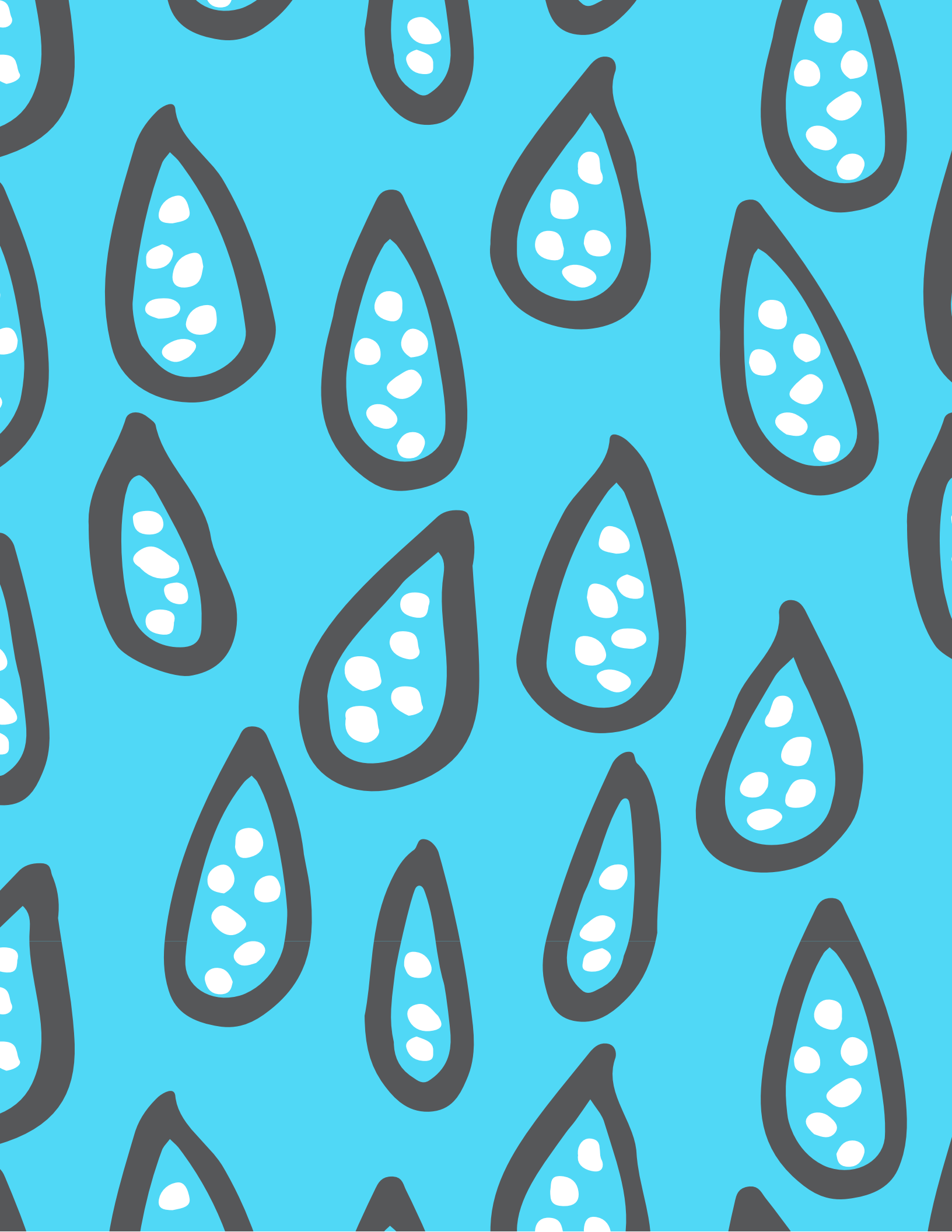


Concepts

Key Terminology

Six Sigma: A data-driven management strategy

Quality: Fitness for use

Two aspects
a) Quality of design - high quality?
b) Quality of conformity - is the high quality consistent?

- **Characteristics** or "**dimensions of quality**" that affect fitness for use as a product
  - (i) Performance — performs required job
  - (ii) Reliability — how often will it fail
  - (iii) Durability — lifetime → will it meet it
  - (iv) Serviceability — easy to repair
  - (v) Aesthetics — product's appearance
  - (vi) Features — what the product does
  - (vii) Perceived Quality — Reputation
  - (viii) Conformance to Standards
- **Producing a Service...** list those dimensions of quality
  - (i) Responsiveness — time to reply to requests
  - (ii) Professionalism — knowledge, timeliness
  - (iii) Attentiveness — caring personalized attention

will call c2qc

Hidden Factory: The part of the plant the customer doesn't see which deals w/ bad quality

Quality Engineering: Consists of activities to ensure that ① that quality characteristics are at desired levels, and ② variability is at its minimum

Sometimes called 'critical to quality characteristic'

Quality Characteristics: Important elements of a product/service to the customer

Variability: Describes or quantifies differences within a set of data or parts or c2qc

Statistical Methods: Analysis, interpretation, and presentation of numerical data

often an upper and lower limit

Specifications: Desired measurements for quality characteristics. This is your target value

Nonconformity: Failure to meet spec

Defect: Nonconformity that hinds use

Variability

- Quality is inversely proportional to variability
  - Variability will impact all quality dimensions
- Variability leads to greater cost & waste

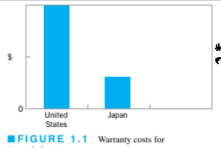


FIGURE 1.1 Warranty costs for transmissions.

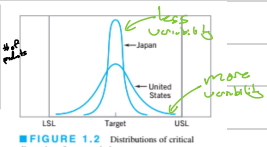


FIGURE 1.2 Distributions of critical dimensions for transmissions.

example to right examines domestic vs. imported car quality

- Why variability leads to more cost for a company

Quality Costs	
Prevention Costs	**Internal Failure Costs**
Quality planning and engineering	Scrap
New products review	Rework
Product/process design	Retest
Process control	Failure analysis
Burn-in ← JR's camping 20 yr test	Downtime
Training ← Personal	Yield losses
Quality data acquisition and analysis	Downgrading (off-specing)
Appraisal Costs	**External Failure Costs**
Inspection and test of incoming material	Complaint adjustment
Product inspection and test	Returned product/material
Materials and services consumed	Warranty charges
Maintaining accuracy of test equipment	Liability costs
	Indirect costs

  - Products found in plant outside of specifications results in higher costs and waste
  - Prevention & Appraisal costs are cheaper costs and result in more consistent products and cheaper costs down the line

Internal Failure & External Failure costs >> Prevention & appraisal costs!

Example: Cost of Variance ← Find manufacturing cost per good produced

Illustrative Example: We are making 100 mechanical components per day where 75% of the parts conform to specifications, and the other 25% are non-conforming. Of the 25% of nonconforming, 60% can be reworked and the other 40% are scraped. Each part costs $20 to manufacture and an additional $4 to be reworked.

$$\frac{\text{cost}}{\text{good}} = \frac{\text{cost to make (\# made total)} + \text{cost to rework (\# reworked)}}{\text{\# of goods sold}}$$

$$= \frac{\$70(100) + \$4(100)(0.25 \cdot 0.60)}{70 + 15} = \boxed{\$22.89}$$

Now the Benefit of Improvement ← Find manufacturing cost per good produced

Illustrative Example: We improve the previous process such that now 95% of the parts conform to specifications, and the other **5% are non-conforming**. Similar to before, of the 5% of nonconforming, 60% can be reworked and the other 40% are scraped. Each part costs $20 to manufacture and an additional $4 to be reworked.

$$\frac{\text{cost}}{\text{good}} = \frac{\$70(100) + \$4(100)(0.05)(0.60)}{95 + 3}$$

$$= \boxed{\$20.53}$$

Quality Engineering

Process: A system of inputs and outputs

Example, Defining a process

Example: A hospital is trying to increase the quality of drug administration. To do this, it is considering providing patients with bar-coded wristbands to help guide workers. Your team is charged with studying the effects of bar-coding by carefully watching 250 episodes in which drugs are given to patients without bar coding and 250 episodes with bar coding. Every time a drug is administered you will check the amount, if any, of discrepancy between what was supposed to be given and what was given.

- Controllable input variable: barcoding
- Key output variable: right amount of drug

Control Charts: A process monitoring technique which tracks averages in a quality characteristic with time or sample number

- **Centerline:** where the characteristic should be if no abnormal sources of variation
- **Control Limit:** Defined by statistics. Alert the user to unusual variability
  - ↳ Different than spec limits

Designed experiments: discovers key variable that have a significant influence on quality characteristics in a process

Six Sigma

Broader Definition: Statistical based, data driven management approach and continuous quality improvement methodology for eliminating defects in a product, process, or service
- ↳ Reduces variability to a level where defects are unlikely

Three Elements of Six Sigma

(i) **Quality Planning:** Listening to the voice of your customer

(ii) **Quality Assurance:** Establishing a system to prevent quality issues from arising

(iii) **Quality Control & Improvement:** A set of specific steps and tools to ensure products meet requirements and are continuously improved

Name Meaning: Refers to the quality level target such that sigma (σ, or variance σ^2) should be small enough so that $6\cdot\sigma$ is within the specification limits

Sigma Quality level: The Probability that product/service is non-defective

Why is Six Sigma Selected?

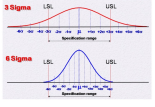
Suppose 100 parts: 3σ: $(.9973)^{100} = .7631$ is probability non-defective → ~24% defective

6σ: $(.9999998)^{100} = .99999998$ non-defective → ~.00002% defective

Some companies use other multiples of σ, depending on what required by company/customers

Example of Six Sigma (could be on HW)

Illustrative Example: Let's say you are making a part that has a radius of 10 mm. Specification limits are between 9 (LSL) and 11 (USL) mm. Before you applied quality improvement, the standard deviation (sigma – a measure of variability) was 1 mm, and after you applied improvements, the standard deviation (sigma) decreased to 0.1. Is the new process 6 sigma quality?



$$\frac{|USL \text{ or } LSL - target|}{\sigma(\text{standard deviation})} = \frac{|9\text{ mm} - 10\text{mm}|}{1\text{ mm}} = 1 \quad \text{for old} \quad \text{"1}\sigma\text{ level"}$$

$$= \frac{|9\text{ mm} - 10\text{mm}|}{0.1\text{ mm}} = 10 \quad \text{for new} \quad \text{"10}\sigma\text{ level"}$$

Lean Manufacturing

Def: Another management philosophy aimed at eliminating waste (e.g. time and materials)

Process Cycle Efficiency (PCE): (Value added time) / (Process time)

↳ **Value added time** = time spent making the product more valuable

Process Cycle Time (PCT): (Number of items in progress) / (completion rate) (number / unit time) ← backlog issues as an example

Why is a slow process (low PCE or high PCT) an expensive process?

- Hidden Factory →
  - (i) Customers don't like waiting
  - (ii) More handling = more personal
  - (iii) More opportunity for damage or loss
  - (iv) Inventory has to be higher
  - (v) More documentation

DMAIC Process

Def: A Project-based 5-step process and problem-solving procedure

↳ Define → Measure → Analyze → Improve → Control

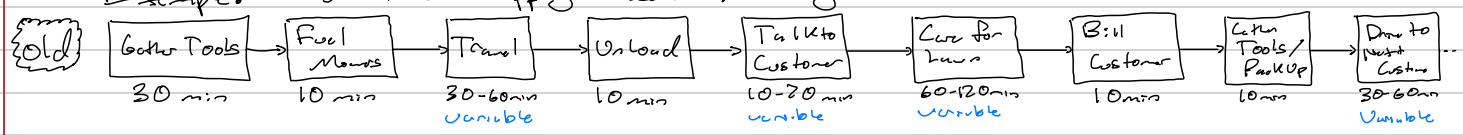
Tollgates: when projects are reviewed to ensure on track

5 stages of DMAIC (will be on HW too)

(i) **Define Stage**

- **Main Obj:** Identify a great opportunity and verify that it represents a legitimate value opportunity or breakthrough
  - **Breakthrough:** Major improvement to a process or product
  - **Value Opportunity:** The financial opportunity at stake
- **Tools used**
  - **SIPOC diagram:** High level map of process
    - → Suppliers: Those who provide information, material or other items that are used on in the process
    - → Input: The actual information or material provided
    - → Process: The set of steps required to do the work
    - → Output: The product delivered to the customer → Other dept in same company
    - → Customers: who buys the product (internal or external)
- **Process Mapping:** Involves creating flow diagrams for systems
- **Value stream mapping:** A variant of process mapping where engineers focus on steps which could be eliminated or simplified to reduce waste (lean concept)
- **Value stream:** The min amount of processing steps from raw material to customer

Example: Value Stream Mapping (Lawn Mowing)



Possible Improvements: Using customer's Lawnmower, storage SOP (leave on truck), prefuel, personal/intern, eliminate/reduce customer interactions, optimize route (graph shortest distance)/logistics

- **Pareto chart:** Plots frequency (# of parts) or cost (time/money) against causes
  - **Pareto Rule:** 80% of the effects come from 20% of the causes