006)/\sigma = 3.09$

$\sigma = (3.02 - 3.006)/3.09 = 0.00453$