LEAN SIX SIGMA

(OMF751)

PREPARED BY
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OMF751 **LEAN SIX SIGMA** **L T P C / 3 0 0 3**

OBJECTIVE: To gain insights about the importance of lean manufacturing and six sigma practices.

UNIT I LEAN & SIX SIGMA BACKGROUND AND FUNDAMENTALS 9

Historical Overview – Definition of quality – What is six sigma -TQM and Six sigma - lean manufacturing and six sigma- six sigma and process tolerance – Six sigma and cultural changes – six sigma capability – six sigma need assessments - implications of quality levels, Cost of Poor Quality (COPQ), Cost of Doing Nothing – assessment questions

UNIT II THE SCOPE OF TOOLS AND TECHNIQUES 9

Tools for definition – IPO diagram, SIPOC diagram, Flow diagram, CTQ Tree, Project Charter – Tools for measurement – Check sheets, Histograms, Run Charts, Scatter Diagrams, Cause and effect diagram, Pareto charts, Control charts, Flow process charts, Process Capability Measurement, Tools for analysis – Process Mapping, Regression analysis, RU/CS analysis, SWOT, PESTLE, Five Whys, interrelationship diagram, overall equipment effectiveness, TRIZ innovative problem solving – Tools for improvement – Affinity diagram, Normal group technique, SMED, 5S, mistake proofing, Value stream Mapping, forced field analysis – Tools for control – Gantt chart, Activity network diagram, Radar chart, PDCA cycle, Milestone tracker diagram, Earned value management.

UNIT III SIX SIGMA METHODOLOGIES 9

Design For Six Sigma (DFSS),Design For Six Sigma Method - Failure Mode Effect Analysis (FMEA), FMEA process - Risk Priority Number (RPN)- Six Sigma and Leadership, committed leadership – Change Acceleration Process (CAP)- Developing communication plan – Stakeholder

UNIT IV SIX SIGMA IMPLEMENTATION AND CHALLENGES 9

Tools for implementation – Supplier Input Process Output Customer (SIPOC) – Quality Function Deployment or House of Quality (QFD) – alternative approach –implementation – leadership training, close communication system, project selection – project management and team – champion training – customer quality index – challenges – program failure, CPQ vs six sigma, structure the deployment of six sigma – cultural challenge – customer/internal metrics

UNIT V EVALUATION AND CONTINUOUS IMPROVEMENT METHODS 9

Evaluation strategy – the economics of six sigma quality, Return on six Sigma (ROSS), ROI, poor project estimates – continuous improvement – lean manufacturing – value, customer focus, Perfection, focus on waste, overproduction – waiting, inventory in process (IIP), processing waste, transportation, motion, making defective products, underutilizing people – Kaizen – 5S

TOTAL: 45 PERIODS

OUTCOME: The student would be able to relate the tools and techniques of lean sigma to increase productivity

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1. Michael L.George, David Rownalds, Bill Kastle, What is Lean Six Sigma, McGraw – Hill 2003

2. Thomas Pyzdek, The Six Sigma Handbook, McGraw-Hill,2000

3. Fred Soleimannejed , Six Sigma, Basic Steps and Implementation, AuthorHouse, 2004

4. Forrest W. Breyfogle, III, James M. Cupello, Becki Meadows, Managing Six Sigma:A Practical Guide to Understanding, Assessing, and Implementing the Strategy That Yields Bottom-Line Success, John Wiley & Sons, 2000

5. James P. Womack, Daniel T.Jones, Lean Thinking, Free Press Business, 2003

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Unit 1 : Lean & Six Sigma Background and Fundamentals:

Historical Overview – Definition of quality – What is six sigma -TQM and Six sigma - lean manufacturing and six sigma- six sigma and process tolerance – Six sigma and cultural changes – six sigma capability – six sigma need assessments - implications of quality levels, Cost of Poor Quality (COPQ), Cost of Doing Nothing – assessment questions

What is Quality?

- Video …. : Quality Dimensions:
- performance, features, reliability, conformance, durability, serviceability, aesthetics, safety, comfort, security, due dates commitment, less waiting time, and so on.
- Tata Example: What is quality?
- High end (BMW) and low end (Alto) products: On the basis of Quality, are they almost same?

- House hold materials: Plumbing etc.
- What is Quality?

"meeting customer expectations."

"meeting (or exceeding) customer expectations."

Quality and Quality Improvement Concepts - Evolution

- **Quality improvement process** - 13th - 19th century - **craftsmen** (a worker skilled in a particular craft) organized into unions (guilds) - manufacturing followed craftsmanship model.
- **Factory system**, - emphasized product **inspection**, started in Great Britain in mid-1750s and grew into **Industrial revolution** in early 1800s.
- 20th century: manufacturers included quality **processes** in quality **practices**.
- **Total quality** in US came as a direct response to the quality revolution in Japan following **World** War II.
- Japanese welcomed the input of Americans Joseph M Juran and William Edwards Deming
- Rather than concentrating on **inspection, focus** to **improve all organizational processes** through **people** who used them.

Quality and Quality Improvement Concepts – Evolution …

- **Deming**, **Juran** and **Crosby** - pioneers in quality management.

- **Deming** (1900-93) (**American)** thought about quality in **management**.
- In 1950, - taught **Japanese** top managements - to improve product/service quality including application of **statistical methods**.
- His focus: **"**the **efficient production** of the **quality** that the **market expects"** and is best known for his "**Plan-Do-Check-Act**“ (**PDCA**) cycle.

- **Juran** (1904 – 2008) also wrote on quality, and was **invited to Japan** in 1954, where his particular ideas flourished.
- His focus was on "**Fitness for purpose**" as defined by the customer.

Quality and Quality Improvement Concepts – Evolution …

- **Philip B. Crosby** (1926 – 2001) started out in quality as a test technician, focused on "**Zero defects**" through "**doing** it **right** the **first time**".
- He believed: An organization that established a quality program will see savings **returns** that would more than **pay off** the **cost of** the **quality program** and hence promoted the idea that "**quality is free**".

- Peter Drucker (1909 – 2005): " Product/service Quality is not **what the supplier puts in,** but what **customer gets out** and is **willing to pay for**."
- Modern definition of quality (from Juran's): **"fitness for intended use."**
- Basically it says that quality is

"meeting or exceeding customer expectations."

A Customer

- ***External** customers:*
  - People **outside** the organization who **receive** the goods and services.
  - **Wholesaler**, **Retailer** and ultimate **consumer**

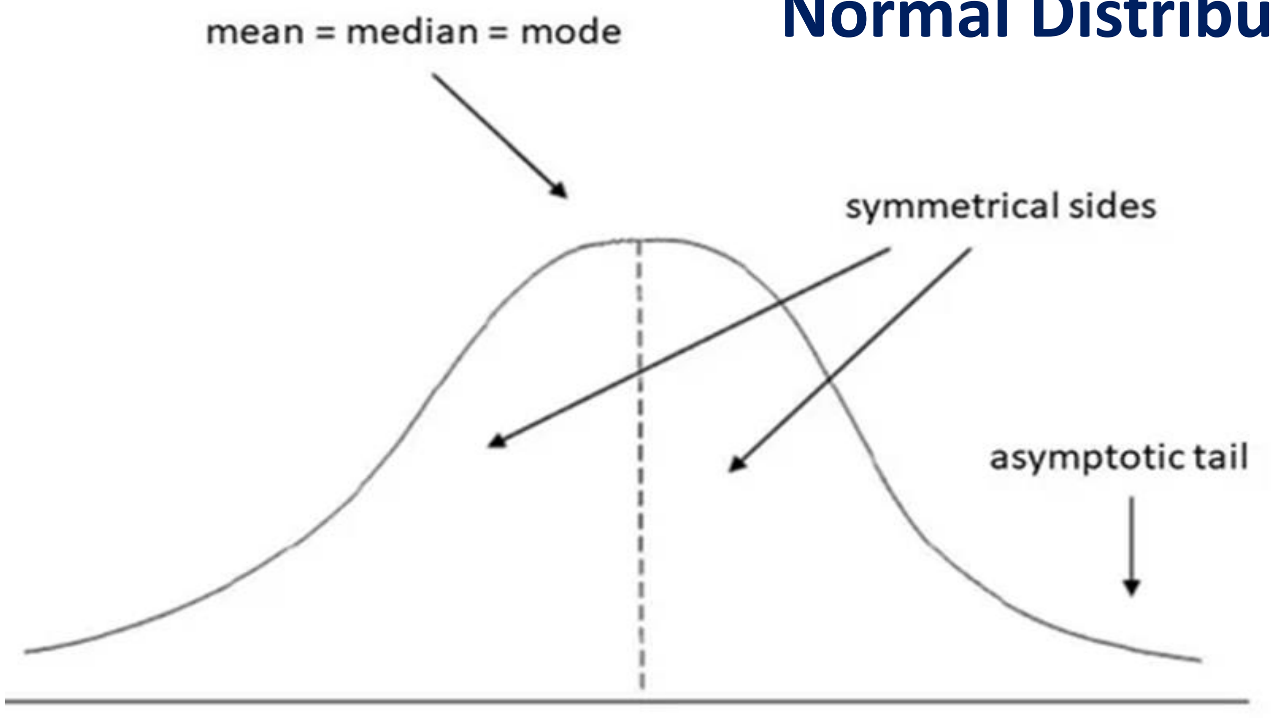
An Internal Customer

- ***Internal** customers:*
  - **Assembly** line operation: Next station **downstream** from ours is internal customer
  - **Purchasing** Dept.: who receives a control report from **Accounting** Dept.
  - **II year teachers** are internal customers for **I year** teachers.

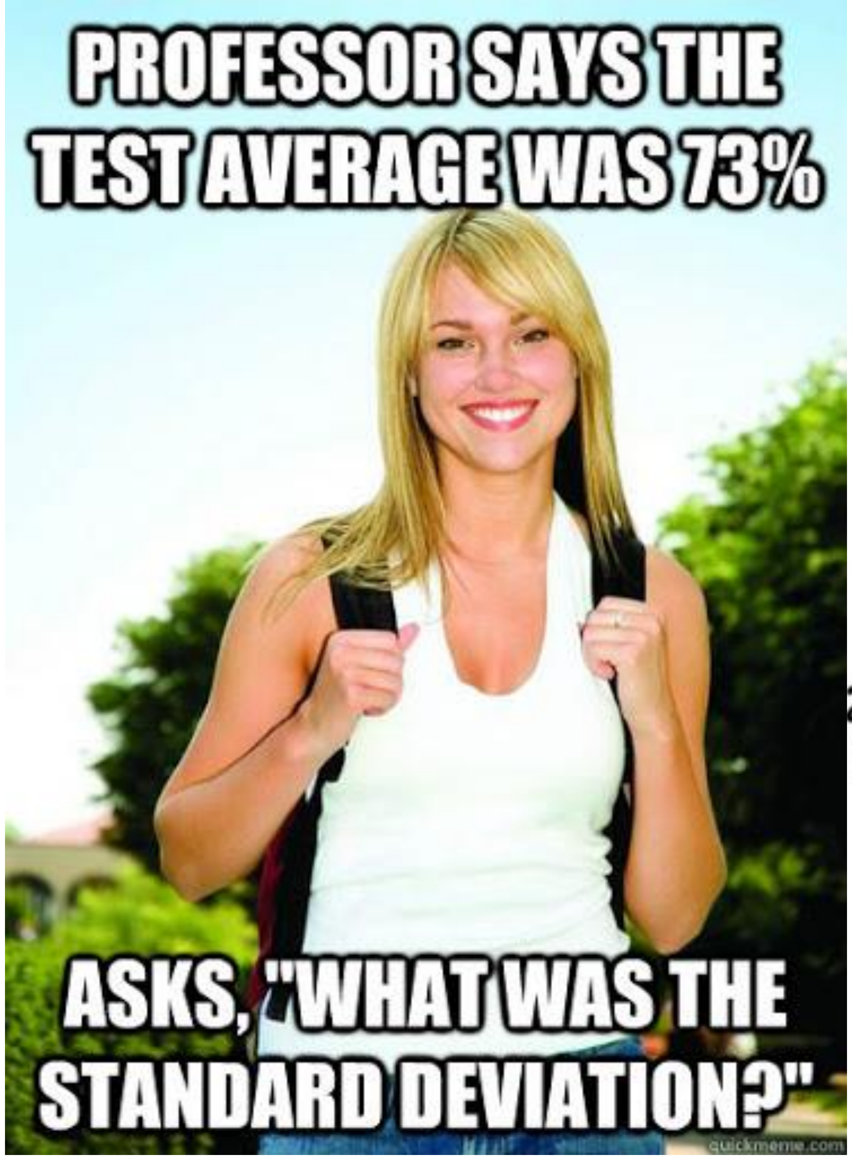
TOTAL QUALITY MANAGEMENT (TQM)

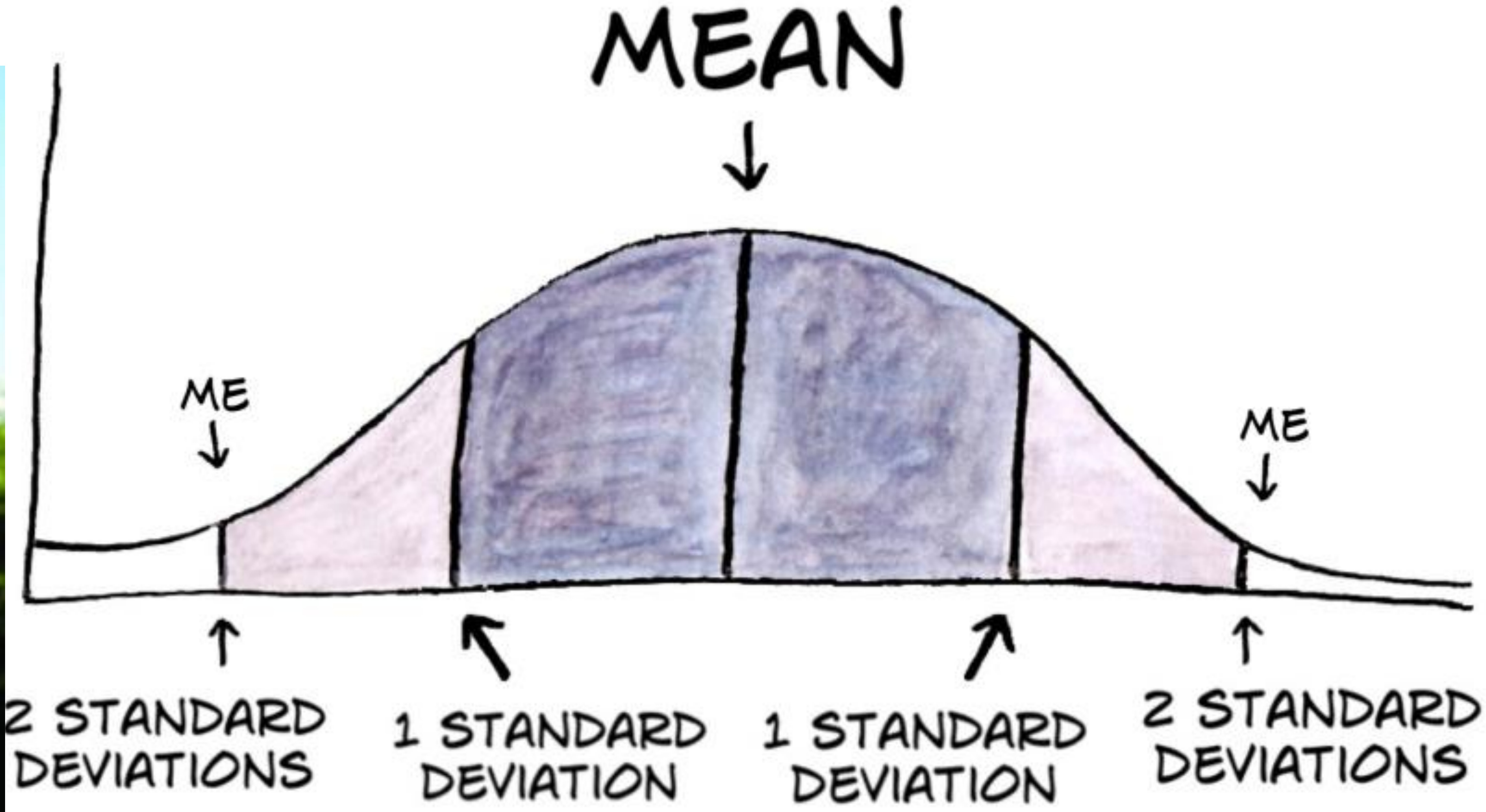
- In 1970s, U.S. **automobiles** and **electronics** sectors had been broadsided by Japan's high-quality competition.
- U.S. emphasized not only **statistics** but approaches that embraced **entire organization**, known as **total quality management** (TQM).
- In TQM, customer satisfaction is ensured through production of **quality** products at a competitive **price**.
- John **Gilbert**: "TQM is a process designed to focus on **customer expectations**, **preventing** problem, building **commitment** to quality in the workforce and promoting **open decision making**".
- New quality systems evolved thereon and the Japanese practitioners moved **beyond** manufacturing into service, healthcare, education and government sectors.
- There on new quality improving concepts came. 1980's: **six sigma, kaizen, Quality circle**, 1990's: **lean production**, 2000: **lean six sigma**.

Normal Distribution



- **Probability** function that describes how the **values** of a variable are distributed.
- **Symmetric** distribution (**Bell** Shaped Curve) where most of the observations cluster around the central peak
- Probabilities for values further away from the mean taper off **equally** in both directions.
- "Asymptotic" - Approaching a value or curve arbitrarily closely (i.e., as some sort of limit is taken).


PROFESSOR SAYS THE TEST AVERAGE WAS 73%
ASKS, "WHAT WAS THE STANDARD DEVIATION?"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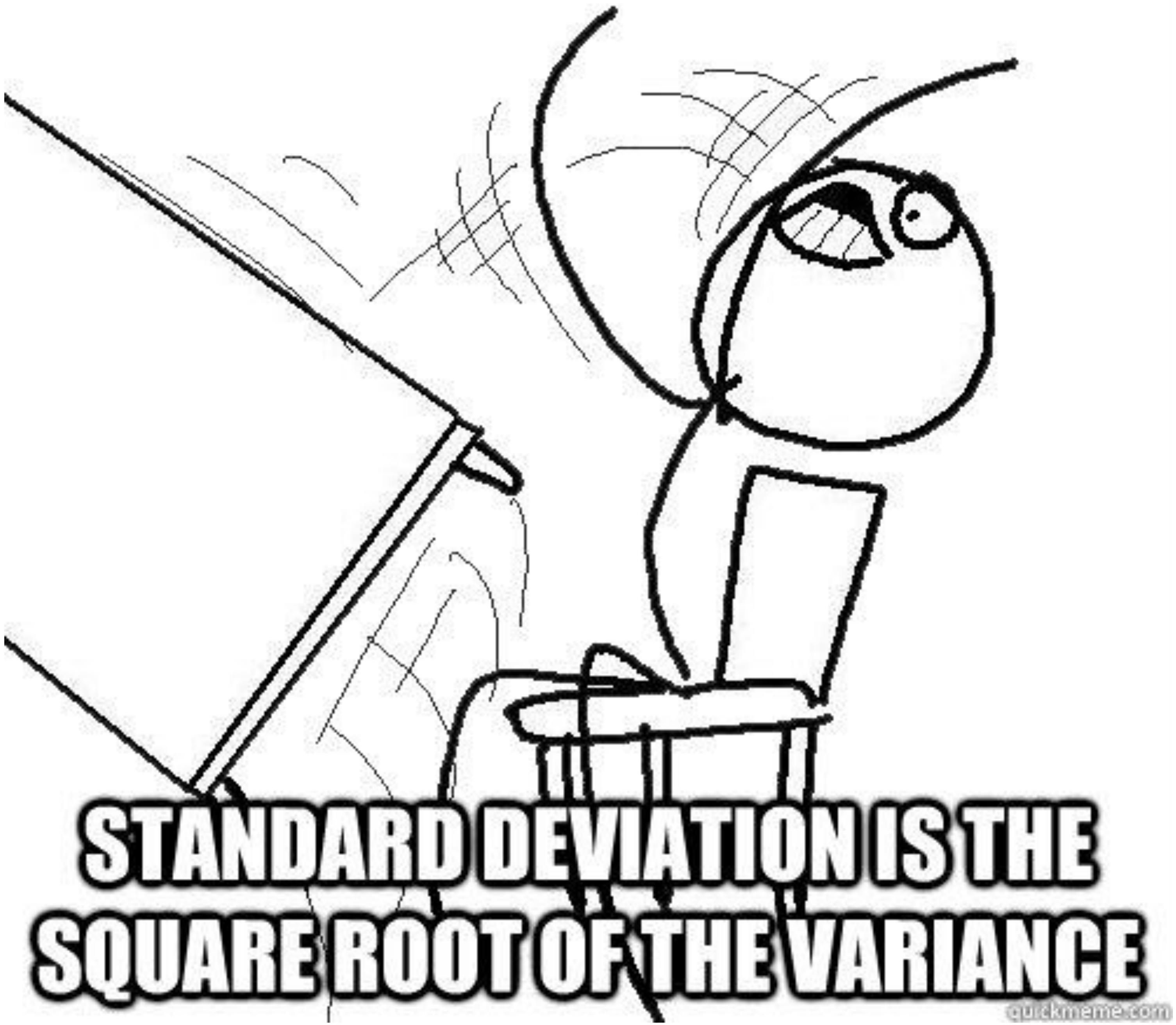
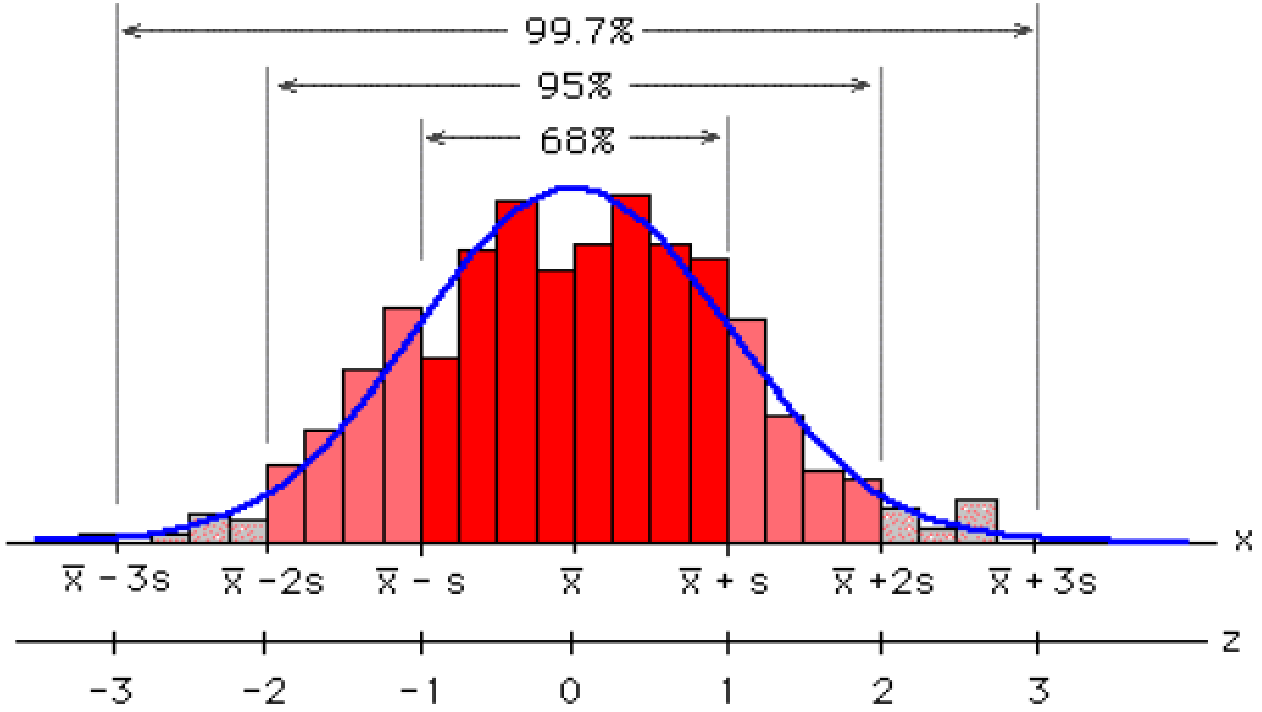

STANDARD DEVIATION IS THE
SQUARE ROOT OF THE VARIANCE
quickmeme.com

SIX HOURS AFTER LEAVING FOR A SHORT DRIVE, GREGORY HAD TO ADMIT HE HAD PROBABLY TAKEN A WRONG TURN.

Standard Deviation σ …

- **SD** is a measure of variability/spread from center of data as defined by mean.
- The **empirical rules** states that for bell shaped data …
  - **68%** of the data is within **1** standard deviation (**1σ**) of the mean
  - **95%** of the data is within **2** standard deviation (**2σ**) of the mean
  - **99.7%** of the data is within **3** standard deviation (**3σ**) of the mean



Standard Deviation (σ)

- **Standard deviation**: Measure of variability & consistency of sample/ population.
- In **real** world application, **consistency** is a great advantage.
- In **statistical** analysis, **less variation** is often better.

$$\text{Population Standard Deviation} = \sigma = \sqrt{\frac{\Sigma(x-\mu)^2}{N}}$$

$$\text{Sample Standard Deviation } = s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$$

- Ex: Find the population mean and sample SD for the data set: **5,10,15,20**

$$\bar{x} = \frac{\Sigma x}{n} = \frac{5+10+15+20}{4} = \frac{50}{4} = 12.5$$

Data	$\boldsymbol{x-\bar{x}}$	$\boldsymbol{(x-\bar{x})^2}$
5	$\mathbf{5-(12.5)=-7.5}$	$\mathbf{(-7.5)^2 = 56.25}$
10	$\mathbf{10-(12.5)=-2.5}$	$\mathbf{(-2.5)^2 = 6.25}$
15	$\mathbf{15-(12.5)=2.5}$	$\mathbf{(2.5)^2 = 6.25}$
20	$\mathbf{20-(12.5)=7.5}$	$\mathbf{(7.5)^2 = 56.25}$
		$\mathbf{\Sigma(x-\bar{x})^2 = 125.01}$

$$s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{125.01}{4-1}} \approx 6.455$$

SD σ: Empirical Rule

- **Student**: "Sir, I want to know about the **distribution** of exam scores. My score is **87** out of 100".

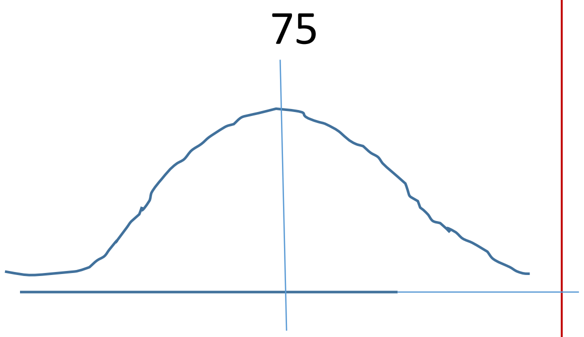
- **Teacher**: "The distribution of test scores are approximately bell-shaped with a mean score of **75** and a standard deviation of **10**".

- As per the **empirical rule**, our interpretation would be:

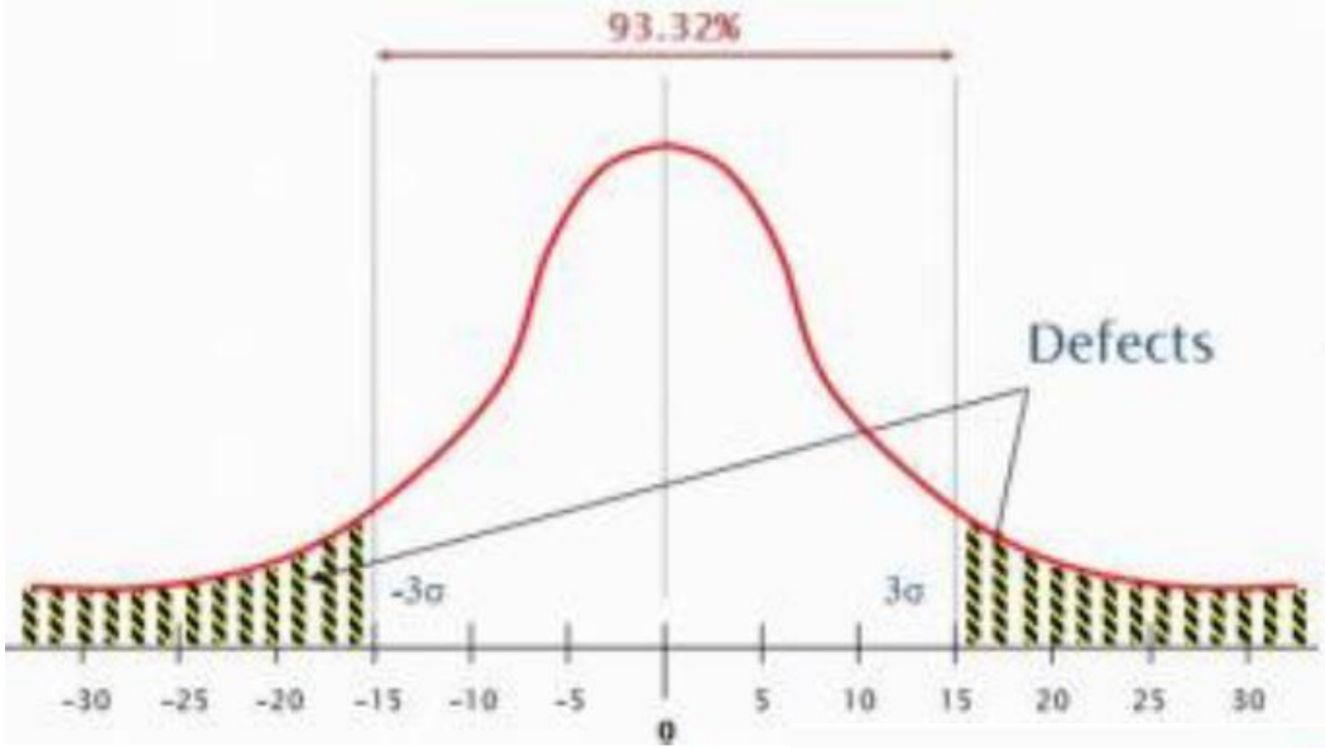
  - **68%** of students scored between **65** and **85** (1 SD)

  - **95%** of students scored between **55** and **95** (2 SD)

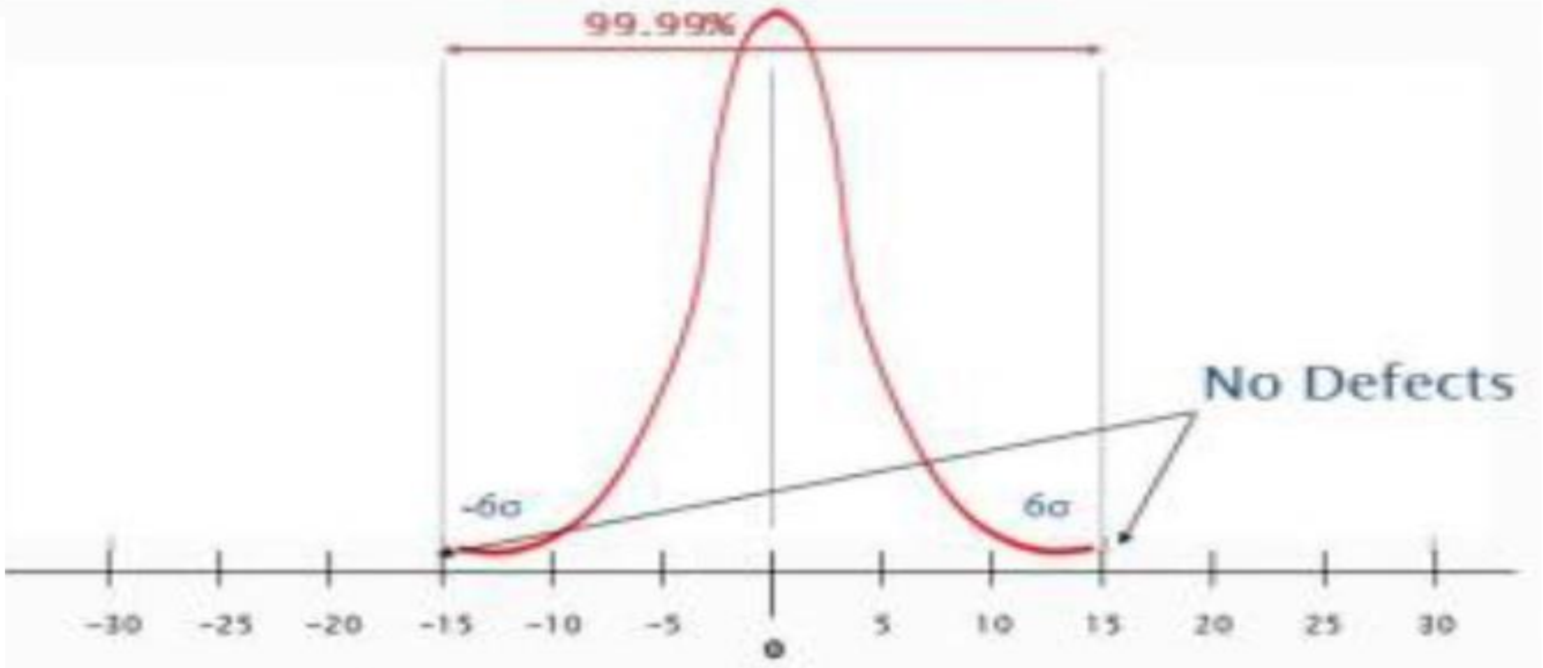
  - **99.7%** of students scored between **45** and **105** (3 SD)



- The student who scored an 87 would be in the upper **16%** of the class, more than 1 SD above the **mean score**.

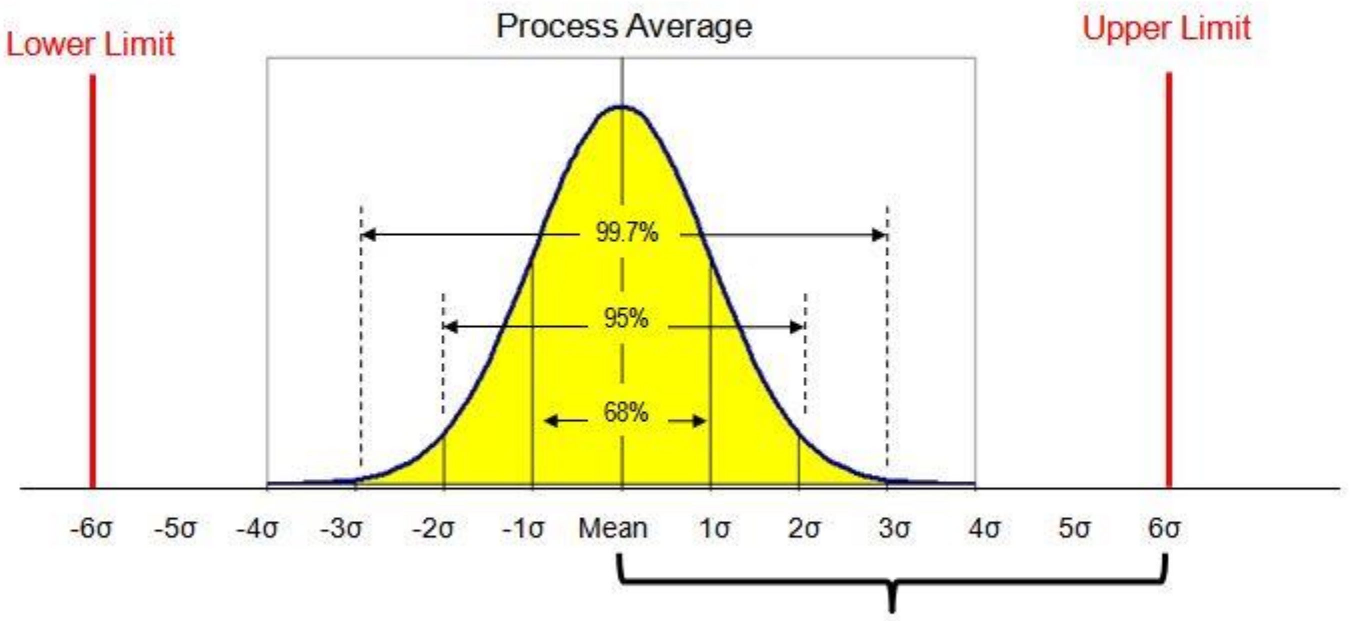


Sigma Level	Defects per Million	Yield
6	3.4	99.99966%
5	230	99.977%
4	6,210	99.38%
3	66,800	93.32%
2	308,000	69.15%
1	690,000	30.85%



What is Six Sigma (6σ) ?

- **6σ** is both
  - a **methodology** for process improvement and
  - a **statistical concept** that **defines variation inherent** in any process.
- **Process variation**
  - → leads to opportunities for **error**;
  - → that lead to risks for product **defects**
  - → Product defects lead to **poor customer satisfaction**.



Why Six Sigma (6σ) Method?

- **6σ method** reduces **variation** and **opportunities** for **error** and thereby
  - **reduces** process **costs** &
  - **increases** customer **satisfaction**.
- Experienced leadership, and intuition in any process, works with a **mathematical** and **statistical** foundation for **decision** making.
- **Experience** might say a process won't work;
  - statistics **prove**; to be true.
- **Intuition** might guide a project manager to believe a certain change could improve output;
  - **6σ** tools help firms **validate** those assumptions.
- **Beta** testing: New system/product tested with a select group of people/processes in a controlled environment, before applying to the whole population.

Decision Making without Six Sigma

- Someone's idea based on past experience or knowledge, may be successful and the idea is implemented.
- Idea's success is **weighed after** implementation; **problems addressed** after they impact products/processes in a way in the present or **future**.
- Beta testing is sometimes used in a **6σ** approach, but the idea or change in question goes through **rigorous analysis** and data **testing** first.
- Organizations that don't rely on data make **improvements** without first understanding the true **gain/loss** associated with the change.
- Some improvements may appear to work on the surface without actually impacting customer satisfaction or profit in a positive way.

Historical overview of SIX SIGMA

MOTOROLA

- In 1980's, Bill Smith, a Motorola engineer studied the **correlation** between product's **reliability** and how often that product was **repaired** during the manufacturing process.

- Conclusion: If a product was found **defective** and correlated during the production **process**, other defects were bound to be **missed** and found later by the **customer** during early use of the product.

- Motorola reduced the cost by **focusing** on product **design** and **manufacturing**. **6σ** architects focused on making improvements in **all operations** within a process.

- A quantum leap in manufacturing technology saved $**2.2** billion in 4 years and Motorola received (1988) first **Malcolm Baldrige** Quality Award (US government) for its **6σ** program based improvement record.

Decision Making with Six Sigma

- **6σ** method lets organizations
  - identify **problems**,
  - **validate** assumptions,
  - **brainstorm** solutions, and
  - **plan** for **implementation** to avoid unintended consequences.
- 1. Using tools (statistical analysis, and process mapping etc.) to problems and solutions, we can **visualize** and **predict** outcomes with a high level of **accuracy**, leading to decisions with **less financial risk.**
- In **6σ** methods even with **expert** use of the tools, **problems** can arise for teams as they implement and maintain solutions.
- 2. So, **6σ** also provides for control methods: once teams implement changes, they can **control processes** for a **fraction** of the **cost** of traditional quality methods by continuing to use **6σ** tools and statistics.

Defining Six Sigma

- **Basic definition**: **6σ** is a statistical representation for a "perfect" process. (Only 3.4 defects per million opportunities - DPMO).
- **99.99966%** of the products from a **6σ** process are without defect. At 5**σ** (1**σ** level below), or **99.97%** accuracy processes experience 233 DPMO.
- Ex.: US **Air Traffic Control** handle 28,537 **flights** daily and 10.416 million in a year. Based on a **5σ** ATC process, errors occur in handling 2,426 flights every year. With a **6σ** process, that risk drops to 35.41 errors.
- 51.4 million **surgeries** performed in a year. Based on a 99.97 accuracy rate, errors in 11,976 surgeries each year. At **6σ**, that drops to 174.
- Examples show the wide **gap** between **6σ** and **5σ**.
- For organizations, it's not just about the error rate—it's also about the **costs** associated with each error.

Examples…

- On a Monday, **Amazon** processed a whopping **36.8** million orders. If each **order error costs** the co. of **$35** (return shipping, labor to answer customer calls/emails, and labor and shipping to right a wrong order).

Cost of Amazon Order Errors, 5σ			
Total orders	Errors	Average Cost per Error	Total Cost of Errors
36.8 million	8574.4	$35	$300,104.00

Cost of Amazon Order Errors, 6σ			
Total Orders	Errors	Average Cost per Error	Total Cost of Errors
36.8 million	125.12	$35	$4,379.20

- In this example, the cost difference in sigma levels is still over $295,000.

And exactly how much less did it cost to implement Five Sigma instead of Six, Dwayne?

Examples

- For most organizations, achieving and maintaining **6σ** "perfection" is difficult and requires **continuous** process improvement.
- But even advancing from lower levels of **σ** to a 4 or 5**σ** process has a drastic **impact** on **costs** and customer **satisfaction**.

Sigma Level	Defects per Million Opportunities	Estimated Cyber Monday Defects	Total Cost (at $35 estimate per error)
One Sigma	690,000	25,392,000	$888,720,000
Two Sigma	308,000	11,334,400	$396,704,000
Three Sigma	66,800	2,458,240	$86,038,400
Four Sigma	6,200	228,160	$7,985,600
Five Sigma	233	8,574.4	$300,104
Six Sigma	3.4	125.12	$4,379

Calculationg Sigma (σ) Level of a Product/Service - Example

$$\left(\frac{\text{\# of opportunities - \# of defects)}}{\text{\# of opportunities}} \right) \text{X } 100 = \text{Yield}$$

- Consider a process: **Distribution** of letters to customers.
- **30,000** letters in preaddressed envelopes/day (150,000 letters/week).
- **Complaints** received: Address is correct but letters inside are addressed/relevant to someone else.

Calculationg Sigma Level

- Random sample of **1,000** letters from the next week's batch had **5** with errors, and estimated as many as **750** letters with errors

  ((**1,50,000*5)/1000**). (Sampling and extrapolation)

- With **150,000** opportunities for error each week and an estimated **750** defects: **((150,000 – 750) / 150,000) * 100** = a yield of **99.5**
- Look up a yield of 99.5 in the **σ** table below and the process described above is currently between **4** and **4.1** sigma.

Yield %	DPMO	Sigma Level
99.7450	2,550	4.3
99.6540	3,460	4.2
99.5340	4,550	4.1
99.3790	6,210	4.0
99.1810	8,190	3.9

Sigma Level is not a final indicator

- Divide the various processes of a product and find σ
- Compare **σ** levels all the **processes** of a product.
- It doesn't always point to **particular process** an organization (lower **σ**) should **improve first**.
- **Costs**, **resources**, and **estimated impact** of improvements should also be considered.
- A **Case**: processes of a **food** processing plant (Cake?)

Process	Performance Metric(s)	Current σ Level
A **decorative** element to food item	Decorative touch-centered on the product and stable so it won't fall off in transit	2.2
Packing product	Product is sealed for freshness	3.1
Shipping of product	Product reaches right customer right time	4.3

Customer Preference or Cost of the Efforts?

- **σ** levels indicate that the process with high defect rate (**decorative** element) needs improvement.
- How much does that matter to the **customer**, and what is the hit to the bottom line?
- It's likely that most customers will notice most that the product is **sealed** for freshness and reaches the right location.
- Hence, the most **expensive errors** might be with improper sealing during packing. So, first use resources to improve the packing process.
- After that, consider whether to improve the decorating process or the shipping process.
- Conducting **customer surveys** to reveal if some customers have stopped buying the product because of the **decorative** element issue.

Calculationg Sigma Level

- An analyst estimates that the loss of sales related to **decorative** issue are costing the company $1,000 a week. Shipping issues are costing the company $500 a week.
- Should the company address the **costlier** issue first?
- What if you were told that the shipping process could be improved with staff training sessions, while the decorative element issue required an **expensive machinery** update?
- Sometimes, organizations have to **consider expense** of improvement.
- Applying a **6σ** project to all situations isn't **financially** lucrative since those improvements take **time** and **money**.
- A **6σ culture** is about **continuous** improvement, which means teams consider all options before embarking on the most lucrative improvement measures.

6σ Case Study: General Electric

- **Fortune 500 companies** use **6σ to** improve/streamline their processes.
- **Motorola** pioneered **modern 6σ** in 1980s, although earlier versions it existed as far back as the 1920s.
- **Henry Ford's** business model and manufacturing techniques all reflect some of **6σ**'s core principles.
- **GE's** adoption of **6σ** methodology marks a **turning point** in the history of **process improvement**.
- Jack Welch (CEO) helped to build **6σ**'s reputation, which carries on into the present day.
- But what difference did **6σ m**ake to GE? And when did it first begin?

6σ Case Study: General Electric …

- The conditions that made it necessary for GE to adopt **6σ** practices.
- **Motorola** engineers concluded that their mandatory method for measuring defects per **1000s** of opportunities did not provide enough fine detail.
- They switched to measuring in **millions**, to provide more granular data.
- One of the most prominent benefits of doing so was the staggering increase in **savings** the company experienced.
- **6σ**'s early success here led to **6σ** methodology becoming a **permanent fixture** of Motorola's operations during the mid-80s.
- Furthermore, outside companies had noticed **6σ**'s successes, which sparked **interest** in how they could utilize it themselves.

6σ Case Study: General Electric …

- There were few companies who managed to implement **6σ** successfully.
- However, it was only a decade later in late 1980s, GE turned their focus towards ensuring **excellent quality**.
- They did so through their use of the **Work-Out** program, which exposed GE to a world of new ideas.
- The **groundwork** laid here by GE’s Work-Out would be important.
- Jack Welch, instigated a new **corporate policy** for GE that pledged to acquire **6σ** goals by the millennium.
- He took a lot of inspiration from companies like Motorola, using **6σ** concepts in much the same way.

6σ Case Study: General Electric …

Implementing 6σ

- It was in 1995 GE's Welch strove to ensure the company **fully integrated 6σ** into its operations.
- This change in operations began when he became aware of GE's many **setbacks**, the company often falling short of its potential.
- He recognized that GE required a **complete overhaul** of all its **fundamental operations**.
- Working with engineers and consultants, Welch **detected** a great deal of **defect** that had **previously** gone **unnoticed**.
- This build-up of **waste** was holding the company back, losing them **money**, and slowing down their production.
- He knew **6σ** could help streamline the company, make it more efficient and productive, eliminate waste, and change it for the better. It did.

6σ Case Study: General Electric …

Timeline of Implementation

- GE's implantation of **6σ** took 5 years, and the end-result was a reported $12 **billion** in **savings**.
- Welch became a lifelong advocate of the **6σ** methodology, championing its effectiveness in businesses, large and small, all over the world.
- **6σ**'s present day success is rooted in that of **Jack Welch** and **GE**.
- By the late 90s, some of the biggest corporations, such as **Samsung**, **Ford**, **Boeing**, **Amazon**, and **GlaxoSmithKline** were all using **6σ**.
- Many of these huge number of multi-nationals, experienced **immediate** and **continuous success** through **6σ** implementation.
- This **snowball** effect cemented **6σ**'s reputation in the business world, ensuring that it continues to succeed even today.

6σ Case Study: General Electric …

- **How Did They Do It?**

  (1) **Training**

- GE began their **6σ** implementation through a strong emphasis on the importance of training.
- By training employees in **data-based problem analysis**, they overcame many obstacles for which they had previously been unprepared.
- **All** GE **employees** were **required** to take a training program in using **6σ** methodologies in the **workplace**.
- The course lasted for 13 days or 100 hours and required them to complete a **6σ** project before the year 1999.
- Their training covered a variety of areas, including how to use **DMAIC**.
- Employees would learn how to **define** and **identify** processes, as well as to **measure** process output.

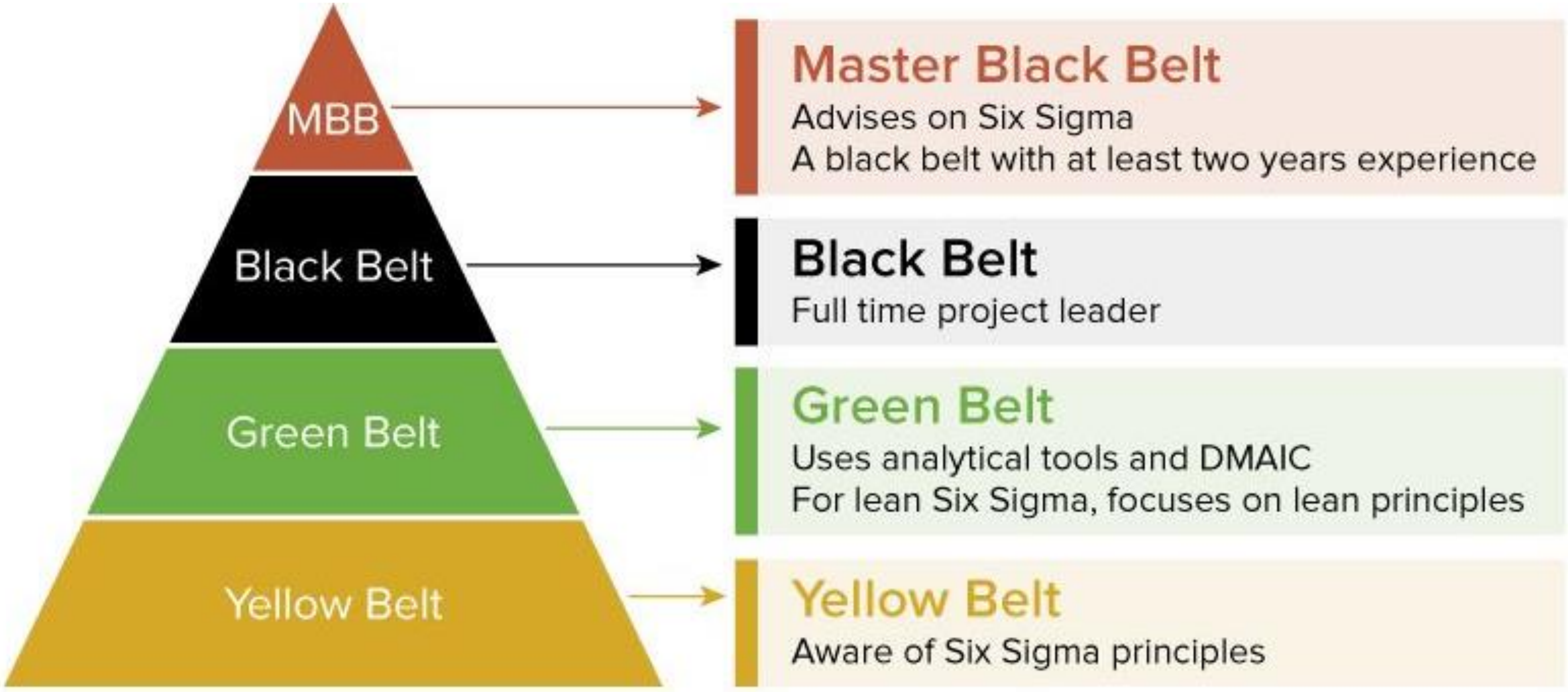
6σ Case Study: General Electric …

- Additionally, they would analyze **criticality** of process **inputs**, while devising **improvements** through **modifying** the **inputs**.
- Finally, they learn to **control** processes by controlling **relevant inputs**.
- After the course, employees undergo **follow-up training** to bolster their **new skills** and utilize them.

(2) **6σ Mentoring**

- It is another important aspect of GE’s **6σ** training and implementation.
- Full-time **6σ Master Black Belts (MBB)** hired to help implement **6σ**, driving process changes, as well as training other staff.
- Each **MBB** mentored employees involved with GE’s core processes for **BB** level training.
- This involved a 4-month training program in which they learned to apply **6σ** techniques in their work, while mentored by their MBBs.

Six Sigma Certification Structure



Six Sigma Certification Structure

	Functional Role in Organization	Six Sigma Role in a Six Sigma Project
1	Managing Director (M.D.)	Six Sigma Deployment Leader
2	General Manager	Six Sigma Champion (Sponsor)
3	Service Delivery Leader – Operations	Six Sigma Champion (Sponsor)
4	Head – Quality	Six Sigma Master Black Belt (MBB)
5	Manager – Quality	Six Sigma Black Belt (BB)
6	Manager – Operations	Six Sigma Green Belt (GB)
7	Asst. Manager - Operations	Six Sigma Green Belt (GB)
8	Team Leader – Operations	Six Sigma Green Belt (GB)
9	Associates – Operations	Six Sigma Yellow Belt (YB)

6σ Case Study: General Electric …

- Dedication to **training** and **mentoring** allowed GE to quickly generate a team of full-time **BB** to implement projects.
- Furthermore, GE also provided **part-time** project leaders and employees with **6σ GB** training to support their **BB**s’ work.

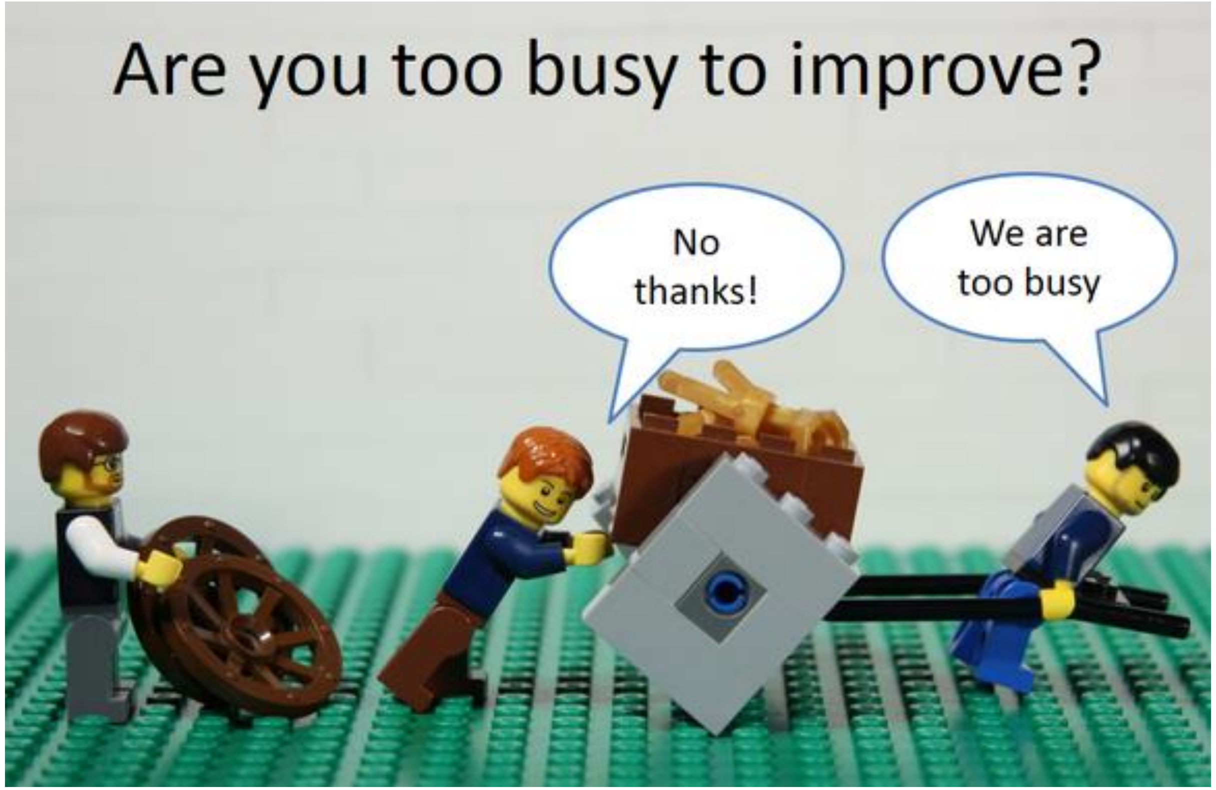
(3) Strong Leadership

- Finally, without a strong leader to direct and support your **6σ** Belts, any attempts at implementing **6σ** will likely fail.
- GE, however, is a prime example of the importance and success of **strong leadership**, **training**, and **mentoring**. (3 major aspects)
- Welch supported GE’s **6σ** implementation by ensuring fundamental commitment from both his **senior executives** and **employee population**.
- He **linked** opportunities for **promotion** and **bonuses** with quality improvement, aligning employee incentives with **6σ** goals.

Differentiation between TQM and Six Sigma;

Sr. no	Six Sigma	Total Quality Management (TQM)
1	**6σ** is a focused, **systematic** approach based on 2 standard methodologies: **DMAIC** and **DMADV**.	TQM is a **holistic** approach encompassing a number of tools.
2	**6σ** focuses on impacting **bottom-line** through **breakthrough** improvements.	TQM advocates **incremental** improvements based on **kaizen**
3	**6σ** defines a formal, clearly defined **organizational infrastructure** consisting of Master Black Belt, BB, GB	Organizational infrastructure are **not** found in TQM
4	**6σ** utilizes **Project Management approach** to identify and implement improvement projects.	TQM does not specify a **formal** approach for implementation.

Lean Manufacturing



8 Wastes

T
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DEFECTS

Waste from a product or service failure to meet customer expectations

OVERPRODUCTION

Waste from making more product than customers demand

WAITING

Waste from time spent waiting for the next process step to occur

UNUSED TALENT

Wastes due to underutilization of people's talents, skills, and knowledge

TRANSPORTATION

Wasted time, resources, and costs when unnecessarily moving products and materials

INVENTORY

Wastes resulting from excess products and materials that aren't processed

MOTION

Wasted time and effort related to unnecessary movements by people

EXTRA-PROCESSING

Wastes related to more work or higher quality than is required

Lean Thinking

- Focus: **Enhancing value** for the customer
  - by **improving** and smoothing **process flow** and **eliminating waste**.
- From **Henry Ford's** first **production line**, Lean thinking evolved over years, but much development was by **Toyota Production System** (**TPS**).
- Toyota built on Ford's production ideas, moving **from high volume, low variety**, to **high variety, low volume**.
- Lean thinking usually seen as a **manufacturing** concept/application, but, many techniques were originally developed in **service** sector.
- For ex: **spaghetti diagrams**, part of the organisation and methods toolkit, and **visual system** used by **supermarkets** to replenish shelves.
- Indeed, it was a **supermarket** that helped shape the thinking behind the **Toyota Production System**.

Lean Thinking

- During a tour to General Motors and Ford, Kiichiro Toyoda and Taiichi Ohno visited Piggly Wiggly, an American supermarket, and noticed **Just in Time** and **kanban** being applied.

- This innovation enabled Piggly Wiggly customers to '**buy what they need at any time**' and avoided the store holding **excess stock**.

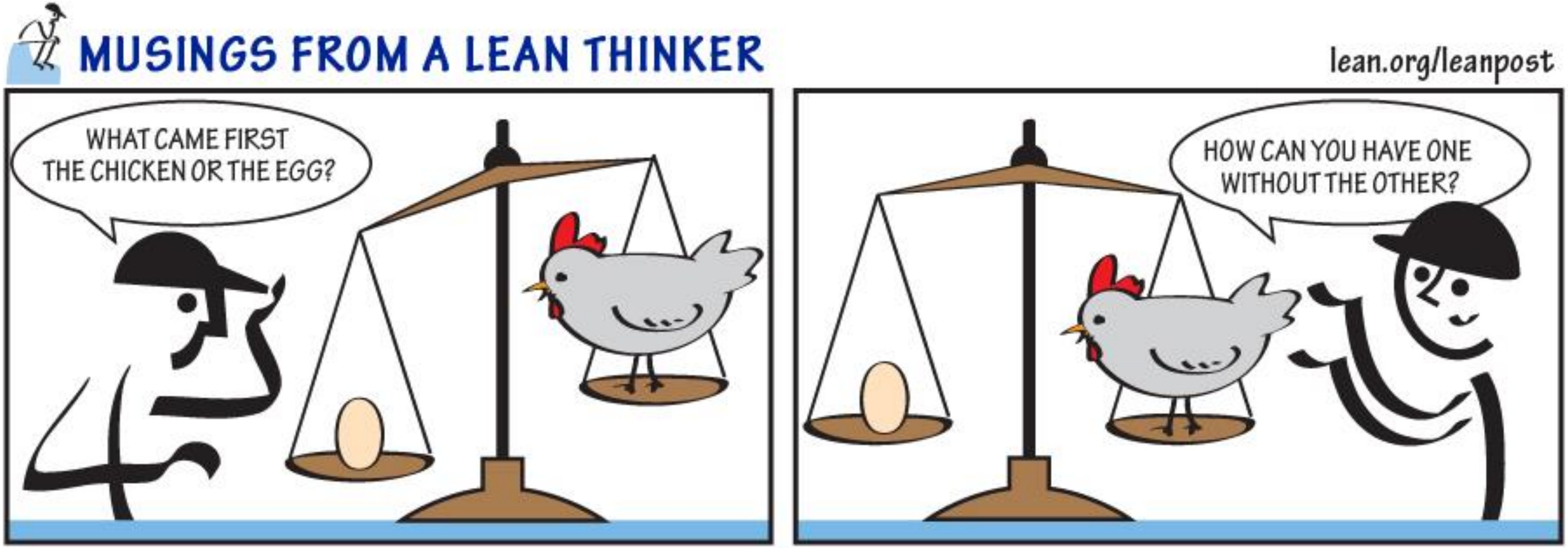
- Kanban is simply a **card** providing the **signal** to order more stock.

- Piggly Wiggly founded in 1916 in Memphis, Tennessee by Clarence Saunders**,** who was also the first to introduce the concept of a **self-service** grocery shop.

- Lean is called 'Lean' not because things are **stripped** to the **bone**.

Lean Thinking

Lean Thinking



Traditional Thinking

Lean Thinking

Lean Thinking

- According to Krafcik (researcher for MIT - International Motor Vehicle Program) the performance attributes of **TPS** compared with traditional **mass production**:

  ✓ Needed **less human** effort to design products and services.

  ✓ Required **less investment** for a given amount of production capacity.

  ✓ Created products with fewer delivered **defects**.

  ✓ Used fewer **suppliers**.

  ✓ Went from concept to launch, order to delivery and problem to **repair** in less time and with less human effort.

  ✓ Needed less **inventory** at every process step.

  ✓ Caused fewer employee **injuries**.

Lean Manufacturing

- Creating more value for customers by eliminating activities that are considered waste
- (**TIMWOODS-** Transportation, Inventory, Motion, Waiting, Over-production, Over-processing, Defects and Skills/knowledge underutilization).
- Works to create process **speed** by **reducing cycle time** and improving **efficiency** by reducing costs.
- Any activity or process that consumes resources, adds cost or time **without creating value** becomes the target for **elimination**.
- Lean focuses on '**system-level**' improvements (Vs 'point improvements') that can dramatically improve a company's bottom line results.
- **This knowledge**, combined with the **understanding** of how to **remove waste**, is critical for successful Lean implementation.
- Focuses on maximizing process **velocity**

Lean Manufacturing

- Provides tools for **analyzing process flow** and **delay** times at each activity in a process
- Centers on the separation of “**value-added**” from “**non-value-added**” work with tools to eliminate the root causes of non-value-added activities and their cost
- Provides a means for quantifying and eliminating cost of **complexity**

- **Lean** and **6σ** are implemented **together** in service organizations as in manufacturing as **quality** and **speed** cannot be separated when improving processes.
- **6σ focuses** more on **quality**, while **Lean focuses** on **speed** by streamlining and reducing complexity.
- There are certain aspects where these two differ from each other.

Lean Manufacturing Vs Six Sigma

Sl No	Lean Manufacturing (LM)	Six Sigma (6σ)
1	LM has Japanese origin, which is traced to the Toyota Production System (TPS), developed by Taiichi Ohno & Shigeo Shingo	**6σ** has a US origin, developed based on the Crosby's philosophy of "Zero Defect". **6σ** is a business strategy first conceptualized by Bill Smith in Motorola in 90's.
2	LM focuses on effective use of resources and elimination of waste.	**6σ** aims for quality improvement by eliminating variations in processes.
3	LM makes use of Japanese manufacturing practices such as JIT, pull system.	**6σ** uses a systematic DMAIC methodology for improvement in processes.
4	LM employs Japanese quality tools such as Kaizen, Poka Yoke, 5S etc.	**6σ** is a data based approach and makes extensive use of basic and advances statistical tools and techniques.
5	LM architecture compromises multifunctional teams.	The organizational architecture for **6σ** includes Champion, Master Black Belt, BB, GB each one having a specific role to play in **6σ** projects
6	LM is more applicable on the manufacturing organizations	**6σ** is being implemented by both manufacturing as well as service industries/ organizations.

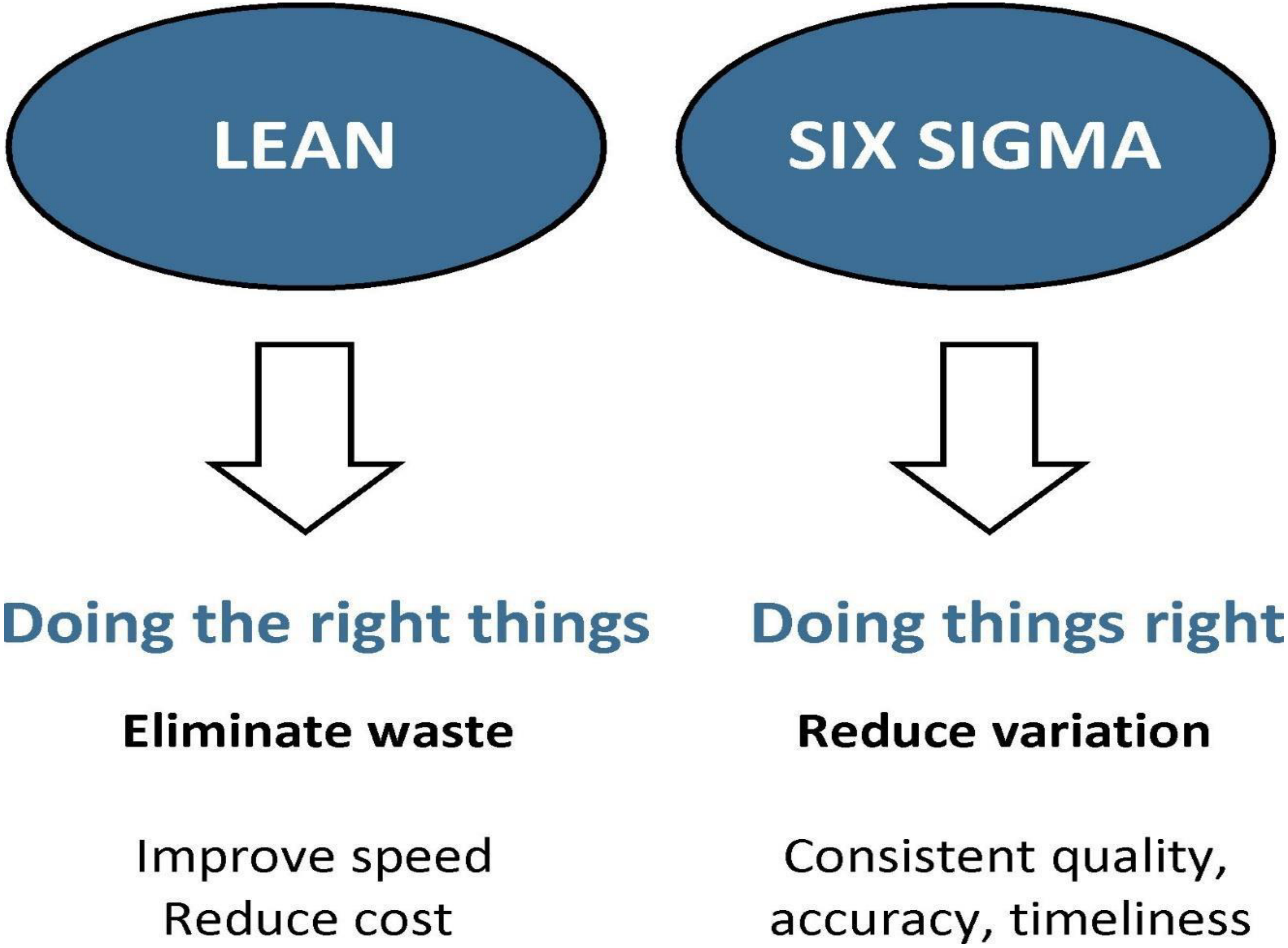
Features of SIX SIGMA

1. **6σ** propagates that all-round quality performance (error free performance excellence with continuous improvement) is bound to result in attainment of desired **business excellence** in terms of reduction in cost of production, Maximizing of customer satisfaction and ROI.
2. The philosophy of **6σ** is to make fewer mistakes in all the organizational activities and keep on reducing the mistakes.
3. It is a business strategy to reduce the cost by attaining good quality.
4. It is a statistical process control technique aimed at achieving total confidence in the company's products and service performances for the customers as well as the management.

- Ultimate goal of 'Do it right the first time every time'.
- Sigma in statistics is used to indicate the standard deviation.
- Reduces the defect and variation in the product by improving the process that produces and delivers the product.

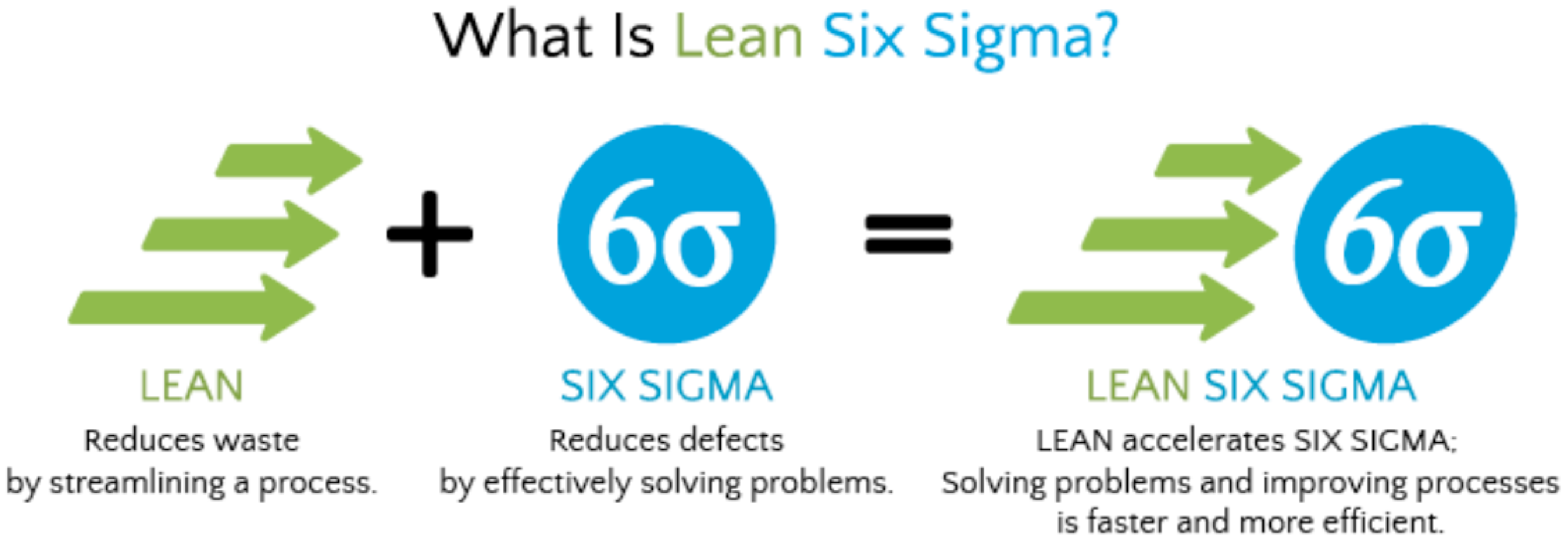
Features of SIX SIGMA

- Six Sigma's main objectives are reduction of variation, defects, costs and cycle time, aimed towards maximization of customer satisfaction.
- The focus of Six Sigma is on the following areas:
  - i. Independent variable to the process
  - ii. Root cause of any problem and its elimination
  - iii. Focus is on the inputs to the process and not on the output.
  - iv. Focus is on the problem and not on the symptom.
  - v. Focus is in controlling the problem and not on monitoring.


LEAN
SIX SIGMA
Doing the right things
Doing things right
Eliminate waste
Reduce variation
Improve speed
Reduce cost
Consistent quality,
accuracy, timeliness

Objectives of Six Sigma

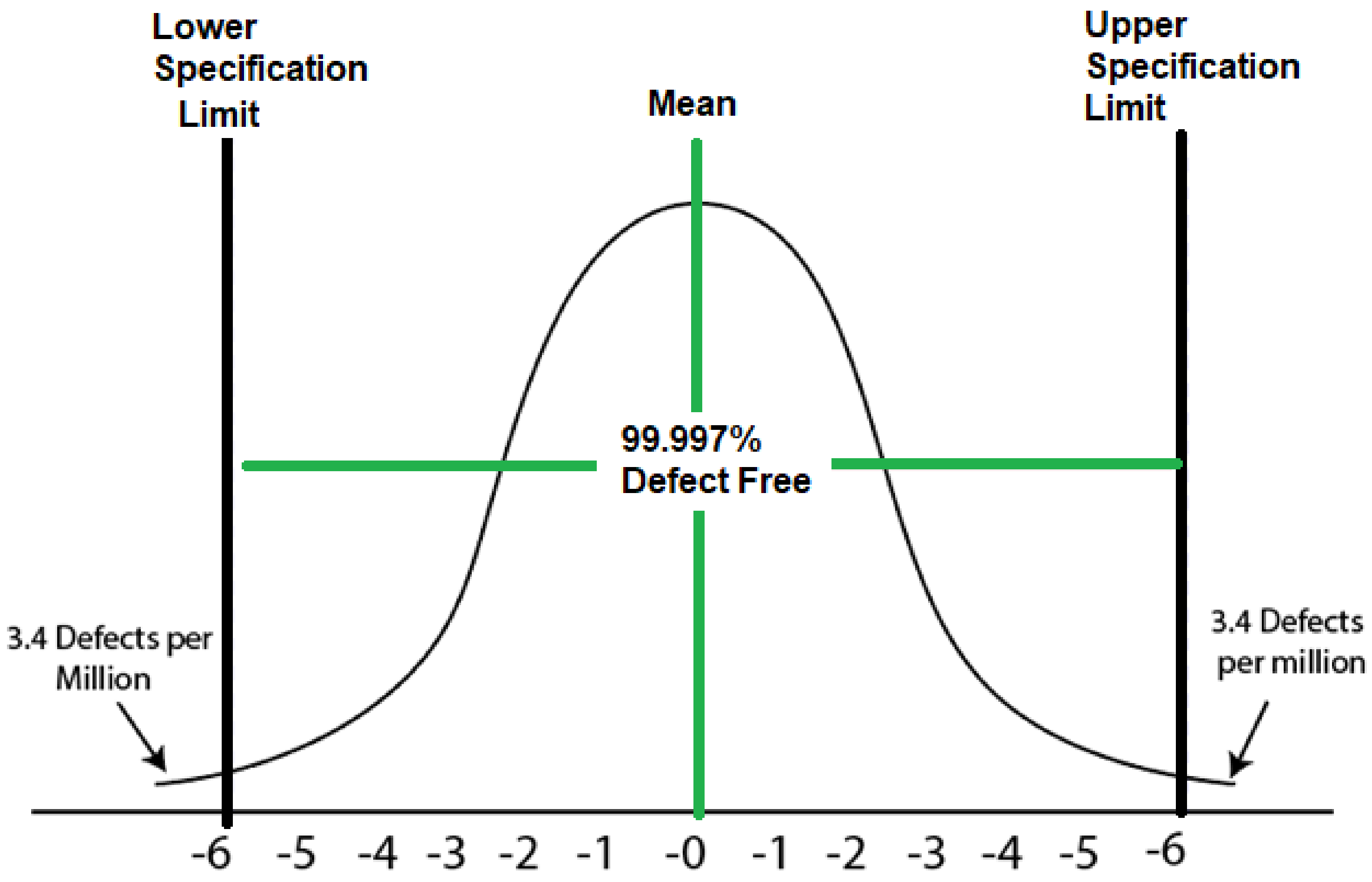
1. **Strategic level**: the goal of **6σ** is to align an organization to its market place and deliver real improvements (in terms of Rs) to the bottom line.
2. **Operational level:** the **6σ** goal is to move the business product/ service attributes within the zone of customer specifications and to significantly shrink process variation.



SIX SIGMA and Process Tolerance

- Even **perfectly designed** processes will have chance of some **variance** in execution which is to be **accounted** for in very **design** of processes.
- **Process tolerance:** **Exact limits** that each of the processes has on **both ends**, the **lower** and the **higher**. (Difference between those 2 levels).
- When it is **properly defined** for each part, **possible problems** that can come up can **easily** be **accounted**, and dealt with, before they've had a chance to **grow** into something **bigger**.
- It refers to the **exact** values that variables can have (usually **related** to the **quality** of the product) and still fall within **acceptable** boundaries.
- **Acceptability** is a very **flexible** definition, and it typically comes straight from the **customer**.
- "**6σ**" indicates - in a **batch** of **identically manufactured** parts, 99.99966% of items are within acceptable tolerance specified by customer.

SIX SIGMA and Process Tolerance



Six Sigma Curve

SIX SIGMA and Process Tolerance …

- Anything that **falls** between upper and lower limits these 2 levels will be **acceptable**, and we tend to ensure majority of products coming out of the plant are right **around** the **average between** the **two**.
- For ex., if a bag of product has an upper limit of 1.02 kg, and a lower limit of 0.98 kg, this gives you a process tolerance of 0.04 kg.
- This value can be **useful** in certain calculations, e.g. when you are trying to figure out **how much** you are **deviating** from the average.
- When we produce large amounts of items, it is unreasonable to check each item if they meet the requirements, **statistical analysis** estimates what the **tolerance** might be.
- Analysts frequently express the statistical tolerance in terms of the **expected %** of parts that will fall within **specifications** and their **confidence** level that the number is **accurate**.

The Importance of the **Average**

- **Average** is where most of the output should be **around. The closer** we maintain everything to that level, the better results we will see overall.

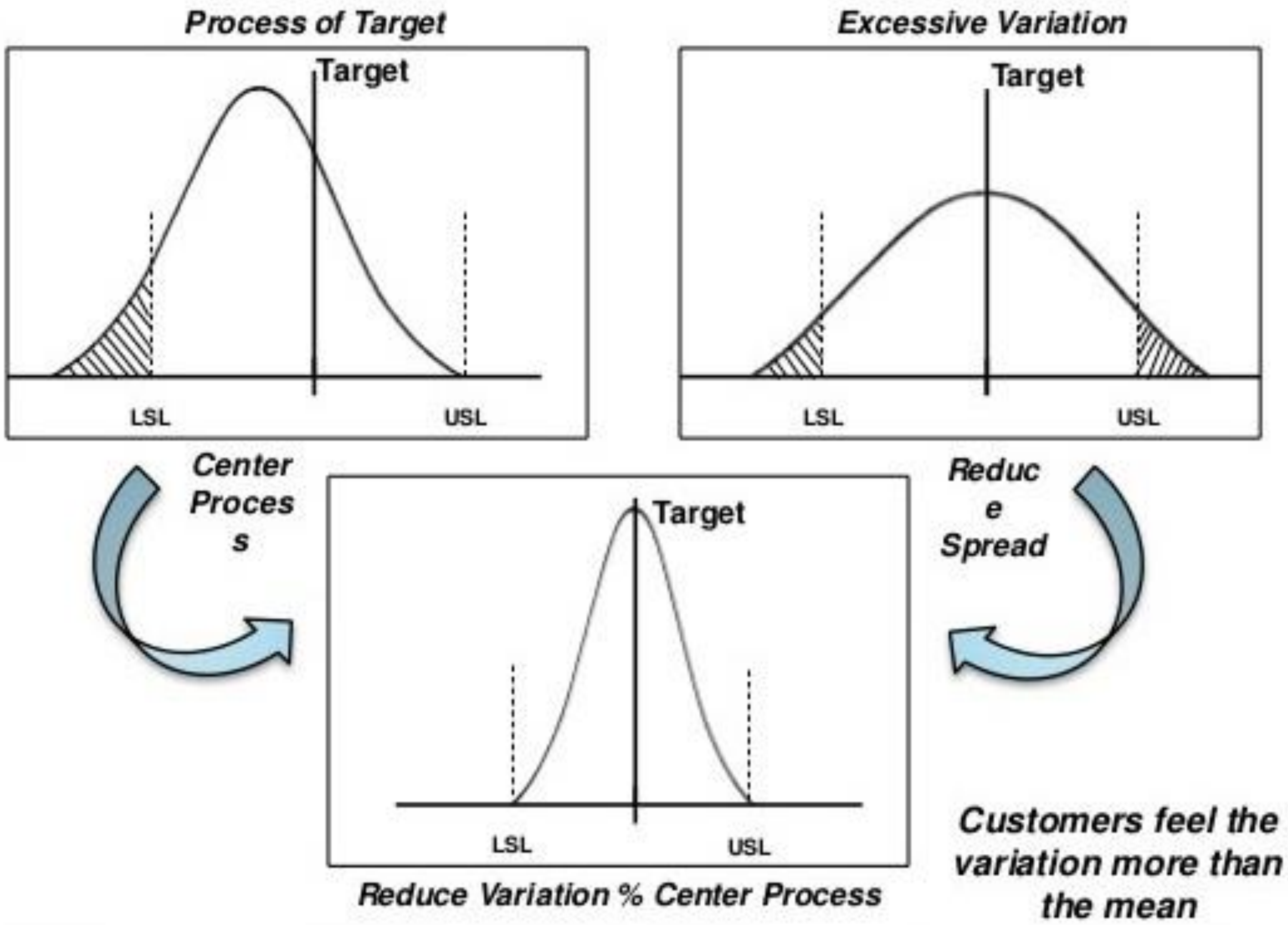
- Simple **average** of all the products is taken to check how much they are deviating from the **expected average**, we get a nearly identical value.

- This makes sense if your **upper** and **lower** deviations are within the norm and **don’t stray** too far from the expected values.

- You should **keep track** of the actual **numbers** of products that **deviate** from the average, and the **value** of **their deviations** as well.

- There are different statistical analysis **tools** that can help to get a good **overview** of the **true situation** within a plant.

- People look at just the **average** (mean) value of their product or service, but fail to evaluate the **variation** (calculated as the **standard deviation**).



Process of Target
Target
LSL
USL
Excessive Variation
Target
LSL
USL
Center Proces s
Reduc e Spread
Target
LSL
USL
Reduce Variation % Center Process
Customers feel the variation more than the mean

SIX SIGMA and Process Tolerance …

- If variation **exceeds** the **limits** (called “capability”), then the goal is to reduce variation and/or **shift** the **average closer** to **center** of the limits.
- Heart of **6σ:**
  - To understand how the **average** and **standard deviation compares** to the **tolerance limits**, and identify the **factors causing** variation.
- Shrinking the Tolerance Limits?
- Unless your customer specifically requests it, you probably **should’t shrink** the **gap** between the tolerance limits.
- The **goal**:
  - To continuously reduce the variation, so you can **achieve** results **closer** to the **average**, which **improves customer satisfaction** and **reduces reliability issues**.

SIX SIGMA and Process Tolerance …

- If you receive **complaints** about the deviation from the expected norms **far too** much, do some changes, such as **tightening** the tolerance limits.
- And in those cases, you don’t necessarily have to shrink the process tolerance from **both ends**.
- If products are primarily **jumping** over the limit, for example, you can **lower** the **upper** level but keep the other one in place.
- That way you’ll prevent unnecessary **repetition** of work within the plant.
- Understanding process tolerance and its implications is a **critical** skill for any responsible **leader**.
- There are many **finer** points to be discussed about process tolerance as well, but once you have a good grasp of the fundamental concepts, the rest should fall into place relatively easily and in a natural progression.

Cost vs. Tolerance Specification

- In a **6σ** environment, less than 3.4 articles out of one million will fall out of the range of acceptable values.
  - **Decreasing** the **tolerance** keeps only the products that approach perfection, but creates a **bigger** pile of **rejects**.
  - **Increasing** the **tolerance** lets more items be shipped, but takes the risk of **disappointing** the **customer**.
- Hence, the tolerance specification has a great impact on the cost of business in **6σ** facilities.
- Cumulative Properties of Tolerance
- The **variations** observed in a manufactured product find roots in the **slight differences** introduced by each step of assembly.
- Deviations, even **invisible** ones, tend to **partially** if not **fully** add to **subsequent variations** in the product.

SIX SIGMA and Process Tolerance …

- Hence, to ensure product meets the requirements (**99.99966**%), each individual step must adhere to even **tighter** tolerance specications.
- **6σ** tolerance at the end of a production line means much better than **6σ** performance upstream.

From **Design** Tolerance to **Process** Tolerance

- "This is not about the product but all about the **process**," would be a way to summarize the **6σ** perspective.
- The **variability** observed in a product reflects the **degrees** of **freedom** that process steps introduce into an item.
- Hence, the effort of designing a product performing within **tolerance** specifications **translates** into the design of an assembly **process** that must operate within **pre-defined** process tolerances.
- This is the reason why the **6σ** methodology achieves product quality by **controlling** and **improving** process **variability**.

SIX SIGMA and Process Tolerance …

- **Business First**
- **6σ** philosophy strongly promotes product of high quality, but will place the efforts to achieve perfect outcomes in the context of **financial** returns.
- Only process improvements that will yield increases in corporate **profits** should be pursued.
- Hence, a **6σ** improvement team will
  - balance **performance level** with **tolerance range** and
  - with **increased profits**.
- If recommendations to improve the process **do not translate** into significant upside **financially**, the team **goes back to the customer** to require them to **relax** the **tolerance** specifications.

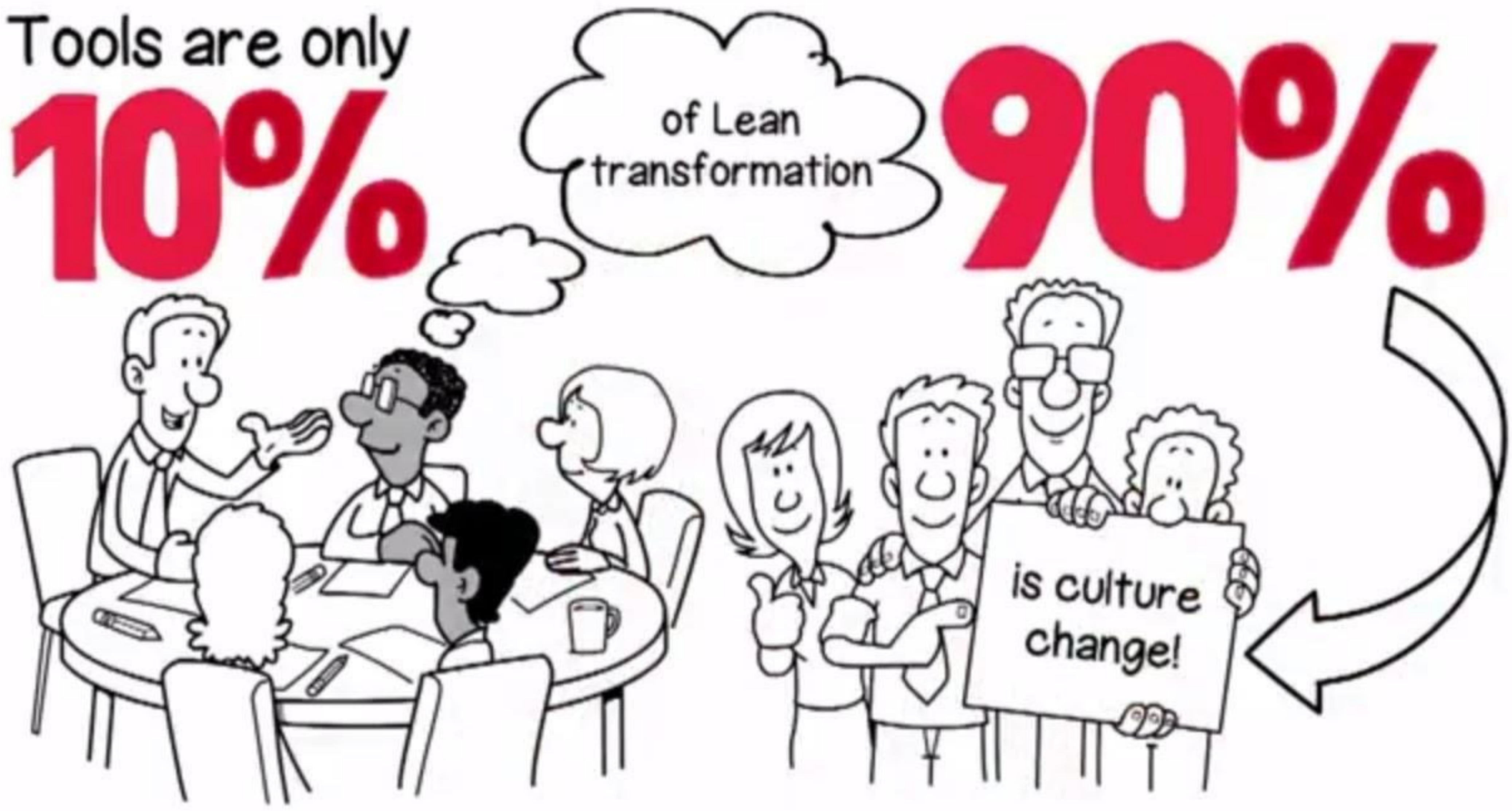
SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING

"I want you to find a bold and innovative way to do everything exactly the same way it's been done for 25 years."

SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING

- CEOs expect **6σ** to help create a company culture of **continuous improvement**, as well as achieve important **financial** results.
- Experience demonstrates that **changing** the **way work** is organized has a more profound and **lasting impact** on **culture** than just educating employees in **problem-solving methods**.
- The power of **6σ** to create a culture of **continuous improvement** lies in the combination of
  - **changing** the **way** work gets done by changing processes, plus
  - **educating** people in new ways of understanding processes and solving problems.
- When a CEO speaks of a **6σ**, or improvement, culture, what are the behaviors he or she is looking for?
- The differences between a traditional and a **6σ** culture can be characterized as:

Sl No	Aspects of Culture	Traditional	Six Sigma
1	Work **orientation**	Departmental, functional and/or task	Process flow and customer-output related
2	**Who** defines what needs improving	Senior managers and department managers	Senior and department managers plus bottom-up suggestions from project leaders and team members
3	**Leadership** for improvement	Functional managers or designated project leaders	Champions and improvement specialist (Belts)
4	**Who** has **skills** to develop and implement solutions	Specialists (e.g., engineers) and managers	Specialists plus project leaders, team members and managers
5	Improvement **methods/tools** used	The most familiar ones	Common, state-of-the-art approach and tools
6	Degree of **operator involvement**	Ad hoc	Widespread through Yellow Belt training
7	How **performance** is **measured**	Actual versus budget	Impact on Xs (causal measures) that affect Ys (outcomes)


Tools are only
10%
of Lean
transformation
90%
is culture
change!

SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING …

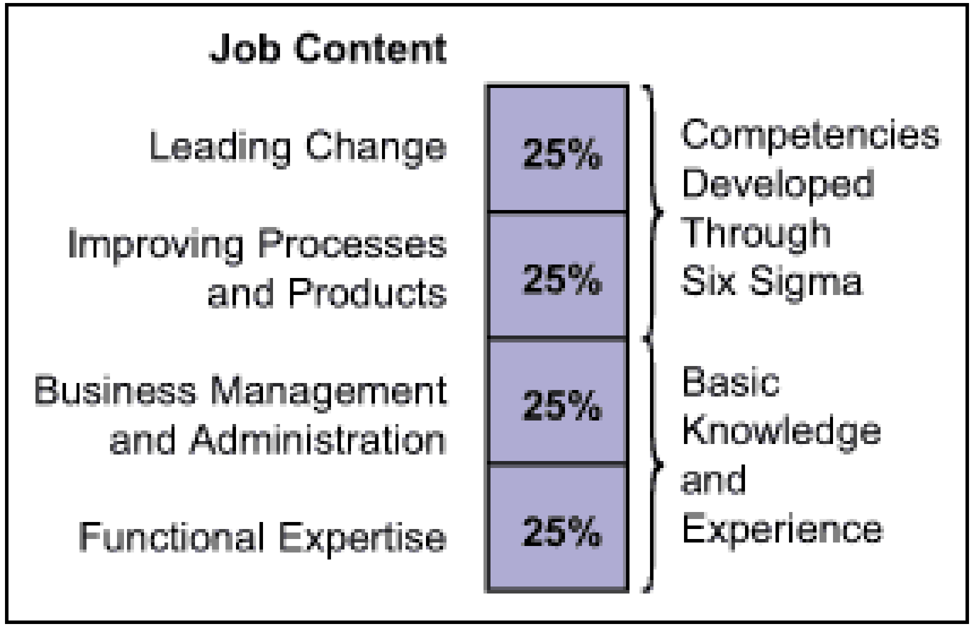
- In a **6σ** culture, **knowledge** of **processes** and improvement is widespread throughout the organization.
- While training in **6σ** methods and tools and applying them, the companies succeeded in creating a **6σ** culture also have in place:
  - **Leaders** with first-hand experience in applying **6σ** to strategic issues
  - **Dashboards** of predictive, process-oriented **measures (KPIs)** that are used regularly to **review** and **improve** operations performance
- **Leaders with 6σ Backgrounds**
- Those who view **Black Belt** positions as development opportunities **reap cultural** benefits when those BB take up key managerial positions.
- High-potential managers who have proven themselves in a particular function are appointed to a 2-year **6σ** leadership assignment.

SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING …

- In Europe, most **BB** get **international exposure** and learn to manage cross-culturally.
- After their **6σ** assignments, these managers assume **line management** responsibilities.
- Having been steeped in **6σ thinking** and learned the **competencies** above, they **never** see the world same **again**. That is a culture change.
- Early in its **6σ** program, **GE** made clear that to be considered as a future leader, one had to become **6σ certified**.
- In GE's new culture, to be a leader meant having **not just functional** or **business** competence, but, half the job is to **lead change** and lead the ongoing effort to improve **processes** and products.
- It's **learning** to **improve** processes/products and **lead change** by doing it.

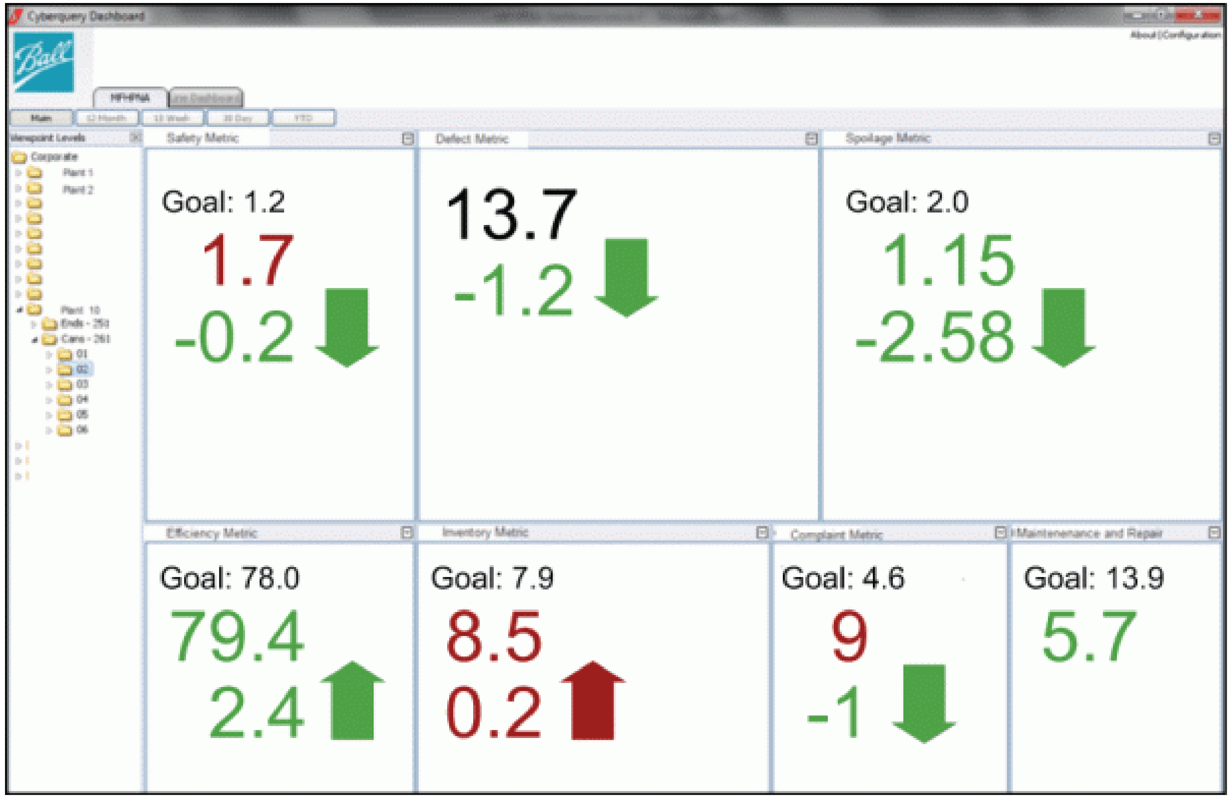
SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING …

- Nothing affects the culture of an organization more than the **outlook** and **behavior** of its leaders.
- When leaders start differentiating "**noise**" from "**signals**," ask for what is "**critical** to **quality**," and want to see the data that proves or disproves a hypothesis – then the culture of a business starts to change.
- **Dashboards**: Focus on Process Performance
- Process-related dashboards use is an essential element in creating a **6σ** culture.
- This augments the work on improvement projects with a day-to-day focus on process performance.



Dash Boards

- "A collection of related measures (outcomes and drivers)
- that are derived from and directly related to the organization's mission and strategic objectives
- …used to monitor, analyze and improve business drivers and their outcomes."



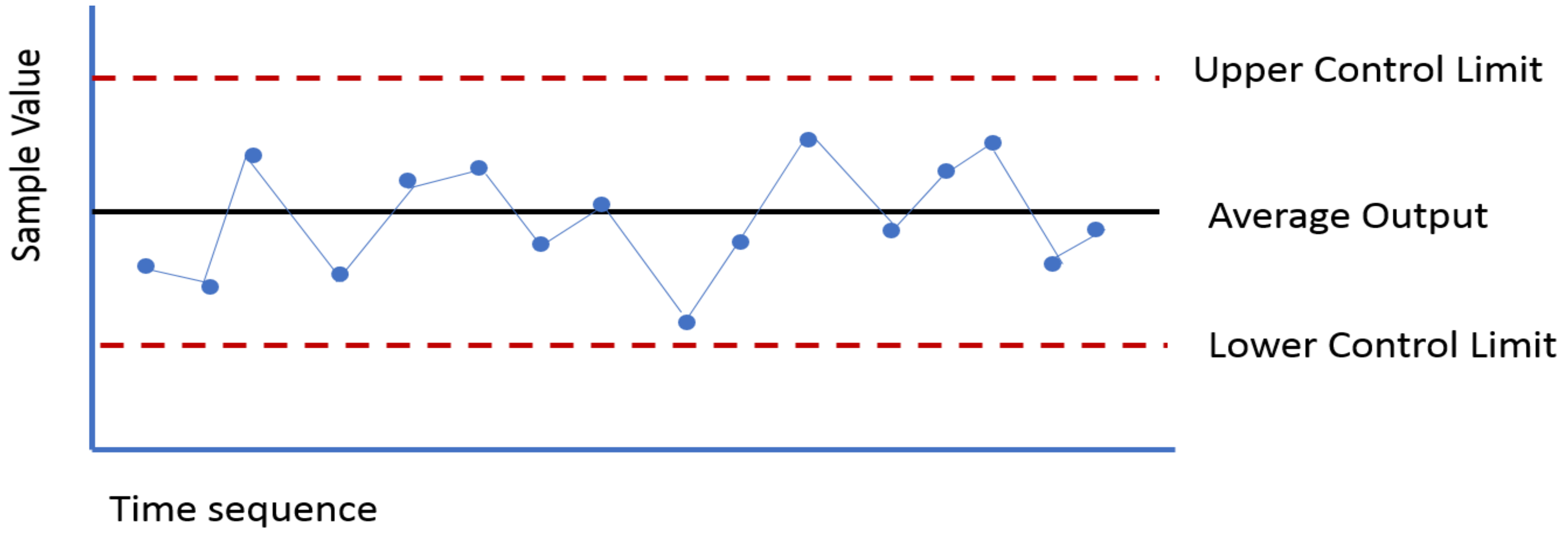
- Managers tend to jump back and forth between strategies and actions. **Dashboards** are a **strategy execution** tool.
- By making the **process connection** between **business outcomes** and **actions**, managers are more deliberate and **balanced** in their actions.

Manufacturing KPI Dashboard Showing Overall Equipment…

This graph/chart is linked to excel, and changes automatically based on data. Just left click on it and select "Edit Data".

SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING …

- A business leader says: “**A strategy is only as good as the action it inspires. I first really understood strategy when I could visualize the connection to execution, using dashboards**.”
- Reviewing process metrics in the form of **control charts** becomes a standard item in regular operations review meetings.
- Peer groups of managers and operators ask: “Are we getting better or worse?” / “What is driving performance?”/ “What can we do to get better?”



SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING …

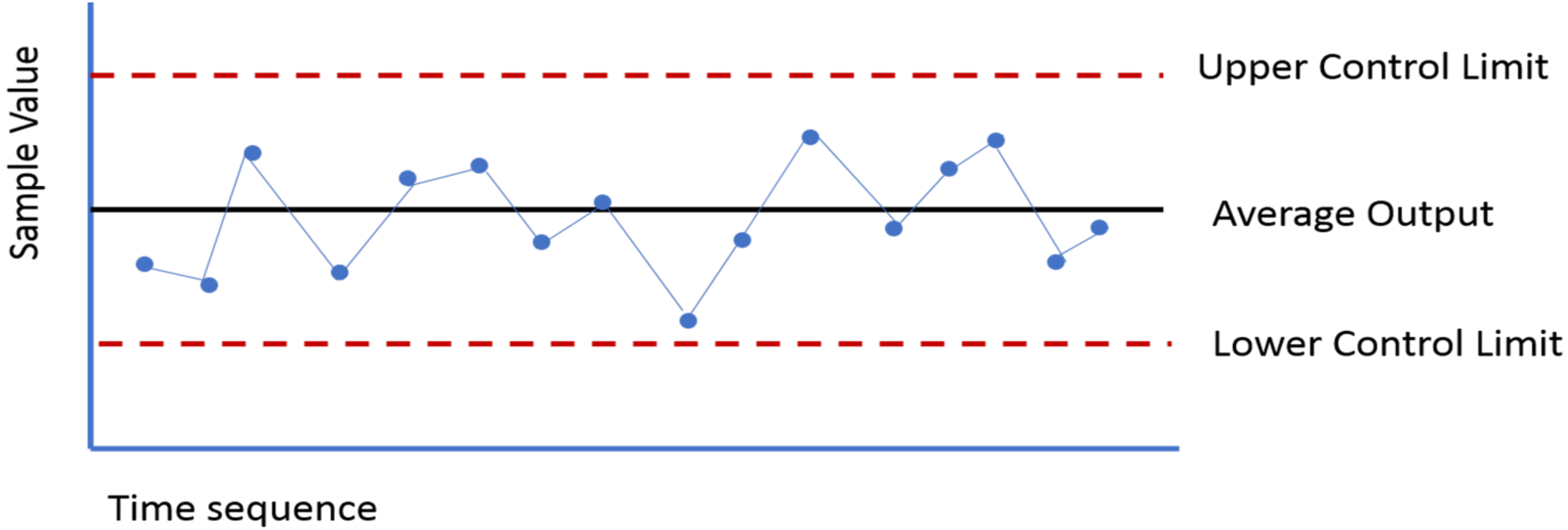
- Many of the actions identified are **day-to-day managerial** and **operator** issues. When a **process** needs to be **redesigned**, it spawns a **6σ** project.
- Most importantly, there is **accountability** for action based on process-related **measures**, and a relentless focus on execution.
- As the **strategy** and **priority** of the business **change**, so do its **dashboards**.
- Conclusion: The **Process of Change**
- **6σ** can lead to profound changes in an organization’s culture – the **beliefs** and **behaviors** accepted as **normal**.
- By **integrating education** with hands-on **problem-solving**, how work gets done starts to change.
- **Knowledge** of processes and improvement becomes more widespread.

SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING …

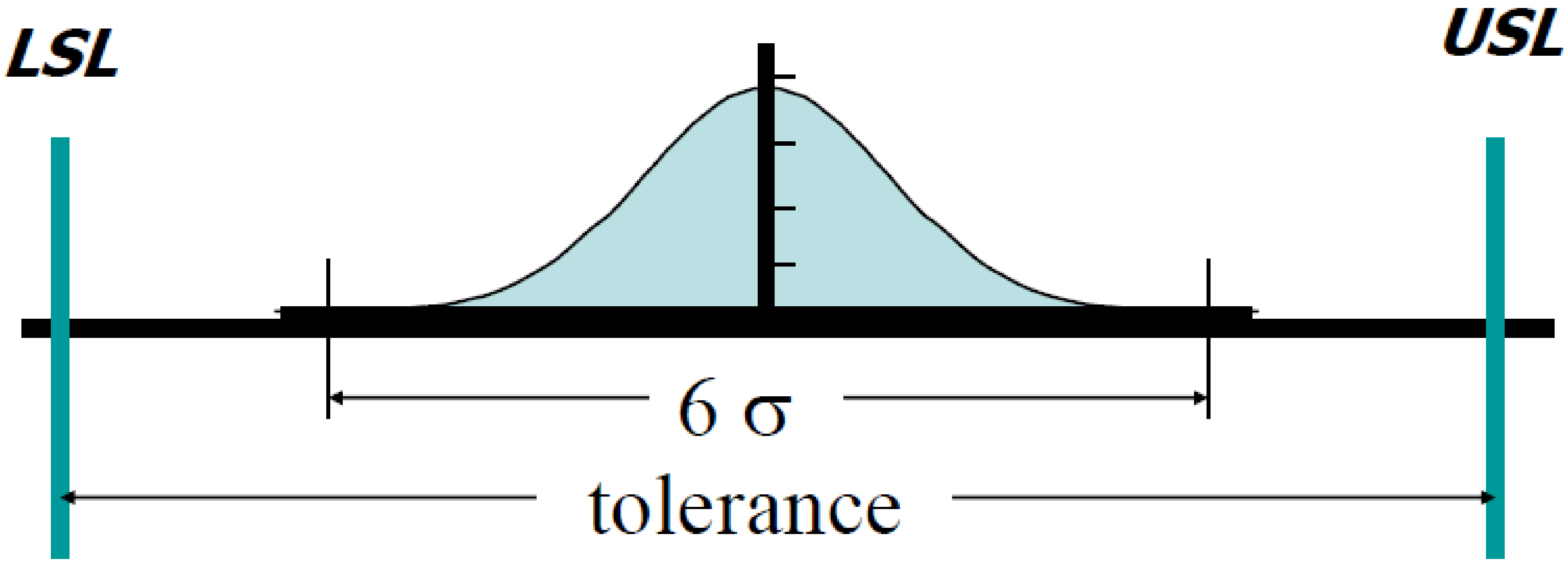
- In addition to project work and training, for companies that created sustainable **6σ** cultures it is a leadership development opportunity.
- As more and more **6σ** “graduates” assume line management roles, they naturally apply **6σ** approaches in their daily work.
- Using **dashboards** in **regular operations review** sessions, they involve **everyone** (whether currently in improvement project or not) in reviewing process-related performance and **committing** to improvement.
- How long does it take to create a **6σ** culture? For most companies, it takes 3 to 5 years.
- For those, starting with a **process-oriented** business, a culture of **team-based** improvement and a quality heritage, it will take less time.

SIX SIGMA CULTURE: BETTER PROCESSES AND PROBLEM-SOLVING …

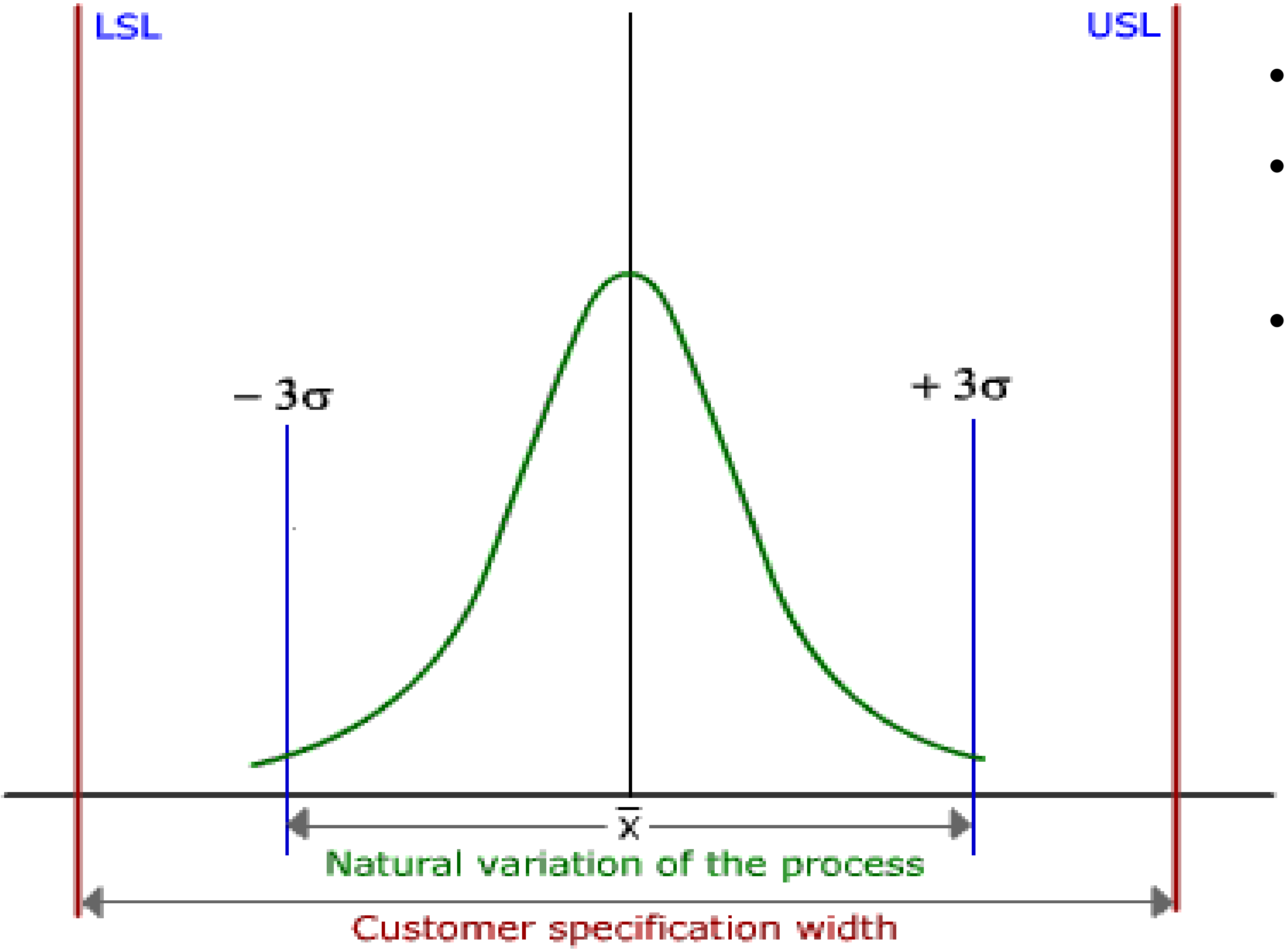
- Key Words:
  - **Leadership**
  - **Dashboards (KPIs** and **Control Charts)**
    - **Business First**
    - **Average**



SIX SIGMA and Capability



$$CapabilityIndex(C_p) = \frac{USL - LSL}{6\sigma}$$

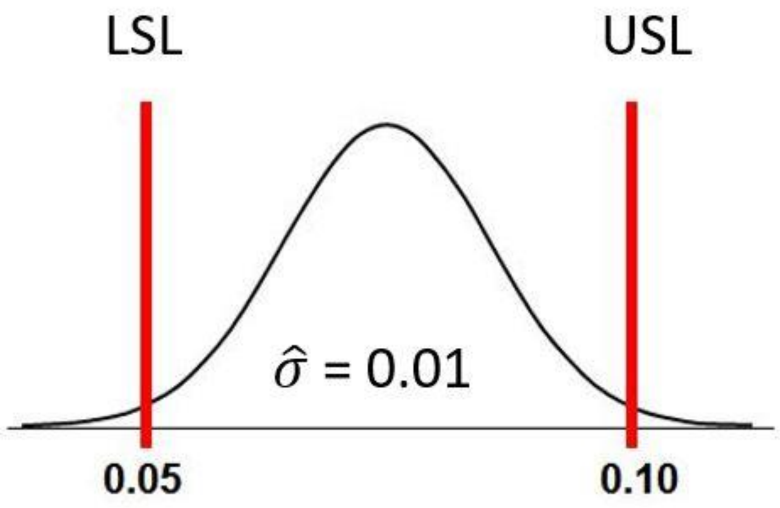


- If:
- Specifications(**tolerance**)
- are **wider** than process / product measurements,
- then it is deemed "**capable**".

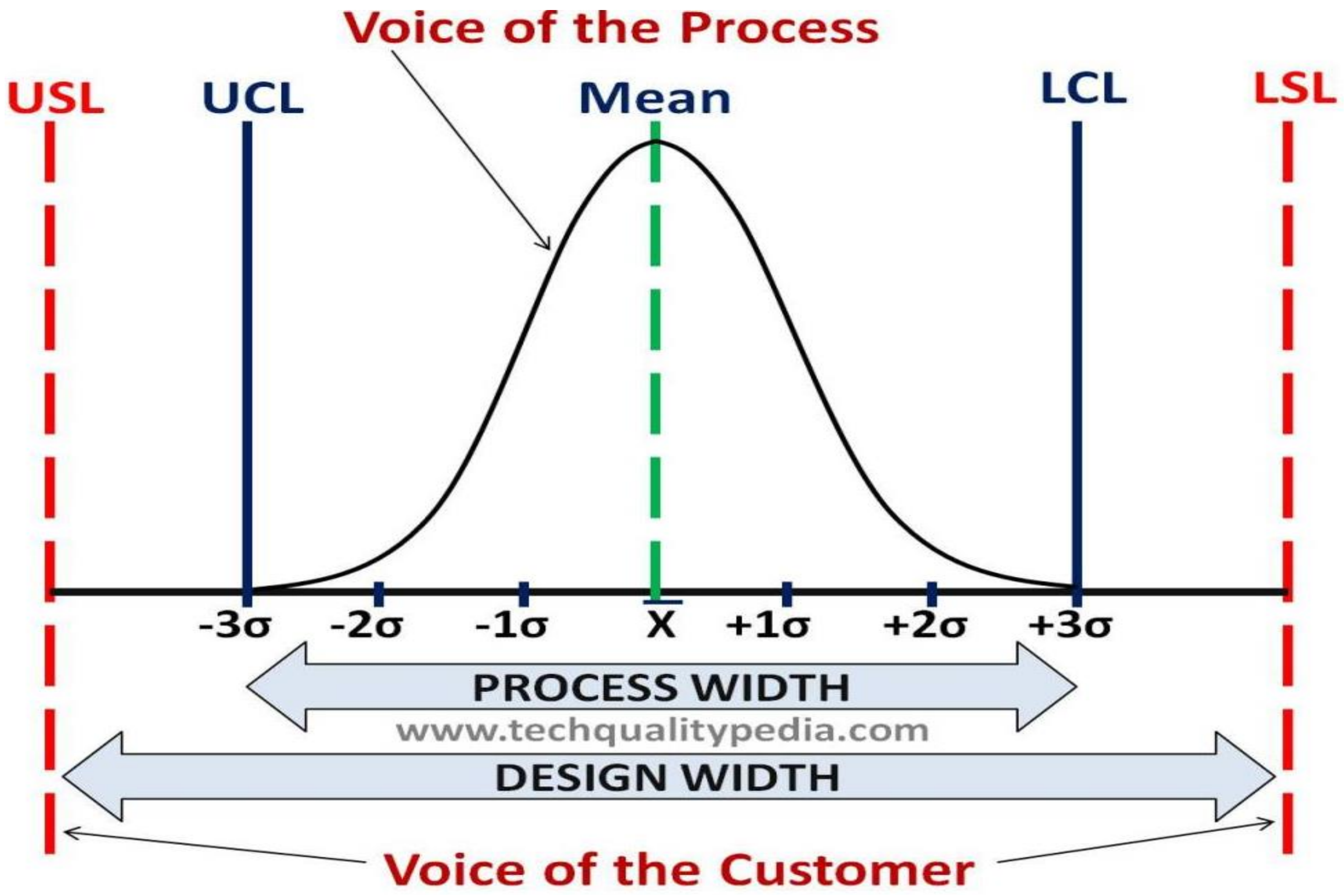
SIX SIGMA and Capability

- A measure of how well the **process/**product **measurements** are **able** to **stay** within the defined limits or **specifications** over the long term.

- Calculations use **SD** of measurements compared to **specification** limits.



$$C_p = \frac{USL - LSL}{6 \text{ x } \hat{\sigma}} = \frac{0.10 - 0.05}{6 \text{ x } 0.01} = \frac{0.05}{0.06} = 0.833$$



Voice of the Process
USL
UCL
Mean
LCL
LSL
-3σ
-2σ
-1σ
X̄
+1σ
+2σ
+3σ
PROCESS WIDTH
www.techqualitypedia.com
DESIGN WIDTH
Voice of the Customer

How to Calculate C_p Ratio

- **C**onsider the manufacture of water bottles. The **target** size is **25** ounces.
- **Specifications** require the manufacturing process to produce –
  - upper limit of **30** ounces
  - lower limit of **20** ounces.
- Actual manufacturing data shows: from **32** ounces to **18** ounces.
- Process is not capable of meeting design specifications, as a portion of the production is **outside** the **upper** and **lower** size limits.

  C_p = Design specification width/Six deviations distance

  = (30 ounces-20 ounces)/(32 ounces - 18 ounces)

  = 10/14 = 0.71
- **C_p < 1** → indicates: Process-not capable to meet design specifications.
- Most manufacturing standards use a Six Sigma standard deviation

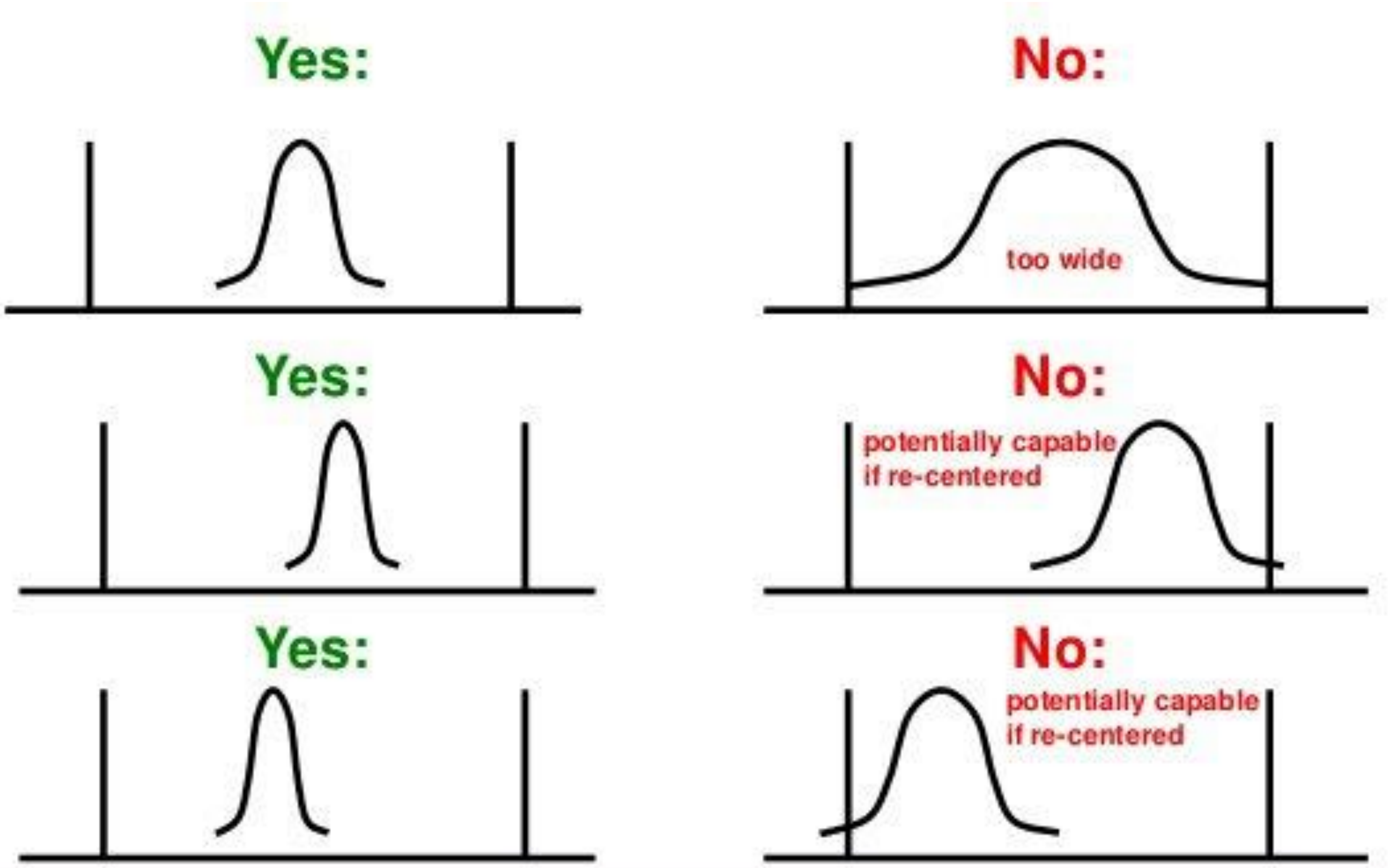
SIX SIGMA and Capability

- **Difference** in capability indices are based on
  - calculations of the **SD**,
  - incorporation of **mean**, and
  - **alignment** of mean to **target/nominal** value.
- **Process Capability** (C_p & C_{pk})
- C_p & C_{pk} : Short-term potential capability measures for a process.
- Process **Capability** (Quality) - **C_p & C_{pk}**, is described using **σ**, easily using a common mathematical framework.
- **σ h**elps to compare apple processes
- With Process **Capability** we try to verify if the process can meet to meet Customer CTQs Critical to Quality (requirements).

	Stable Process Under Statistical Control	Unstable Process NOT Under Statistical Control
Process is Centered	Cp	Pp
Process is Not Centered	Cpk	Ppk

- **C_p & C_{pk}** are used when a process is under **statistical control**. This often happens with a **mature** process that has been around for a while.
- Process **capability** uses the process **σ** value determined from either the Moving Range, Range or **σ** control charts
- **P_p & P_{pk}** are used when a process is too **new** to determine if it is under statistical control.
- Ex. there is a short **pre-production** run.
- Because there is **not** a lot of **historical** data we take large samples from the process to account for variation.
- Process Performance generally uses sample **σ** in its calculation.

Process capability index (C_{pk}) ...



C_p & C_{pk}

- C_p & C_{pk} measure how **consistent** data is around **average** performance.
- Index '**k**' (**centralizing** factor) takes into consideration the fact that the data may be not centered.
- **C_{pk}** tells us what a process is capable of doing in **future**, assuming it remains in a state of statistical control.

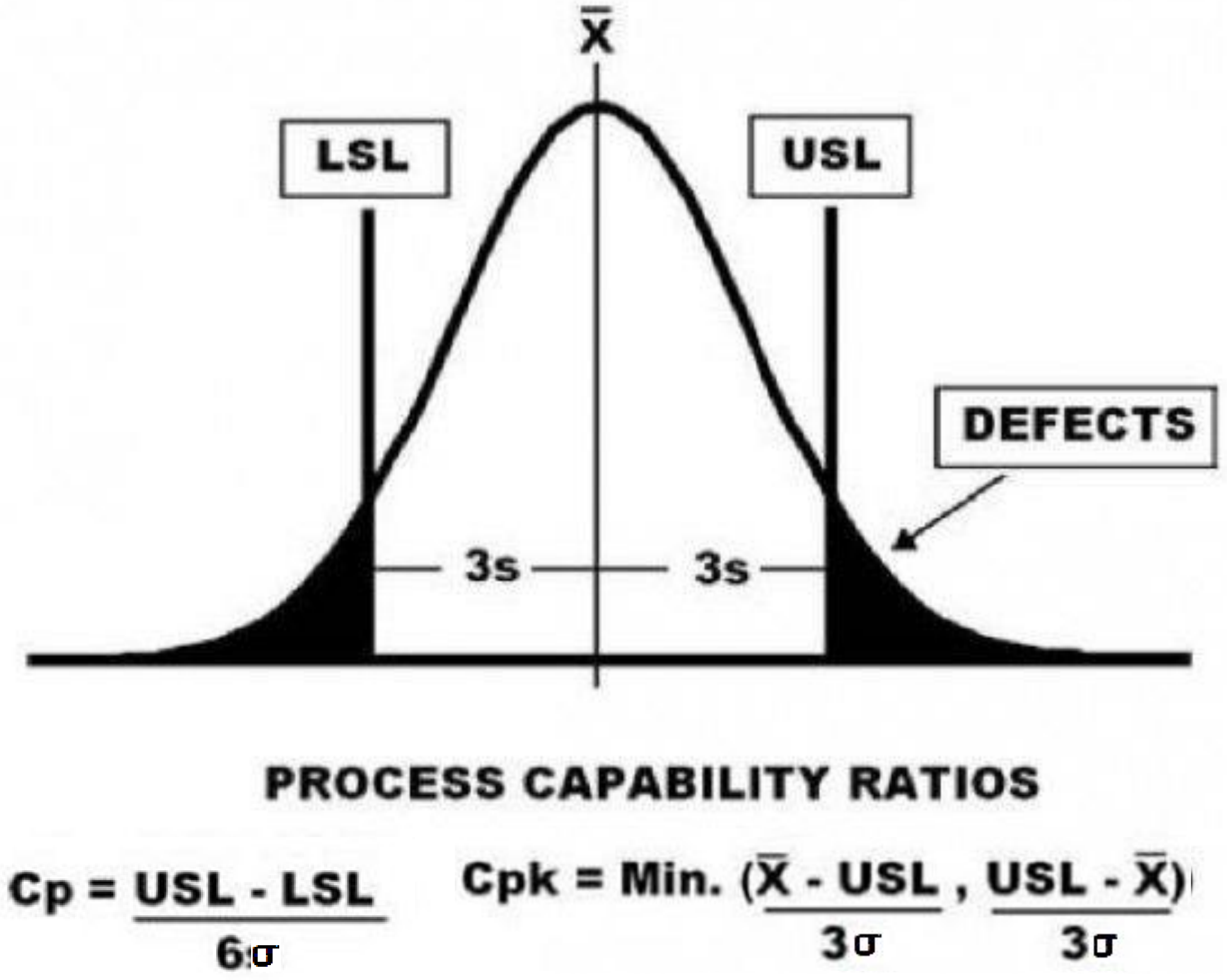
The Shooting at a Target Analogy

- In perfectly centered data set, No difference between C_p & C_{pk}.
- Think of throwing darts at a dart board and having the center of the bull's eye be the 0,0 on a cartesian plane and the edges being out 3 units from that center point
- (we will use the edge of the dart board or 3 and -3 as our USL and LSL).

Analogy with Archery

c) Decides to concentrate on controlling the spread and finally increases accuracy (Good Cp but bad Cpk)

d) After gaining stability finally targets the center and the result is excellent (Good Cp and Cpk).



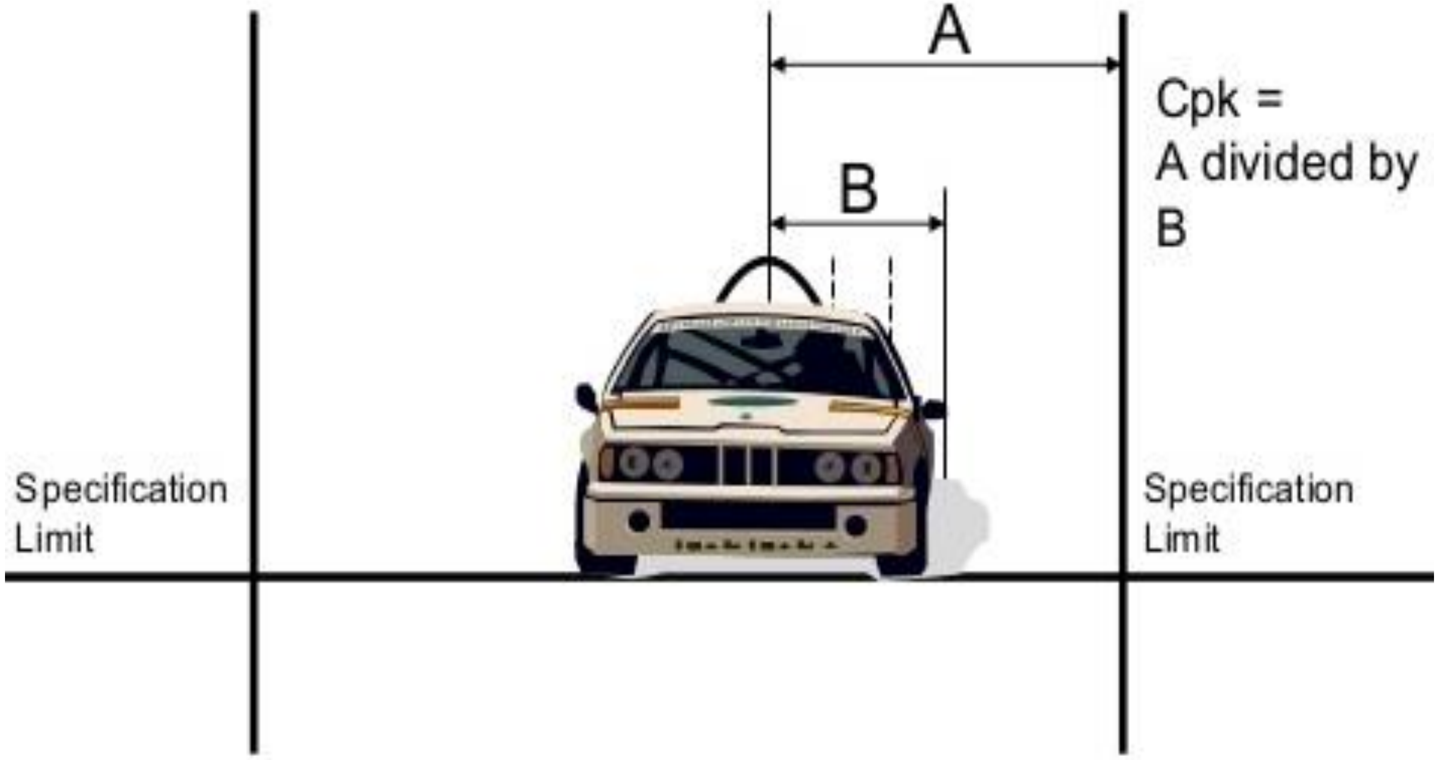
- In a perfectly centered sample of darts, the average distance from the center will be 0.
- A little algebra will show us that the $\mathbf{C_{pk}}$ and C_p numbers come out the same.
- Min((0- -3)/3**σ** , (3-0)/3**σ**)
- = (3- -3)/6**σ**
- = 1**σ**.

C_p & C_{pk}

- Things get a little harrier when the darts move up, say to be centered at an average of 2 units above center.
- Now you end up with a $\mathbf{C_{pk}}$ of (3-2)/3$\boldsymbol{\sigma}$ = 1/3$\boldsymbol{\sigma}$, but your Cp is still the same 1$\boldsymbol{\sigma}$ as before.
- It is important to note that because $\mathbf{C_{pk}}$ uses the minimum function, it will always be equal to or smaller than the $\mathbf{C_p}$ for the same set of data.

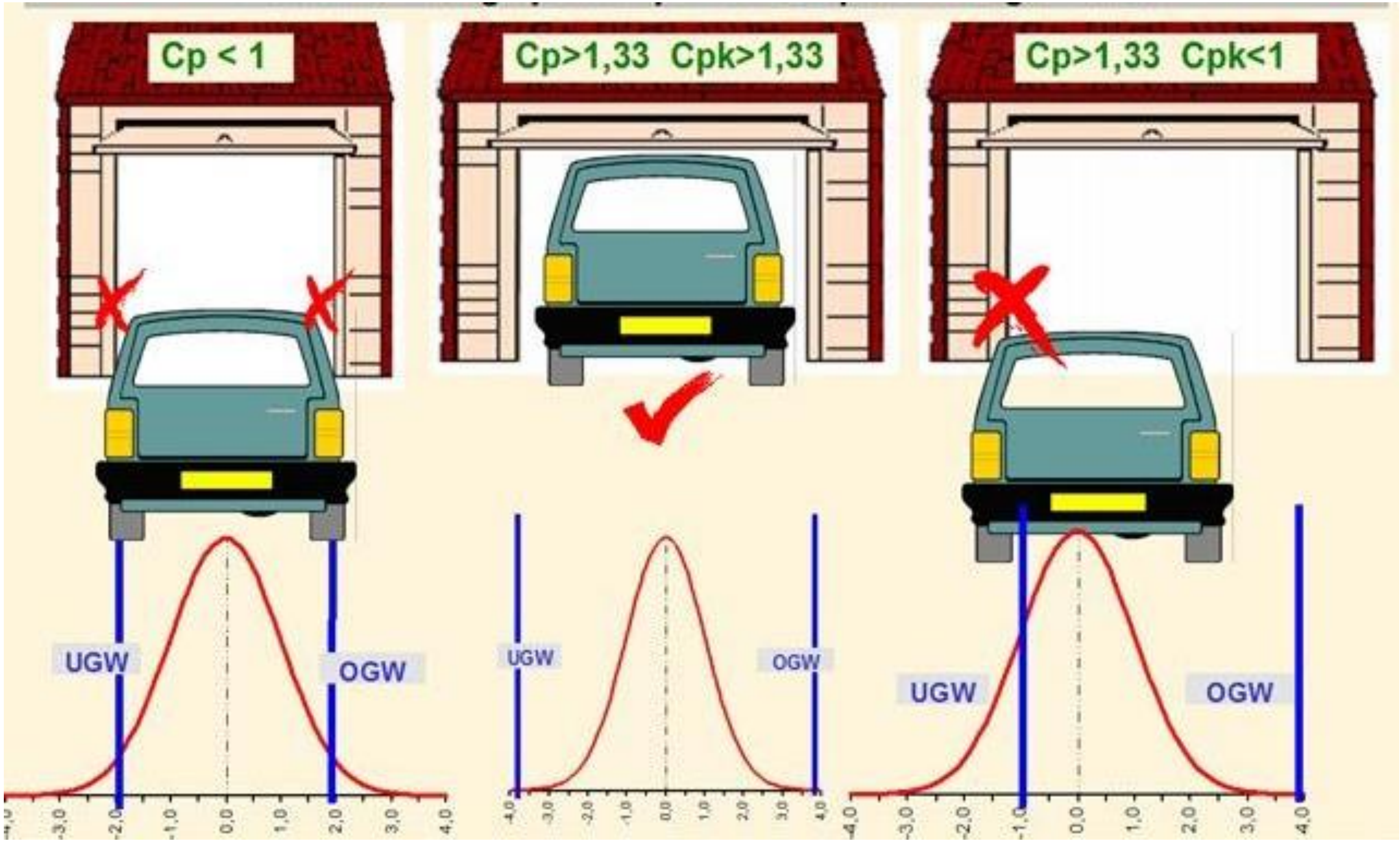
- C_{pk}: 'Parking a Car in the Garage' Analogy

- Walls of your garage – where you have to fit your car in – Customer specification limits.
- If you go past those limits, you will crash,
- and the customer will not be happy!



Analogy:
The bell curve is your automobile.
The spec limits are the edges of your garage door.
If A = B, you are hitting the frame of your garage door with your car.

- C_{pk}: ‘Parking a Car in the Garage’ Analogy



SIX SIGMA and Capability

- If your process has a lot of **variation**, that means the process average is all over the place.
- Not good for parking a car, and not good for any other process. To give your parking process the best chance of success you should work on **reducing** variation and centering.
- If the car is too **wide** for the garage, nothing you do to center the process will help. You have to change the **dispersion** of the process (make the car smaller.)
- If the car is a lot **smaller** than the garage, it doesn't matter if you park it exactly in middle; it will fit and you have plenty of room on either side.
- That's one of the reasons the **6σ** philosophy focuses on removing variation in a process.

Process capability index (C_{pk})

- $\mathbf{C_{pk}}$ measures producer's capability to produce a product within customer's **tolerance** range.
- $\mathbf{C_{pk}}$ is used to estimate how **close** you are to a given target and how consistent you are to around your average performance.
- $\mathbf{C_{pk}}$ can also estimate future process performance, assuming performance is consistent over time.
- The **higher** the $\mathbf{C_{pk}}$ value the better the process is.
- If you have a process that is in control and with little variation, you should be able to park the car easily within the garage and thus meet customer requirements.
- $\mathbf{C_{pk}}$ tells you the relationship between the size of the car, the size of the garage and how far away from middle of the garage you parked the car."

Process capability index (C_{pk}) …

- **How to Calculate C_{pk}**
- **C_{pk}** Calculation Formula
- The **C_p** index is not sufficient by itself to analyze a process capability.
- What would happen if the nominal production output value shifts towards either the upper or lower limits and some of the production fall outside the design specifications? This is when a **C_{pk}** is needed.
- **C_{pk}** formula takes the minimum results of the calculation.
- **C_{pk}** is a measure to show how many standard deviations the specification limits are from the center of the process.
- On some processes you can do this visually. Others require an equation.

Process capability index (C_{pk}) …

- **C_p** is an abbreviation. There are really two parts; the upper and the lower denoted **C_{pu}** and **C_{pl}** respectively. Their equations are:
  - **C_{pl}** = (Process Mean – LSL)/(3*Standard Deviation)
  - **C_{pu}** = (USL – Process Mean)/(3*Standard Deviation)
  - **C_{pk}** is merely the smallest value of the **C_{pl}** or **C_{pu}**:
  - **C_{pk}= Min (C_{pl}, C_{pu})**

$$Cpk = \text{Min.}\left(\frac{\bar{X} - USL}{3\sigma}, \frac{USL - \bar{X}}{3\sigma}\right)$$

- **Why are we dividing by 3 to find C_{pk}?**
- The 6 sigmas – or 6 SDs account for nearly all eventualities on a process (assuming normal distribution), The "/ 3" because we are looking at only one side of the distribution.

Process capability index (C_{pk}) …

- **C_{pk}** measures how close a process is performing compared to its specification limits and accounting for natural variability of the process.
- **Larger** is **better**.
- When **C_{pk}** is **negative** it means that a process will produce output that is outside the customer specification limits.
- When the mean of the process is outside the customer specification limits the value of **C_{pk}** will be Negative
- We generally want a **C_{pk}** of at least 1.33 or higher to satisfy most customers.
- **C_{pk}** can have an upper and lower value reported.

Process capability index (C_{pk}) …

- For instance,
- Machine A has a $\mathbf{C_{pk}}$ of 1.7 and
- Machine B has a $\mathbf{C_{pk}}$ of 1.1.
- From $\mathbf{C_{pk}}$ value, we can say that
- Machine A is better than B.

C_{pk}	Process Yield
0.5	86.8%
0.8	98.4
1.0	99.7%
1.2	99.97%
1.33	99.99%

$$\mathbf{Cpk = Min.} \left(\frac{\bar{X} - USL}{3\sigma}, \frac{USL - \bar{X}}{3\sigma} \right)$$

- Since $\mathbf{C_{pk}}$ uses specification limits and parts variation (sigma), we can also arrive at the yield processed and losses from the machine.
- ($\mathbf{C_{pk}}$) **>=** (**1.33**) indicates, the process is capable & meets specification limits.
- Any value less than this may mean variation is too wide compared to the specification or the process average is away from the target.

Process capability index (C_{pk}) …

Instance 1:

Upper specification limit (USL) =16

Lower Specification limit (LSL) = 4

Mean (μ)= 10 & Standard deviation (σ)= 2

Given the formula to calculate, Cpk = min[USL−μ/3σ, μ−LSL/3σ]

= min[16-10/6, 10-4/6]

= min [1 , 1]

= 1

When curve stretches from +3 to -3 it is believed to occupy 99.73% and here the machine is producing 99.73% good parts.

Process capability index (C_{pk}) …

Instance 2:

Upper specification limit (USL) =18

Lower Specification limit (LSL) = 0

Standard deviation (σ)= 2

Cpk = min[USL−μ /3σ, μ−LSL/3σ]

= min[18-10/6, 10-0/6]

= min [1.33, 1.67]

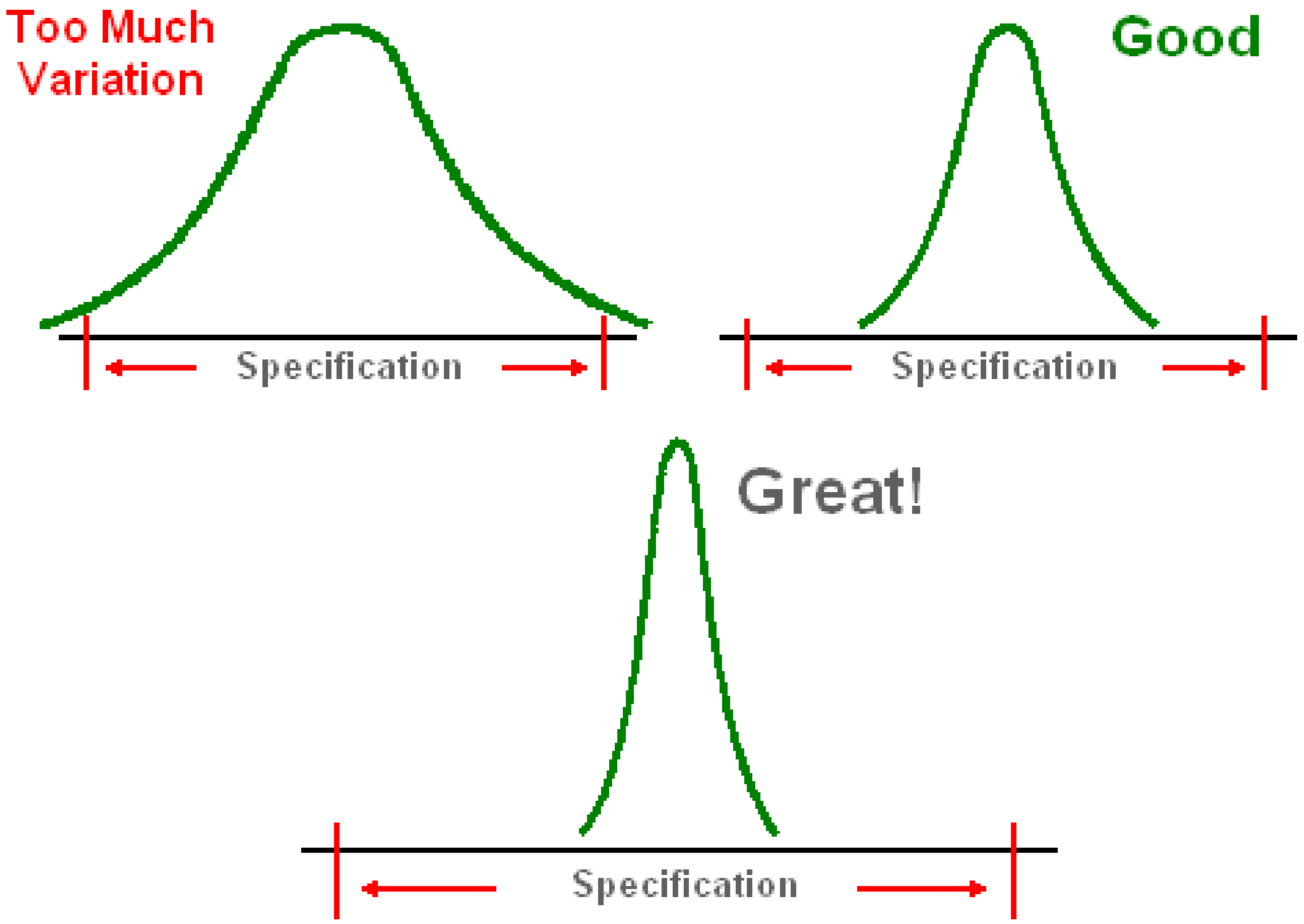
= 1.33

Here atleast, 99.99% of the outputs from the machine are good.

Process capability index (C_{pk}) …

- If C_{pk} is **less** than **zero** (**Negative**):
    - the process **mean** has gone beyond one of the **specification** limits.
- If C_{pk} is **greater** than **zero** but less than one,
    - the process mean is within the specification limits, but some part of the production output is outside the specification limits.
- If C_{pk} is **greater** than **one**,
    - the process mean is perfectly centered and is well within the specification limits.
- In general, the higher the C_p and C_{pk} values, the higher the Sigma level.
- A C_{pk} greater than 1.33 is considered good and indicates a Sigma level 4.
- But a C_p or a C_{pk} greater than 3 implies that the specification limits are very loose and should be tightened.

Process capability index (C_{pk}) …



What are Good Values for C_{pk}?

- Remember the Car parking in the garage analogy?
- C_{pk} = Negative number: Process will regularly crash the car into the wall.
- C_{pk} =0.5: There is a good chance hitting the wall on entry.
- C_{pk} =1: Car may be just touching the nearest edge of the entry.
- C_{pk} =2: There is a great clearance. We could **double** the width of your car before you hit the side of the garage.
- C_{pk} =3: There is an excellent clearance. You could **triple** the width of your car before you hit the side of the garage.
- The C_p ratio and the C_{pk} index are important metrics to use when evaluating the performance of a manufacturing process.
- Statistical sampling and continuous monitoring of the production process are essential to consistently producing a product that meets customers' demands.

6σ DEPLOYMENT PLANNING AND READINESS ASSESSMENT

- The stumbling blocks for a successful deployment of **6σ:**
  - Lack of senior **leader** support,
  - lack of **data**,
  - longer-than-expected project **cycle** time,
  - **part-time** BB resources, and
  - most important, poorly **defined** projects.
- To address common issues in **advance** and **mitigate** the risk of failure, Champions/MBB use 2 **key** requirements in deployment planning:
  - 1. **6σ** success equation and 2. Readiness assessment for **6σ**
- 1. **6σ** Success Equation
- Successful **6σ** deployment requires – the right Belts, the right projects and the right support system. $Y = f(x_1, x_2, x_3)$:
- Success = f (R_{Belts}, $R_{Projects}$, $R_{Support\ System}$)

6σ Success Equation …

- 1. The right Belts means all of them, from YBs up through Master BBs.
- 2. The well-defined projects and should include a robust pipeline of projects at a ratio of 2 projects per active Belt at any given time.
- 3. The right support means:
  - a complement of passionate Champions,
  - involved senior leaders,
  - highly analytical and skilled data owners,
  - excellent and available SMEs and process owners,
  - a robust financial management and reporting system,
  - an excellent HR support system,
  - good and available data, right metrics and validated measurement systems, and
  - a good **6σ** training vendor and curriculum customized to the organization's **culture** and **needs**.

2. Readiness Assessment for 6σ – Cultural Assessment

- When **nominating** Champions, Selecting projects and BBs, the organization must be aware of **cultural** and **operational b**arriers:

  Cultural Assessment:

- Varies from simple **observation** to a formal **survey** of all employees.
- The goal of the assessment is to identify whether **change** will be accepted across the organization.
- And if so, at what **speed** can the change be implemented?
- Also answer the following questions:
- How do senior leaders cascade important **information** throughout the organization?
- How are important **decisions** made?

2. Readiness Assessment for 6σ – Cultural Assessment …

- **Who** makes the decisions?
- How **fast** are the decisions implemented?
- How does the organization **recognize** successes and failures?
- How does the organization **handle failures**?
- Does everyone in the firm **understand** the **mission**, **vision** and **strategy** of the firm as a whole?
- Is everyone in the firm **aware** of the **critical** customer, **revenue** and operating **expense** issues across the firm?
- How does the firm **set** up **corporate** goals?
- How **clear** are these corporate goals?
- Are the corporate goals **measurable**?

2. Readiness Assessment for 6σ – Operational Cultural Assessment

Operational Assessment

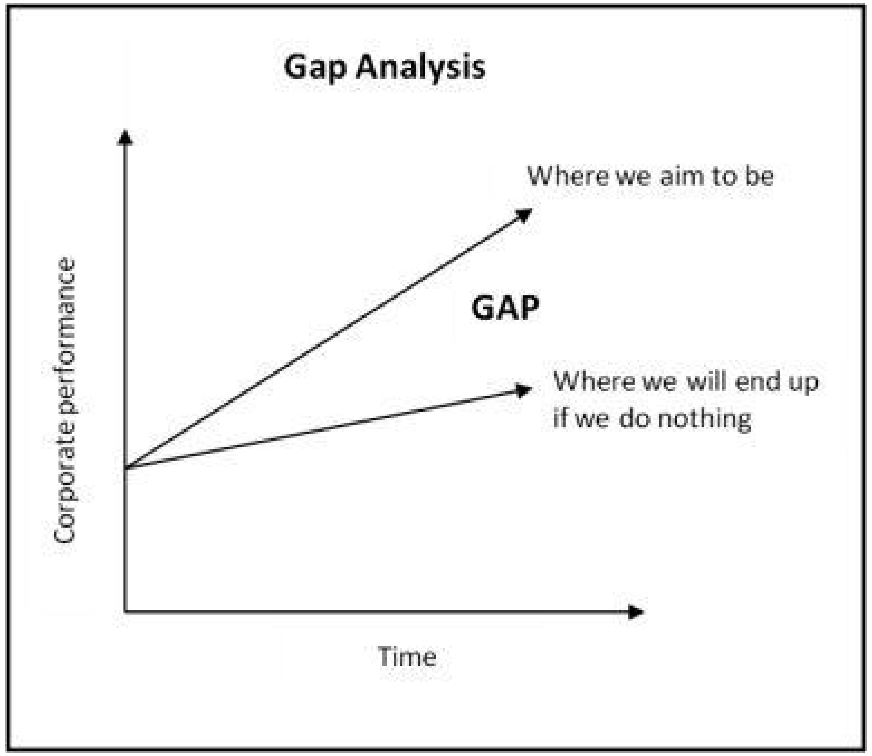
- Measures the **maturity** of the processes, **measurement** systems and **data** systems in an organization. Also answer:
- How does the organization **measure** success?
- **Does** the organization measure the **right** things?
- How **often** does the organization measure these things?
- Does the organization have a **few** metrics that all employees **understand** and **use**?
- Are **decisions** based on data or assumptions?
- Who **owns** each critical process?
- Who owns the data?
- Where is the data?

2. Readiness Assessment for 6σ – Operational Cultural Assessment …

- Is data stored on spreadsheets on employee laptops or in a data warehouse?
- Has the data been validated?
- Are the company's reports written in simple, scientific or financial terms, or free form using fuzzy language?
- Are there updated **process maps** of the most critical processes?
- Do the executives know what a process map is?
- Success equation and readiness assessment provide an organization with the knowledge to build
  - a **tailored deployment plan** for launch of **6σ** that includes the right elements and mitigates the risk of failure.
  - One other key element of deployment success which cannot be over-emphasized is time: **Time to plan well**.

Gap Analysis

- Gap Analysis is an assessment tool used in **6σ** to compare an organization's current performance to its desired/potential performance.



Steps in a Gap Analysis

- Look at the existing situation. Figure out the situation you want to be in.
- What is the gap? Why is there a gap between these two situations?
- What metrics can you use to measure this gap? How can you overcome this gap?
- List out the resources needed and find how they can help fill the gap.

- **Gap Analysis Metrics**
- Metrics used for gap analysis be: **Measurable, Meaningful** and **Improvable**

Gap Analysis Metrics …

- **Measurable**
- For ex: annual income and outgoings are 2 measurable metrics commonly used in gap analyses.
- There are many such as Public opinion, production statistics, and market share are just a few examples.
- **Meaningful**
- The metrics that you use should be instrumental in bridging the gap.
- For ex: if the organization’s main issue is negative public opinion, income is not a meaningful metric.
- Metrics like social media sentiment score are meaningful in this context.
- **Improvable**
- If you can’t improve it, why bother tracking it?

Gap Analysis Metrics …

- Use metrics that you can affect.
- For ex: a company that catches snakes for people in suburbia is likely to experience a slump in business over winter.
- Using ‘number of call outs’ as a metric might not provide many options for change, whereas ‘percentage of market share’ would.
- **Complementary**
- Sometimes using a single metric will leave out a lot of the picture.
- For example, imagine that you focus solely on customer satisfaction.
- Your customer satisfaction is steadily rising, but the number of customers is sharply dropping off. The overall situation is bad, but using only a single metric makes it look good.
- Using customer retention rate as a complementary metric would help deliver a more realistic understanding of the situation.

Gap Analysis Example

- A not for profit organization is running a street kitchen.
- It’s serving 200 meals a day to underprivileged people in the neighborhood.
- However, demand is exceeding supply. The organization is constantly turning people away without meals.
- A group forms to figure out a solution.

Gap Analysis - Example

- It decides that a gap analysis would be useful.
- 1. **Existing situation**
- The organization is currently serving 100 breakfasts and 100 lunches every weekday.
- 2. **Ideal situation**
- The group does some research about the area.
- This organization is the only one operating in the area to offer meals.
- There are approximately 1000 people living nearby who struggle to obtain nutritious meals every day.
- 3. **Calculating** the **gap**
- Not every family would need meals every day.

Gap Analysis – Example …

- The group estimates that 500 breakfasts and lunches per day would adequately meet the current need.
- That would mean increasing the number of meals served by 400%.
- 4. **Understanding** the **gap (Intuition Vs Data based Decisions)**
- The **group assumed** that lack of supplies would be the primary issue.
- But **investigation**, though, it turns out this isn't quite the case.
- When there is no enough external **funding** for 5 times the amount of food, the main issues seem to be around planning and wastage.
- Lots of food is going **cold** and therefore inedible.
- **Times** between cooking and serving are high.
- Cooks are used to **family** cooking and often struggle to keep up with the high **throughput** needed.

Gap Analysis – Example …

- 5. **Metrics**
- Obviously, number of **meals served** per **day** is an important **metric**.
- But after looking at the gap, the group decides to use **food wastage %** and preparation to **serving times** as well.
- 6. **Resources**
- Group is out of its depth, as no member is a professional caterer.
- So it seeks the assistance of **local** eateries to develop a plan of action.
- 7. **Filling** the **gap**
- The group meets with **industry professionals** to get ideas on how to **improve** its key metrics.
- Brainstorming delivers a few workable options.

Gap Analysis – Example …

- The group votes and comes up with a shortlist:
- Offer more cold options like muffins (cakes) and fruit. This decreases wastage due to bacteria growth.
- Switch to less complicated meals. This decreases prep time.
- Use production lines. This decreases prep and serving times.
- Group estimates that this will increase number of meals served to 300 per meal. This gets halfway to the target of 500 per meal.
- Other Analysis Tools:

Benchmarking - evaluate by comparison with a standard.

SWOT Analysis

PEST – How Political, Economic, Social and Technological, impact business.

Cost of Quality (COQ)

- **Cost of Quality** (**COQ**): Quantifying "quality" costs to organization.
- **COQ = COPQ + COGQ**
- **Cost of Quality = Cost of Poor Quality + Cost of Good Quality**

Cost of Poor Quality (COPQ)

- COGQ: Cost of **quality conformance**, including any costs associated with both **appraisal** and **prevention**.
- COPQ: Costs of **non-conformances,** both internal and external to the organization;
- Costs associated with a result of producing **defective** product/service.
  1. Cost involved in **fulfilling** the **gap** between the desired and actual product/service quality.
  2. Cost of lost **opportunity** due to loss of **resources** used to rectify **defect**.
  - Normally includes:
    - All the **labor** cost,
    - **rework** cost,
    - **disposition** costs (seller's expenses of sale), and
    - **material** costs **added** to the unit up to the point of rejection.

Iceberg Anology

Cost of Poor Quality (COPQ)

- COPQ quantifies the negative outcomes due to waste, inefficiencies and defects in a process. There are three categories in COPQ:

1. Appraisal costs:

- Costs incurred to **determine** the degree of **conformance** to quality requirements. - Inspection (purchased, manufactured), Testing (acceptance, field), Quality Audits, Calibration etc.

2. Internal failure costs:

- Costs associated with **defects** found **before** the customer receives the product or service. (Scrap, Rework, Re-inspection)

3. External failure costs

- Costs associated with **defects** found **after** the customer receives the product or service. (Warranty, Corrections and Removals, Product Liability, loss of brand reputation)

Cost of Poor Quality (COPQ)

1. **Appraisal costs**

- Costs due to **measuring** and **monitoring** quality related activities.
- Associated with the **suppliers**' and **customers**' **evaluation** of **purchased** materials, **processes**, **products**, and **services** to ensure that they **conform** to **specifications**.
- They could include:
    - **Verification**: Checking of incoming material, process setup, and products against agreed specifications
    - **Quality audits**: Confirmation that quality system functions correctly
    - **Supplier rating**: Assessment/approval of suppliers of products/ services

Cost of Poor Quality (COPQ)

2. Internal failure costs

- Costs incurred to **remedy** defects discovered before the product or service is delivered to the customer.
- Occur when the **results** of work **fail** to reach **design quality** standards and are detected before they are transferred to the customer.
- They could include:
    - **Waste**: Performance of unnecessary work or holding of stock as a result of errors, poor organization, or communication
    - **Scrap**: Defective product/material that cannot be repaired,used, or sold
    - **Rework** or **rectification**: Correction of defective material/ errors
    - **Failure analysis**: Activity required to establish the causes of internal product or service failure

Cost of Poor Quality (COPQ)

3. External failure costs

- Costs incurred to remedy defects discovered by customers.
- Occur when products/services fail to reach design quality standards are not detected until after transfer to the customer.
- They could include:
  - **Repairs/servicing**: Of both returned products and those in the field
  - **Warranty claims**: Failed products that are replaced or services that are re-performed under a guarantee
  - **Complaints**: All work and costs associated with handling and servicing customers' complaints
  - **Returns**: Handling and investigation of rejected or recalled products, including transport costs

Cost of Poor Quality (COPQ)

- **PREVENTION** COSTS
- Activities to eliminate defects from ever occurring- SPC (statistical process control), Quality Planning, Quality Training, investment in quality-related information systems
- Costs incurred to prevent or avoid quality problems.
- These costs are associated with the design, implementation, and maintenance of the quality management system.
- They are planned and incurred before actual operation, and include:
  - **Product/service** requirements: Establishment of specifications for incoming materials, processes, finished products, and services
  - **Quality planning**: Creation of plans for quality, reliability, operations, production, and inspection
  - **Quality assurance**: Creation and maintenance of the quality system
  - **Training**: Development, preparation, and maintenance of programs

Cost of Poor Quality

Cost of Conformance	Cost of non-Conformance
PREVENTION COST - *Training cost* - *Quality planning cost* - *Quality system design cost* - *Quality audit cost* - *Quality improvement projects*	**INTERNAL FAILURE COST** - *Rejection cost* - *Rework/Repair cost* - *Loss due to down grading* - *Re-testing costs,* *etc.*
APPRAISAL COST - *Inspection & test cost* - *Calibration cost* - *Laboratory expenses* - *product/process audits,* *etc.*	**EXTERNAL FAILURE COST** - *Warrantee Expenses* - *Claims* - *Returns/Replacements* - *Complaints handling,* *etc.*

B9 =B7+B8

Total Cost of Poor Quality=Repairs on Finished goods+Warranty costs and product returns

	Particulars	B Amount
3	Sales	$1,000,000
4	Quality checks and Inspection	$10,200
5	Raw Materials Appraisal Costs	$30,000
6	Total Cost of Good Quality	$40,200
7	Repairs on Finished goods	$15,000
8	Warranty Costs and Product Returns	$5,000
9	**Total Cost of Poor Quality**	$20,000
10		

Example of COPQ Calculation

COPQ Calculation		
Cost for Failure or loss	**Amount**	**% COPQ**
Scrap due to defect	$3,250.00	1.33%
Rework & Repair	$45,000.00	18.42%
Warrenty Failure	$56,500.00	23.13%
Material Waste during Production	$38,550.00	15.78%
Total	$143,300.00	58.66%
Cost of appraisal	**Amount**	**% COPQ**
Incoming Inspection	$22,500.00	9.21%
Inprocess Inspection	$35,250.00	14.43%
Pre Dispatch Inspection	$28,000.00	11.46%
Total	$85,750.00	35.10%
Cost of Prevention	**Amount**	**% COPQ**
Performance testing destructive	$15,250.00	6.24%
Total	$15,250.00	6.24%
Grand Total	$244,300.00	

COST OF QUALITY AND ORGANIZATIONAL OBJECTIVES

- **Costs** of doing a **quality** job, conducting quality **improvements**, and **goals** must be managed well for a **long-term** desirable effect.
- These costs must be a **true measure** of the quality effort
  - And they are best determined from an **analysis** of costs of quality.
- Such an **analysis** provides
  1) A method of **assessing** the **effectiveness** of quality management and
  2) A means of **determining problem** areas, **opportunities**, **savings**, and action **priorities**.
- Cost of quality is also an important **communication** tool.
- Philip Crosby demonstrated what a powerful tool it could be to raise **awareness** of the importance of quality.

COST OF QUALITY AND ORGANIZATIONAL OBJECTIVES

- He referred to the measure as the "**price of non-conformance**" and argued that organizations choose to pay for poor quality.
- Some organizations will have true quality-related costs as high as **40**% of **total** operations.
- A general rule of thumb is that COPQ: About **10-15%** of **operations**.
- Effective quality improvement programs (QIP) reduces this substantially,
- Thus making a direct contribution to **profits**.
- The quality cost system, **once established**, should become **dynamic** and have a **positive** impact on the achievement of the organization’s mission, goals, and objectives.

The Cost of Doing Nothing (CODN)

- Doing nothing when there is no problem in the system is not a good decision.
- For example: The **problem** with your work force has been diagnosed.
- You've determined the **requirements** of any **solution**.
- Now it's time to outline your **options** – and Do **Nothing** is **one** of them.
- The reasons why "Do Nothing" is not the best option.
- "The Do Nothing Guide" contains 20 categories for which to consider the impact of doing nothing.

CODN - Problem 1: Revenue performance inconsistencies

- Story: Mete Products supplies businesses with high-cost engg products.
- After some great and average years, they had 6 quarters of bad sales.
- During this slump, Oliver (SVP Sales Operations) analyzed Sales to find the cause – the **lack** of a **sales process** to be the culprit.
- Oliver **outlined** what requirements a solution should have.
- **But** then, Mete caught some market tailwinds and had some blowout sales quarters.
- The pain was no longer acute, so Mete chose the "**do nothing**" option.
- **No sales process** was implemented since times were good again.
- Oliver didn't push for it since he saw no appetite for it.

CODN - Problem 1: Revenue performance inconsistencies …

- **Impact**: After 2 quarters and sales, Mete’s sales tanked again.
- This time it was worse, though.
- A coup in production was brewing – they were frustrated with the **backlog-to-surplus** swings caused by **poor** sales **forecasting**.
- A supplier due to the inconsistency in orders and went to a competitor.
- The board fired the SVP of sales and he took some of the top sales producers with him.
- Sellers that remained were not being developed in new sales practices – they became unmarketable.
- HR could not find enough interested candidates to fill open positions as the new candidates smelled a problematic sales force.
- The stock price dropped.

CODN - Problem 1: Revenue performance inconsistencies…

- Oliver quantified the impacts in a business case for implementing a sales process.
- Post-implementation, Mete has gotten back to average sales – trending upward.
- Forecasts are much more accurate now due to a standard sales process.
- Oliver now knows to uncover impacts of “do nothing” early in the process.

- **Problem** 2: New hire reps take too long to be productive
- Story: Kel International develops (B2B) business to business applications for mobile devices.
- They have a wide product set and international customers.
- For multiple reasons, seller turnover tends to stay on the high side.

CODN - Problem 2: New hire reps take too long to be productive…

- HR does a great job in keeping a candidate pipeline full.
- However, new hires take about 12 months to reach full productivity.
- Hanna, an HR Business Partner to Sales, helped look into this.
- She found that there was no onboarding program for new hire sellers and worked with Sales to define what a Sales onboarding program should accomplish.
- Sales looked at Hanna’s problem description and suggestions.
- They decided to “do nothing” since they were consistently making the number.
- Hanna wasn’t pushing Sales too much as she was offered to help with a major initiative for international recruiting.
- **Impact**: Although HR kept busy with recruiting, the performance management statistics weren’t good for sales.

CODN - Problem 2: New hire reps take too long to be productive…

- Some Sales Managers didn’t give enough attention to new hires.
- New hires were getting frustrated – many of them quitting before the 6th month.
- Those that stayed were taking all of the Sales Managers’ time for coaching.
- Star performers weren’t getting as much attention from Sales Managers as they wanted. So, some of these A players started to leave.
- Sales Managers were overwhelmed with time commitments to constant new hires.
- Product Development was annoyed at the low new product sales as the Sales “didn’t have bandwidth” to learn and sell new products.
- They stayed in the **comfort** zone of legacy products they knew.
- Marketing was not happy with the inconsistency of Sales in delivering value propositions.

CODN - Problem 2: New hire reps take too long to be productive…

- Deal quality started to suffer (discounting was a widely used practice.)
- Customer complaints increased about the new “unknowing” account managers.
- Burnout settled in and Sales Managers started to leave.
- Hanna finished the international recruiting initiative and returned to support Sales.
- She quickly realized there were more than onboarding problems now.
- However, she did what Oliver did – quantified the impact of not fixing onboarding.
- She convinced Sales that an onboarding program would help.
- They agreed, it was implemented, and they’re already getting results. Hanna won back her hero status.

The Cost of Doing Nothing (CODN) - Next Steps

- Doing nothing is a prevalent option to solving problems.
- It usually holds least short-term risk, both personally and corporately.
- It doesn’t require a committee’s unanimous decision. Many times it doesn’t even have a business case attached.
- Instead, just pointing out that “things are going well” is justification enough.
- There may be a time for doing nothing. Deciding whether doing nothing is worth it.
- 1. Determine the impacts of doing nothing
- 2. Quantify those impacts
- 3. Build a business case to show that doing nothing is a bad option
- 4. Take a calculated risk for long-term gain and do something to fix sales problems

Four Levels of Quality

- 1. Fitness for **STANDARD**
  - inspection oriented
  - no consciousness to customer/mkt
- 2. Fitness for **USE**
  - Must satisfy customer need for use
  - Eg. shampoo & body oil
- 3. Fitness for **MARKET**
  - Must achieve low cost as well as 1 & 2

4. Fitness for **LATENT REQ'TS**
  - Things That Will Delight Your Customers. Represent behaviors that users do not expect based on their previous experiences
  - Listening to the voice of the customer
  - Uncovering latent req't adds value ==> need continuous innovation

Four Levels of Quality…

- **1) Fitness to standard**
- A product is of quality if it is what it is supposed to be.
- **Definition:** conformance to the specifications
- Quality is thus checked by comparison between the **output** and the **specifications**.
- **Methods:**
  - - **Standardization;**
  - **- Statistical quality control;**
  - **- Inspection.**
- **Standardization:** Set of actions taken for the product and the process to be clearly identified.

Four Levels of Quality

- A set of written procedures for example.
- The classical test for checking whether standardization has taken place is: "If the people go, do the procedures stay?"
- Inspection is a simple mean by which the items are sorted. Good items are kept and bad ones are dropped.
- We can decide to check all the products (total inspection) or only some of them (statistical control).
- Inspection plans are discussed later in this chapter.
- **Drawbacks:**
  - - Inspectors are "the **enemy**";
  - - Inspections do not add any **value**;
  - -Conformance to **specifications** doesn't mean conformance to **needs**
- Based on this last drawback, the following definition was introduced.

Four Levels of Quality - 2) Fitness of Use

- Here, a product is of quality if it performs as **expected** not as **specified**.
- **Difference** is between: **Intended** use of a product (its specification) and its **real** use.
- **Definition: conformance** to the **expected** use
  - A screwdriver is specified for a given size.
  - We generally want to use the same screwdriver for any kind of screws.
  - And maybe for opening a can of paint.
  - Note that the fitness of use is difficult to reach since this use may vary over customers and time.
- **Methods:** market research / contact
- Here we enter the world of **marketing**. The only way is to ask the consumer.

Four Levels of Quality - 2) Fitness of Use …

- **Drawbacks:**
- - Inspectors are "the enemy";
- - Inspections do not add any value
- "Fitness of use" supposes that definitions of the specifications are "consumer based".
- Fitness of use requires thus fitness to (the new) specifications and therefore also requires inspections.
- Higher quality implies better inspection and therefore higher costs.
- Too large inspection costs could also be dangerous.
- The answer is then the following.
- Instead of "**inspecting**" the quality of the product, the focus came on "**building**" the quality in the product.

Four Levels of Quality - 3) Fitness of Cost

- Means high quality in the eye of users but now at low or reasonable **cost**.
- **Definition:** conformance to the expected **use** and to the expected **price**.
- To reach this goal the variability of processes is to be reduced so that no products have to be discarded (and therefore none need to be checked).
- Only way of reaching this goal: To control the processes and not products.
- **Methods:**
  - Statistical quality control (SQC)
  - Stochastic process control (SPC);
  - Providing feedback at each step;
  - Promote participation of the workers in the design and improvement; (7 QC steps and 7 QC tools)

Four Levels of Quality - 3) Fitness of Cost …

- SPC: Technique aiming at controlling the process by which products are made.
- The aim is to detect any dis-functioning of the process.
- Each worker should provide some feedback on the work of his/her predecessor.
- The goal is
  - first to detect any mistake as quickly as possible and
  - second to allow some learning to take place.
- **Drawbacks:** - everybody can copy

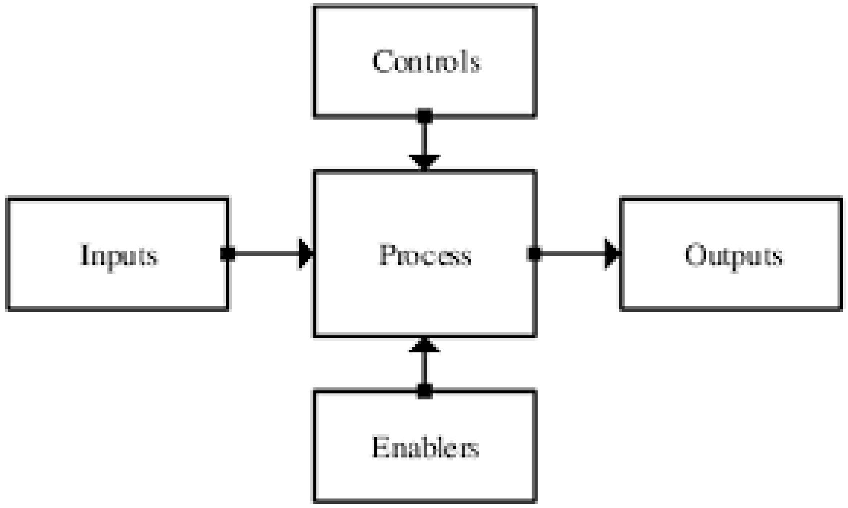
Four Levels of Quality - 4) Fitness to latent requirement

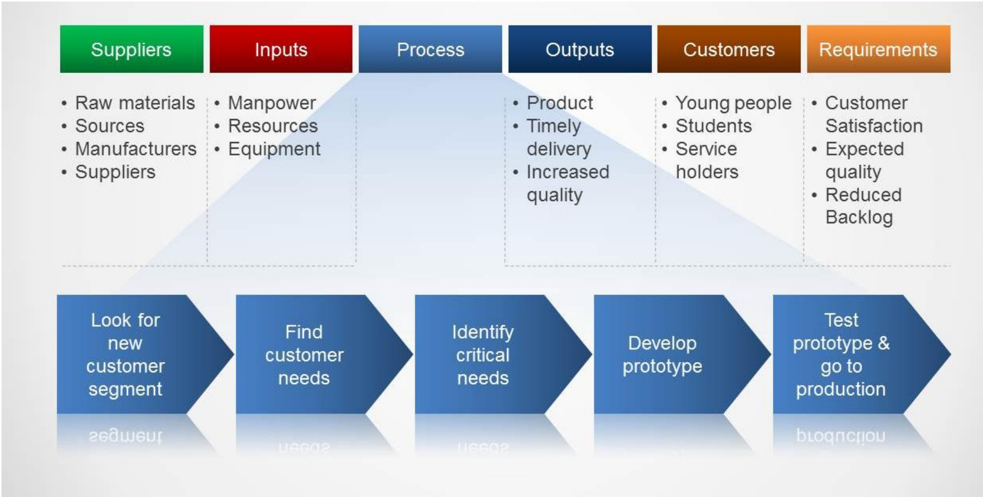
- This means high quality in the eye of the users and low cost.
- **Definition:** conformance to the unexpected needs
- Examples of products which fitted to latent requirements are the Polaroid camera and the walkman.
- The idea is to give the company a monopoly for a while.
- **Example:** The Watch
  - The "fitness to standards" is reached when all parts are ok;
  - the "fitness to use" means that the watch gives the correct time;
  - the "fitness of cost" means the watch works and its price is ok.
  - Finally, the swatch is an example of the fitness to latent requirement.

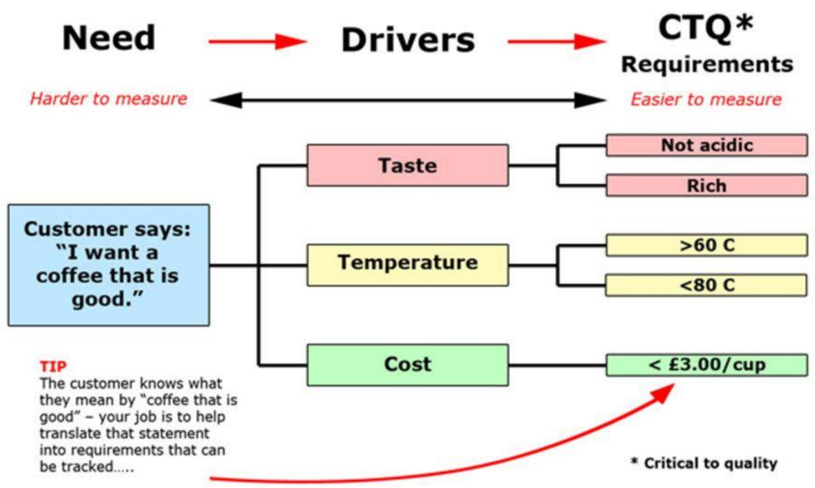
UNIT II

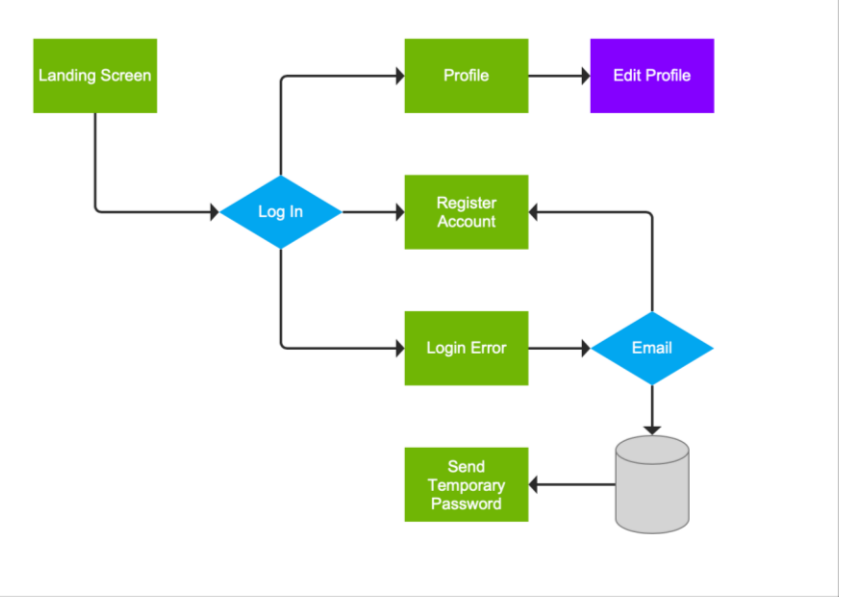
- **THE SCOPE OF TOOLS AND TECHNIQUES**

Tools for Definition

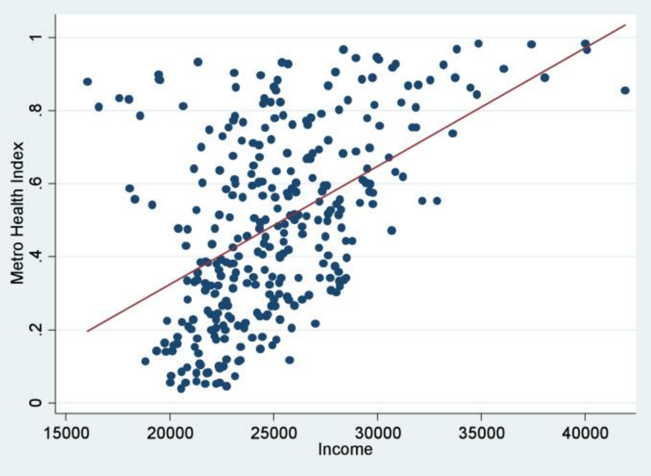


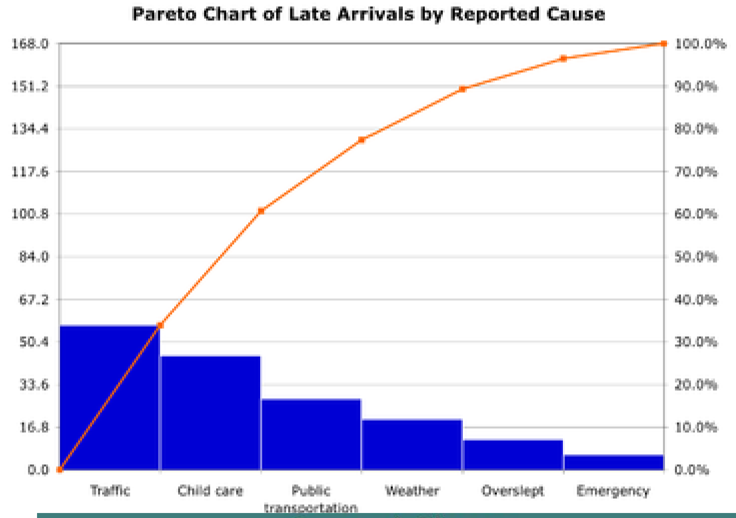




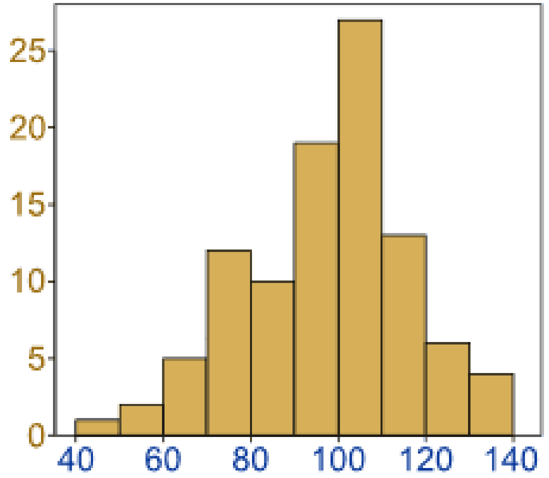


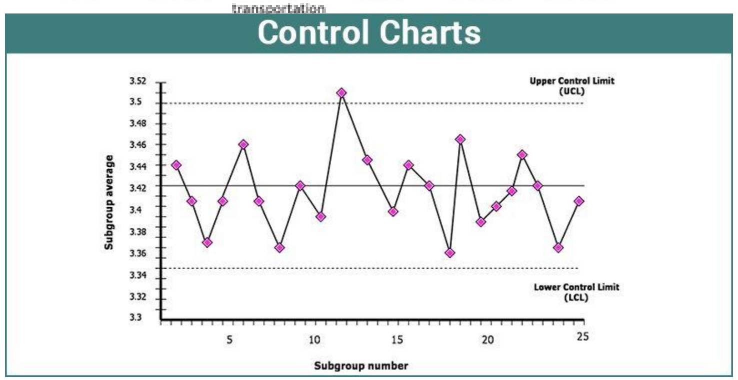
Defect Types/ Event Occurrence	Dates: Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	TOTAL
Supplied parts rusted		|||||||||	|||||	||||	||			20
Misaligned weld			|||			||		5
Improper test procedure								0
Wrong part issued					||				3
Film on parts								0
Voids in casting				||||	||			6
Incorrect dimensions						||		2
Adhesive failure								0
Masking insufficient									1
Spray failure			|||||					5
TOTAL		10	13	10	5	4		

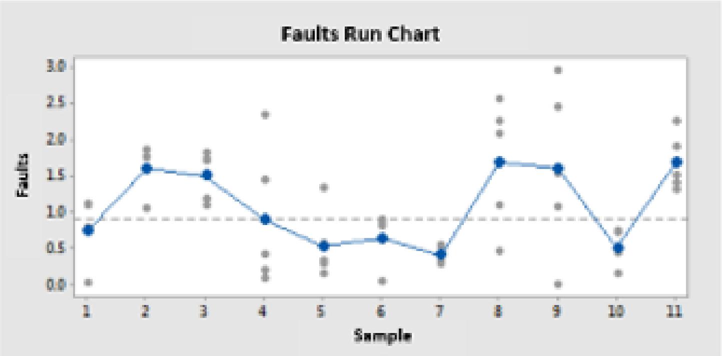


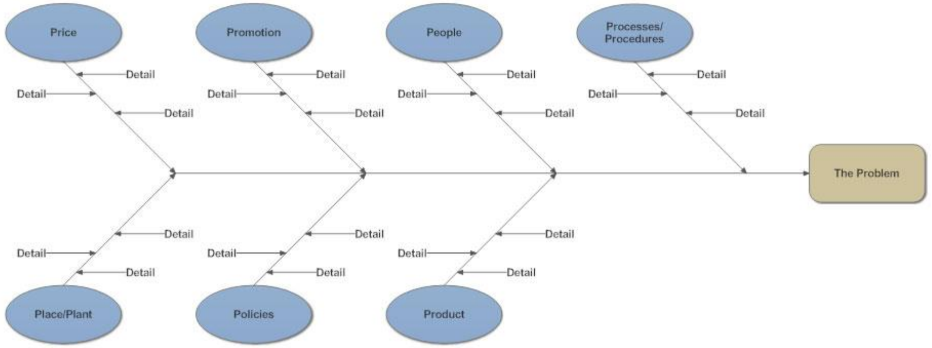


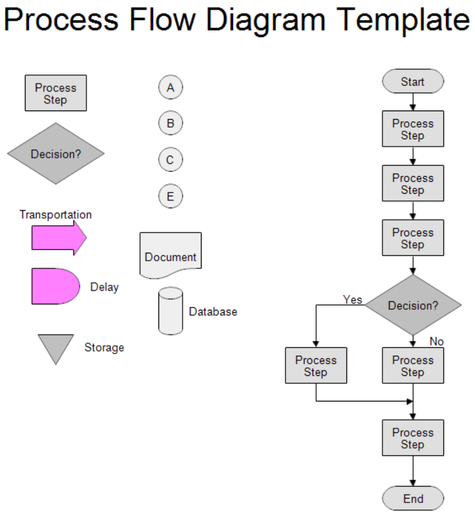
Tools for Measurement



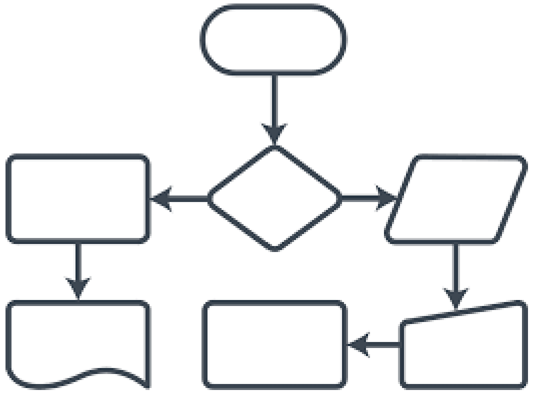


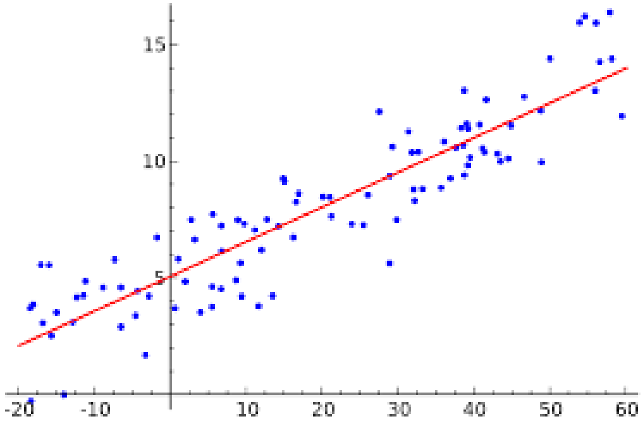


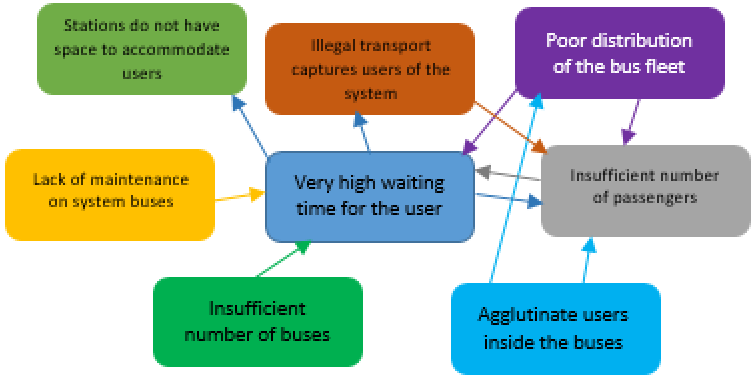


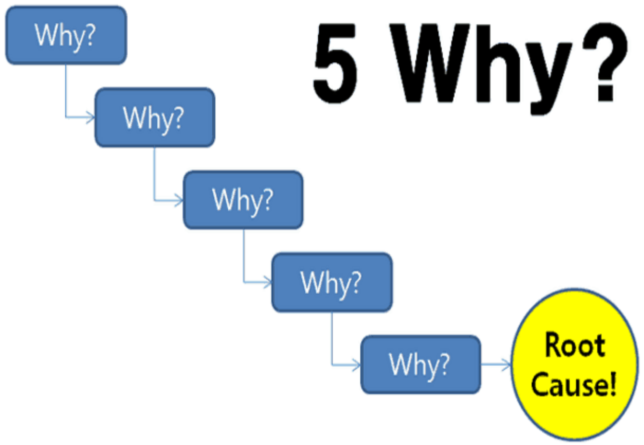


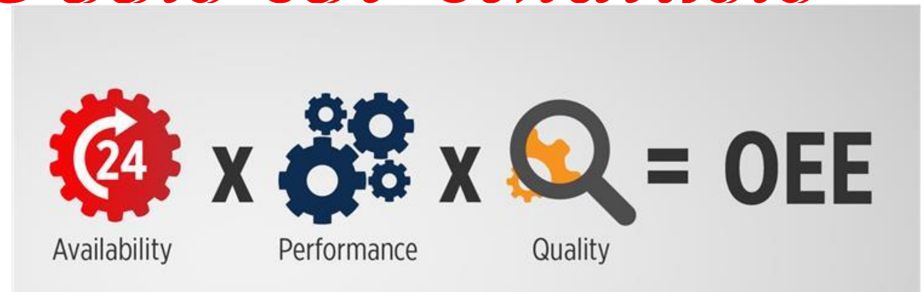
Tools for Analysis

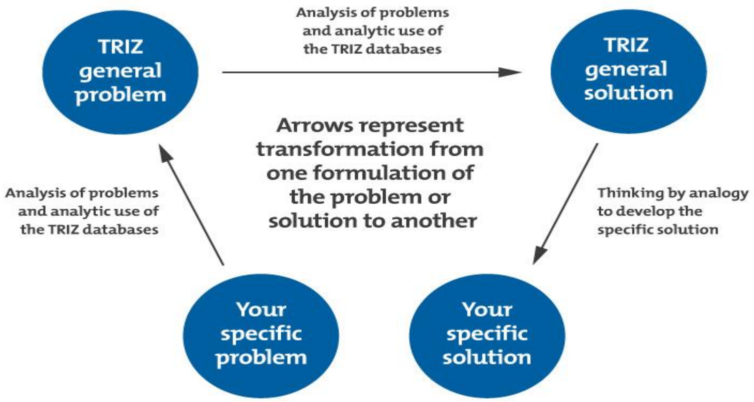












Process Mapping

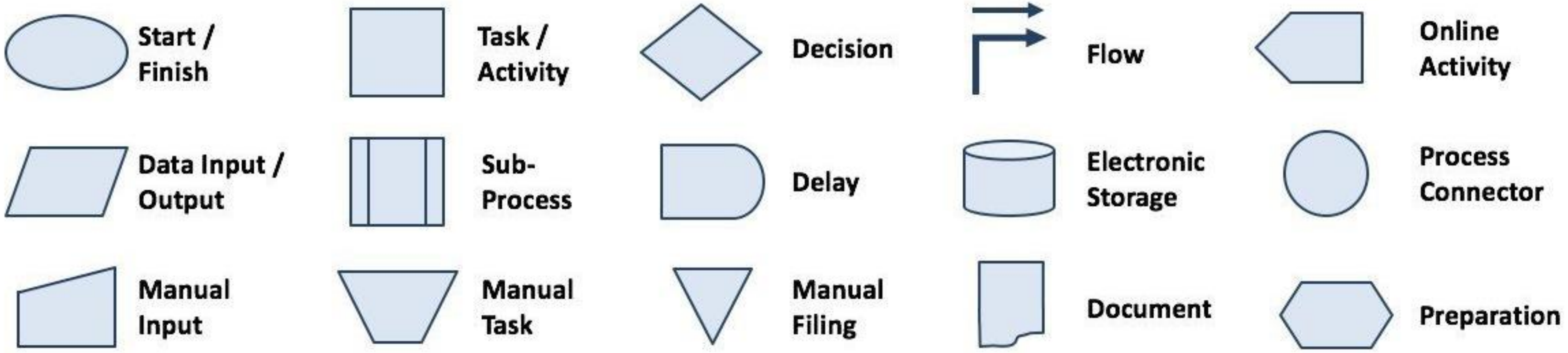
- The process map is a tool that graphically shows the inputs, actions and outputs of a process in a clear, step-by-step map of the process.
- Process mapping is the graphical representation with illustrative descriptions of how things get done. It helps the participants to visualize the details of the process closely and guides decision making

- Pictures guide better than words.
- The use of graphs, charts, tables and images guides better than a big compiled report with lot of data fixation issues in it.
- Decision making becomes fast
- Process can easily be tracked
- Visual illustration for training would be much more effective than any oral tools

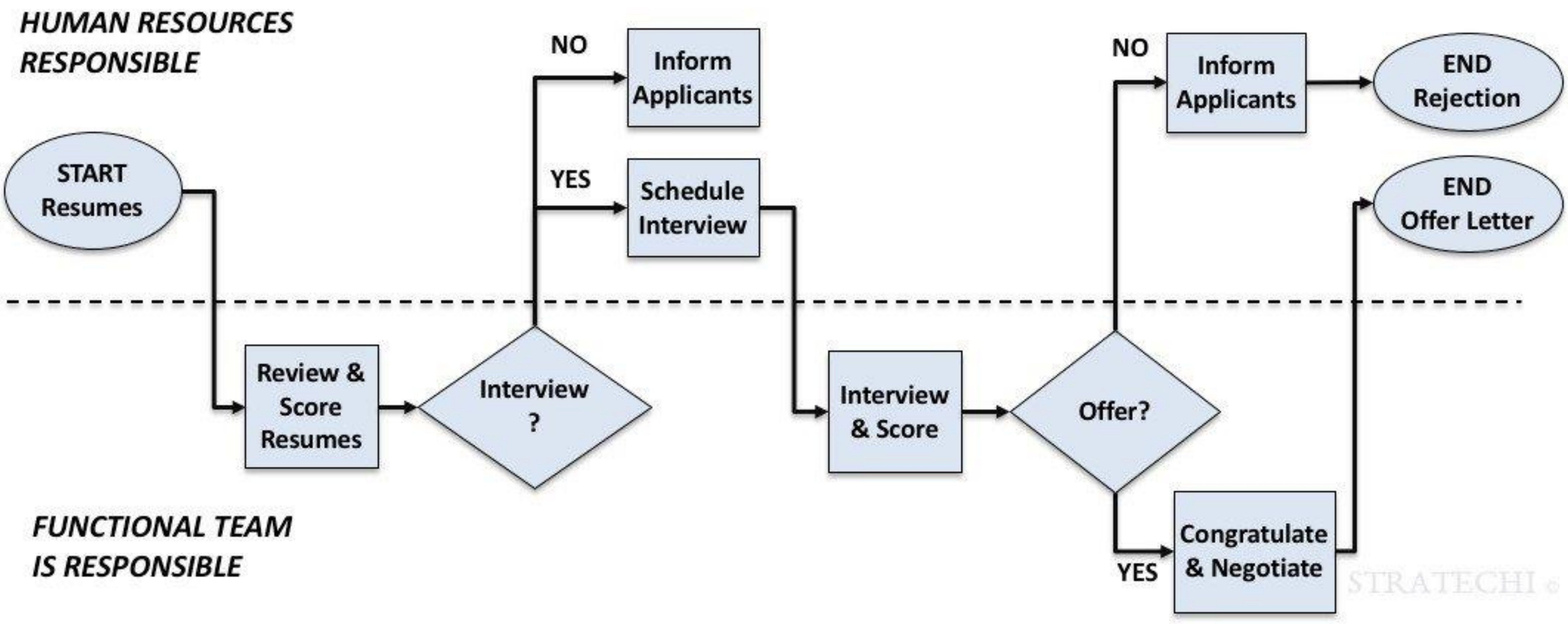
How to Start Process Mapping

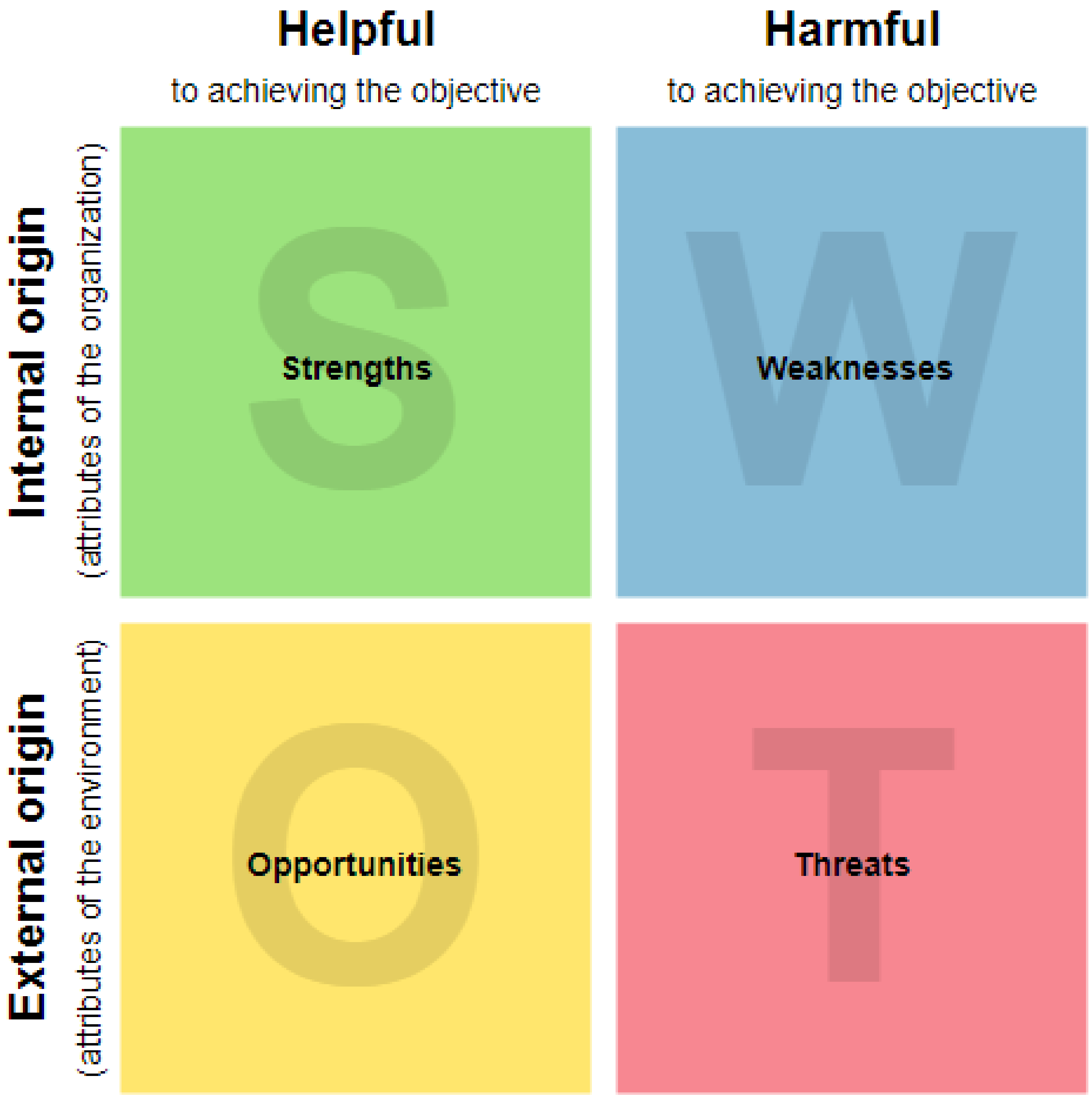
- **Step 1: Select the process**
- **Step 2: Identify the scope of the process steps**
- **Step 3: Plan and schedule resources**
- **Step 4: Select Mapping techniques**
- **Step 5: Conducting interviews**
- **Step 6: As-Is process**
- **Step 7: Analyze, evaluate and Sign- off**

Process Mapping Symbols



HIRING INTERVIEW PROCESS WITH SWIM LANES




Helpful
to achieving the objective
Harmful
to achieving the objective
Internal origin
(attributes of the organization)
External origin
(attributes of the environment)
Strengths
Weaknesses
Opportunities
Threats

- **The Snoozy Inn is a 40-unit, no-frills operation in the less scenic part of a major Queensland resort town. The owner, Mr. Smith, firmly believes that there is a need for his style of low-cost family accommodation amid the luxury and beauty of the area. His rooms are large, family-style rooms (there is no television, for example). Although there is plenty of room for future expansion, the grounds are fairly bare with a bit of landscaping, but mostly grass.**
- **Mr. Smith can serve breakfast to the rooms and provides tea-making facilities. There are now a lot of good restaurants and take-aways in the area. Mr.. Smith's prices are less than half of what similar motels charge and only a fraction of what the big five-star properties are charging. And, really, he isn't all that far away from the beach, shops and other attractions.**
- **The problem is occupancy. He has some regulars who come every holiday period (and have been doing so for the four years he has owned the property). Overall, occupancy is about 50% year round and he knows from the local tourist office that the other properties average around 68% occupancy year round. New developments could mean trouble. This lack of occupancy can be quite frustrating for Mr. Smith. Cars pull in, drive around the parking areas, and then drive away.**
- **Currently Mr. Smith does very little advertising in local district guides and the holiday papers, mainly because he really thinks word-of-mouth is the best form of advertising. He is a member of the local tourist committee, but too busy to go to meetings. However, he does receive the local statistics and knows the average stay in the area is 3.8 nights, and that local families and couples and increasingly overseas visitors are his potential customers.**
- **He's not desperate yet, but he's getting worried and disillusioned. He thought he would be overrun with guests, but that hasn't happened.**

PEST ANALYSIS

Political Factors measure how stable a nation is, and how active a government is in the wider economy.

POLITICAL FACTOR

Economic policies and factors can impact a businesses chances for expansion.

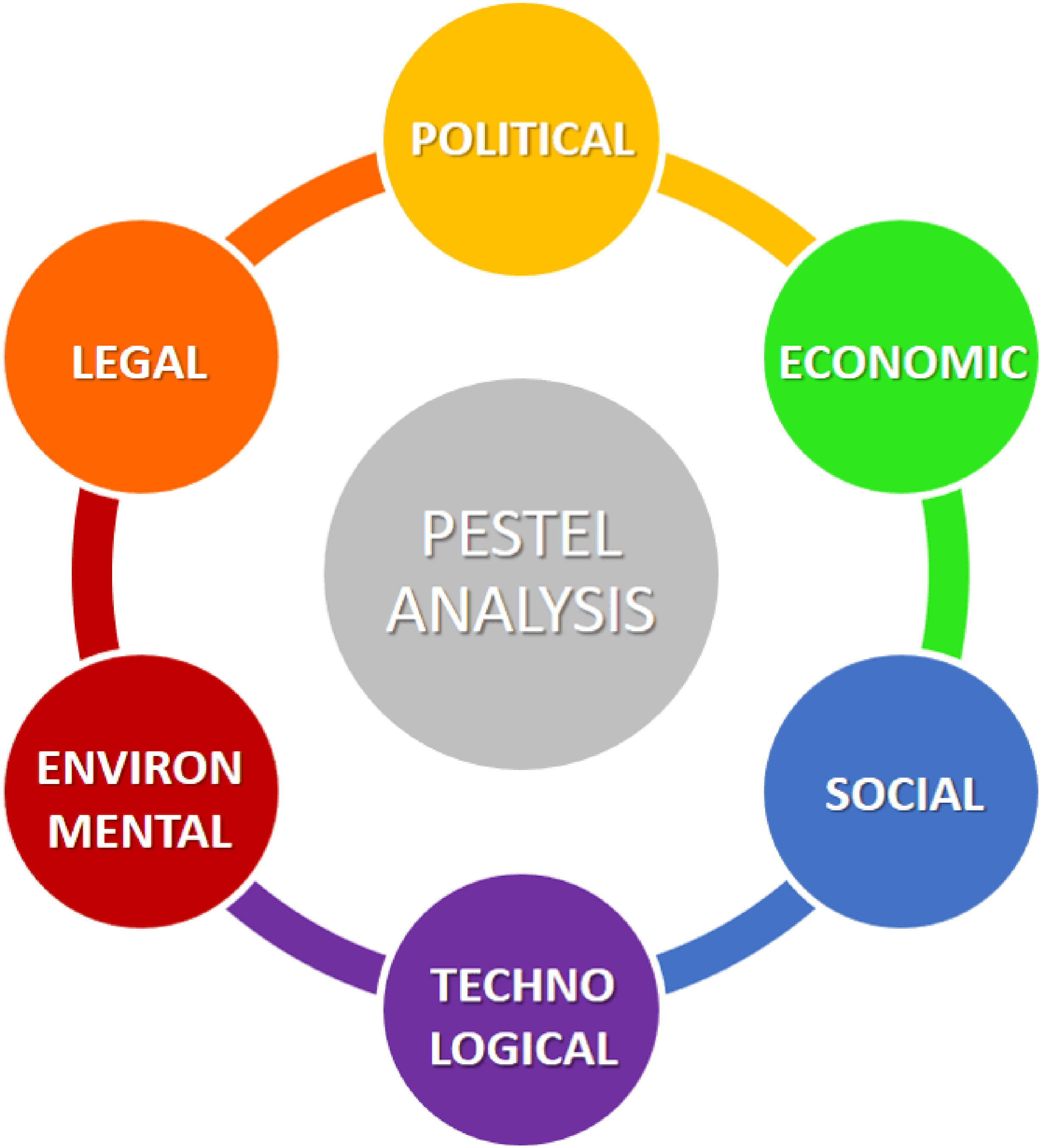
ECONOMIC FACTOR

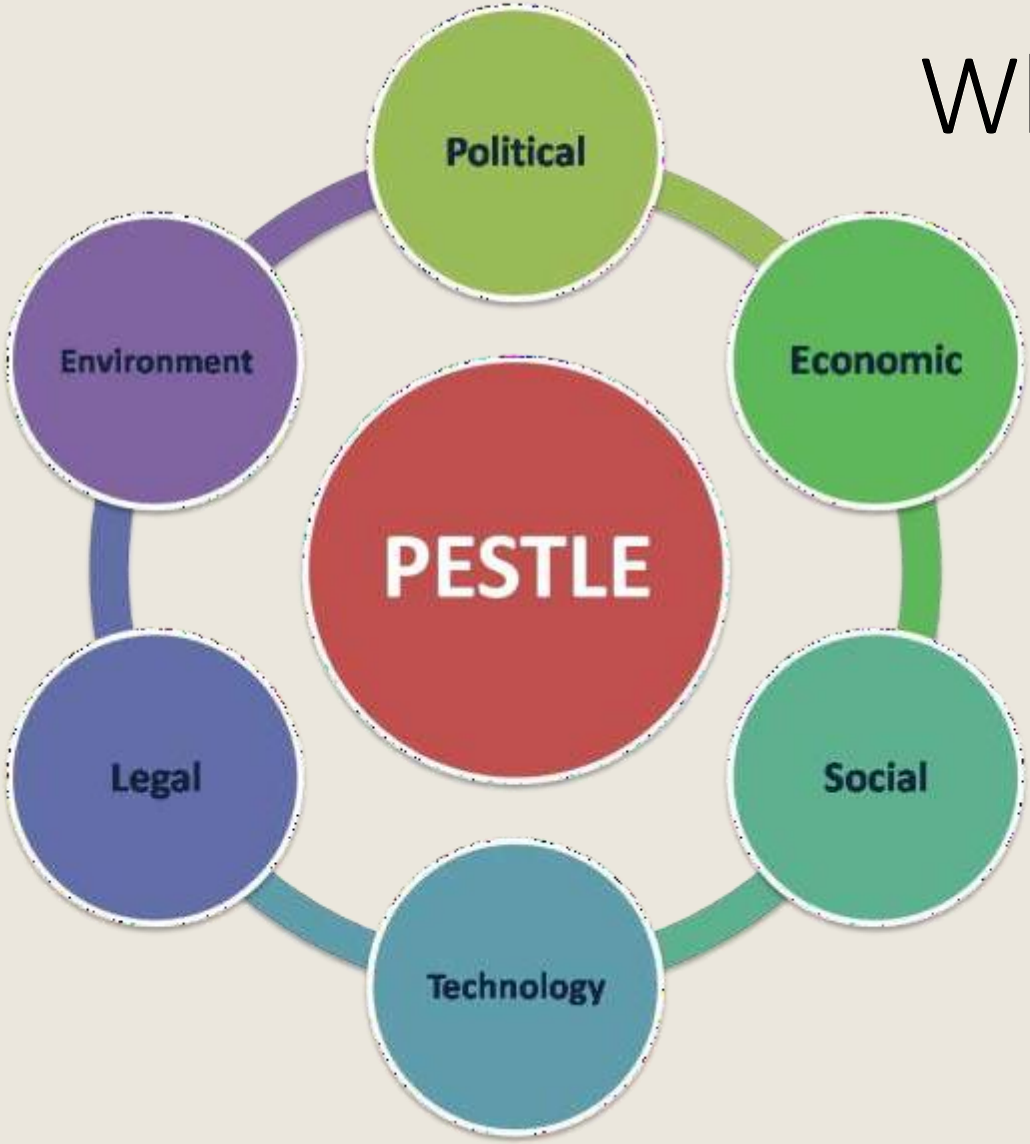
Social factors affect how nations behave, act, and buy goods and services in the market.

SOCIAL FACTOR

Technological factors can include areas such as R&D, automation, and innovation. This is increasingly relevant in emerging markets.

TECHNOLOGICAL FACTOR


POLITICAL
ECONOMIC
SOCIAL
TECHNO
LOGICAL
ENVIRON
MENTAL
LEGAL
PESTEL
ANALYSIS



What isPESTLE Analysis?

- A **PESTLE analysis** is a framework or tool used by marketers to analyze and monitor the macro-environmental (external marketing environment) factors that have an impact on an organization. The result of which is used to identify threats and weaknesses which is used in a SWOT **analysis**.

- The 6 factors make up the acronym **PESTEL.**
- Each letter represents one factor. It is often called PESTLE.
- You may these factors using other tests too. PEST, STEEP, and STEEPLE are similar analyses. Some other variations are STEPJE, STEP, and LEPEST.
- Managers can choose any based on the nature of the firm and the factors they wish to study.

Political Factors

- The political factors account for all the political activities that go on within a country and if any external force might tip the scales in a certain way.

  - *Trading policies*
  - *Government changes*
  - *Funding*
  - *Foreign pressures*
  - *Conflicts in the political area*
  - *Shareholder and their demands*

Economic Factors

- The economic factors take into view the economic condition prevalent in the country and if the global economic scenarios might make it shift or not.

  - *Disposable income*
  - *Unemployment level*
  - *Foreign Exchange rates*
  - *Interest rates*
  - *Trade tariffs*
  - *Inflation rate*

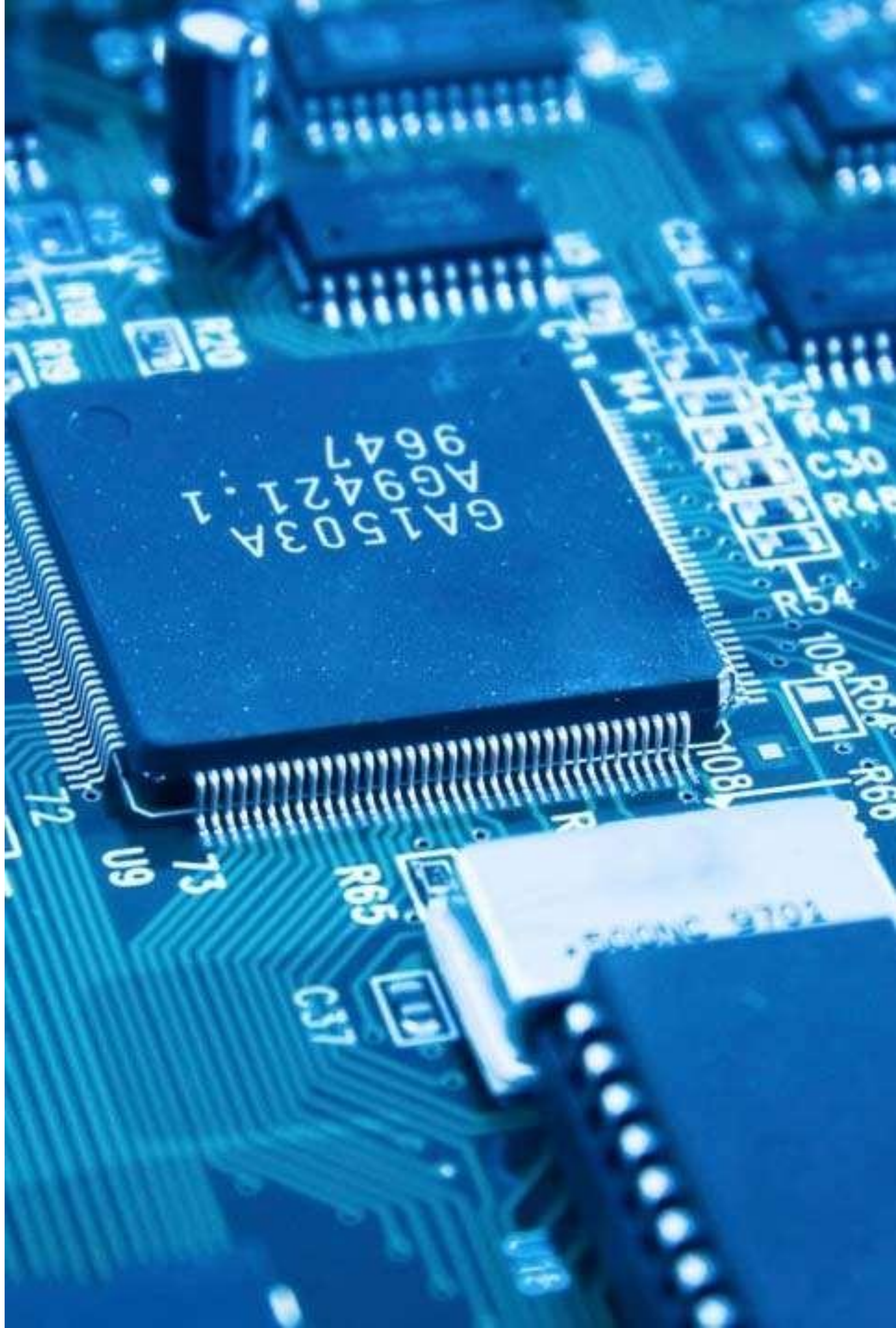
Social Factors

- Social factors are your consumers. You need to look at buying habits, emotional needs, and consumer behaviour in this section. Because these are the people who directly influence your sales.

  - *Ethnic/religious factors*
  - *Major world events*
  - *Demographics*
  - *Consumer opinions and attitudes*
  - *Trends*
  - *Education*
  - *Brand preferences*

Technological Factors

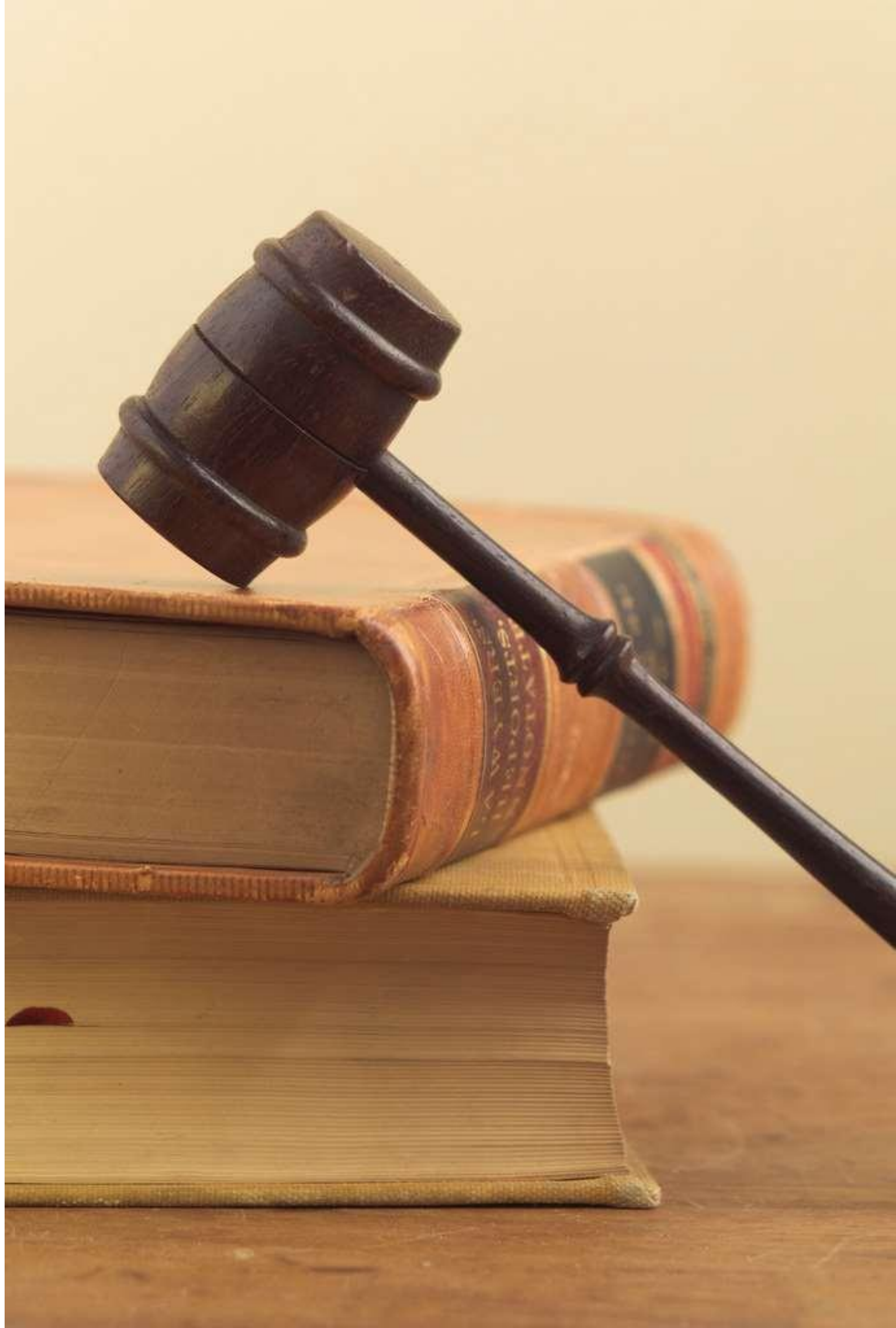
- Technology can be directly involved with company products, like manufacturing technologies.
  - *Technological development*
  - *Research and development*
  - *Associated Technologies*
  - *Patents*
  - *Licensing*
  - *Information technology*
  - *Communication*



Legal Factors

- Legal factors have to do with all the legislative and procedural components in an economy. Also, this takes into account certain standards that your business might have to meet in order to start production/promotion.

    - *Employment law*
    - *Consumer protection*
    - *Industry-spesific regulations*
    - *Competitive regulations*
    - *Future legislation*
    - *Environmental regulations*



Environmental Factors

- Environmental factors have to do with geographical locations and other related environmental factors that may influence upon the nature of the trade you're in. For example, agri-businesses hugely depend on this form of analysis.

  - *Ecological*
  - *Environmental issues*
  - *Staff attitudes*
  - *Management style*
  - *Environmental regulations*
  - *Consumer values*

Regression Analysis

Regression analysis is a mathematical measure of the averages relationship between two or more variable in terms of the original units of data.

Types of Regression

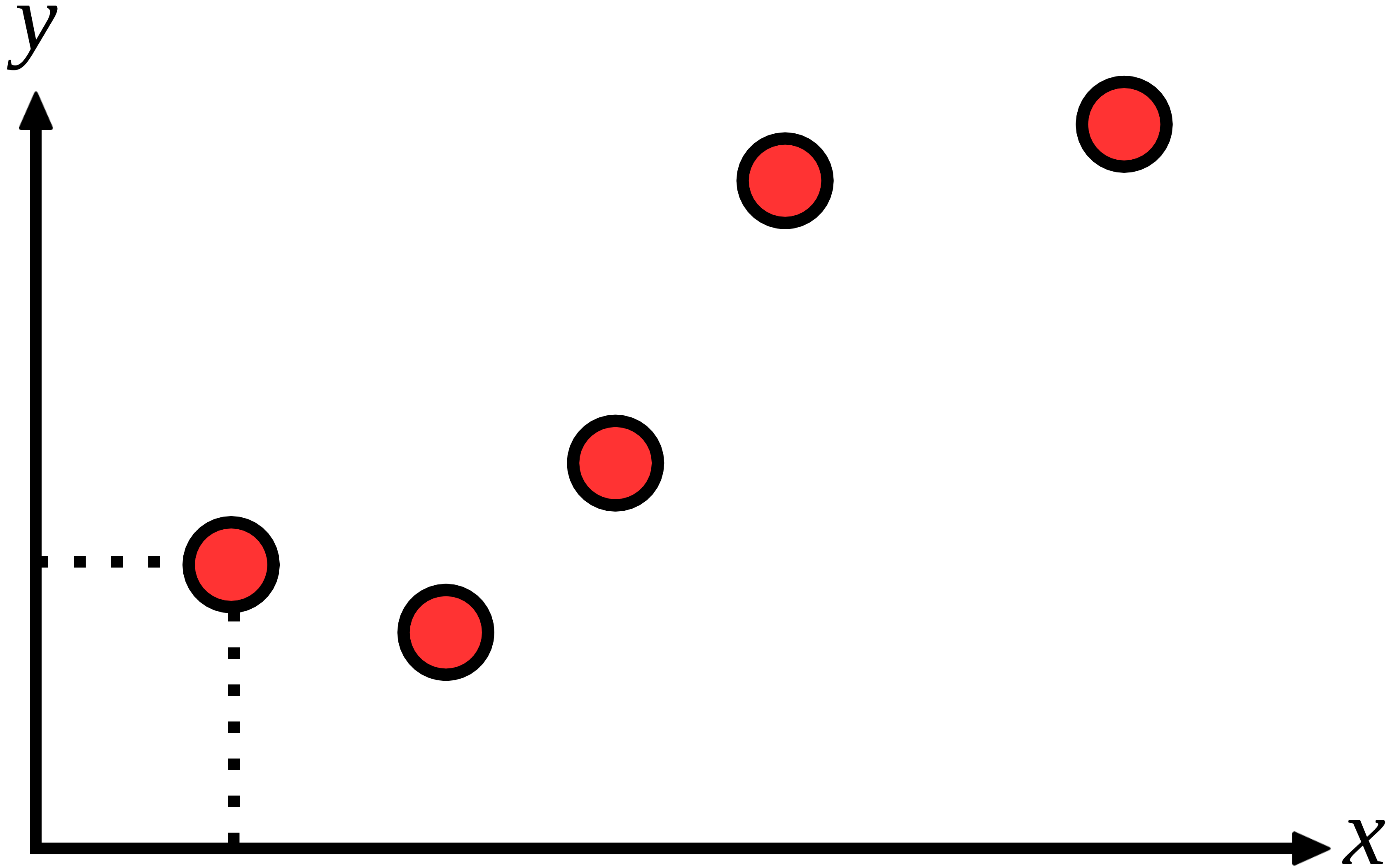
(i) Simple Regression (Two Variable at a time)

(ii) Multiple Regression (More than two variable at a time)

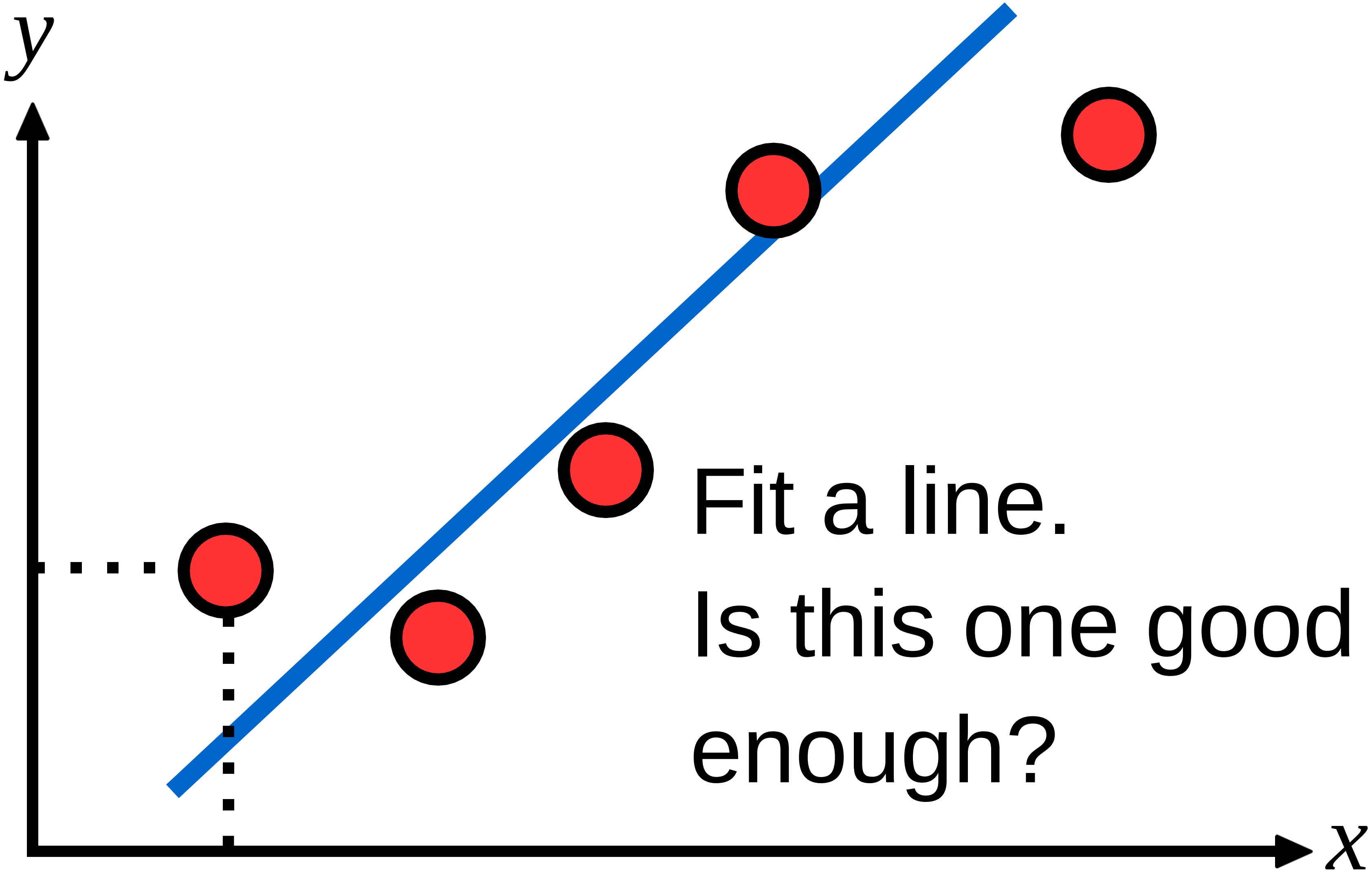
Linear Regression: If the regression curve is a straight line then there is a linear regression between the variables .

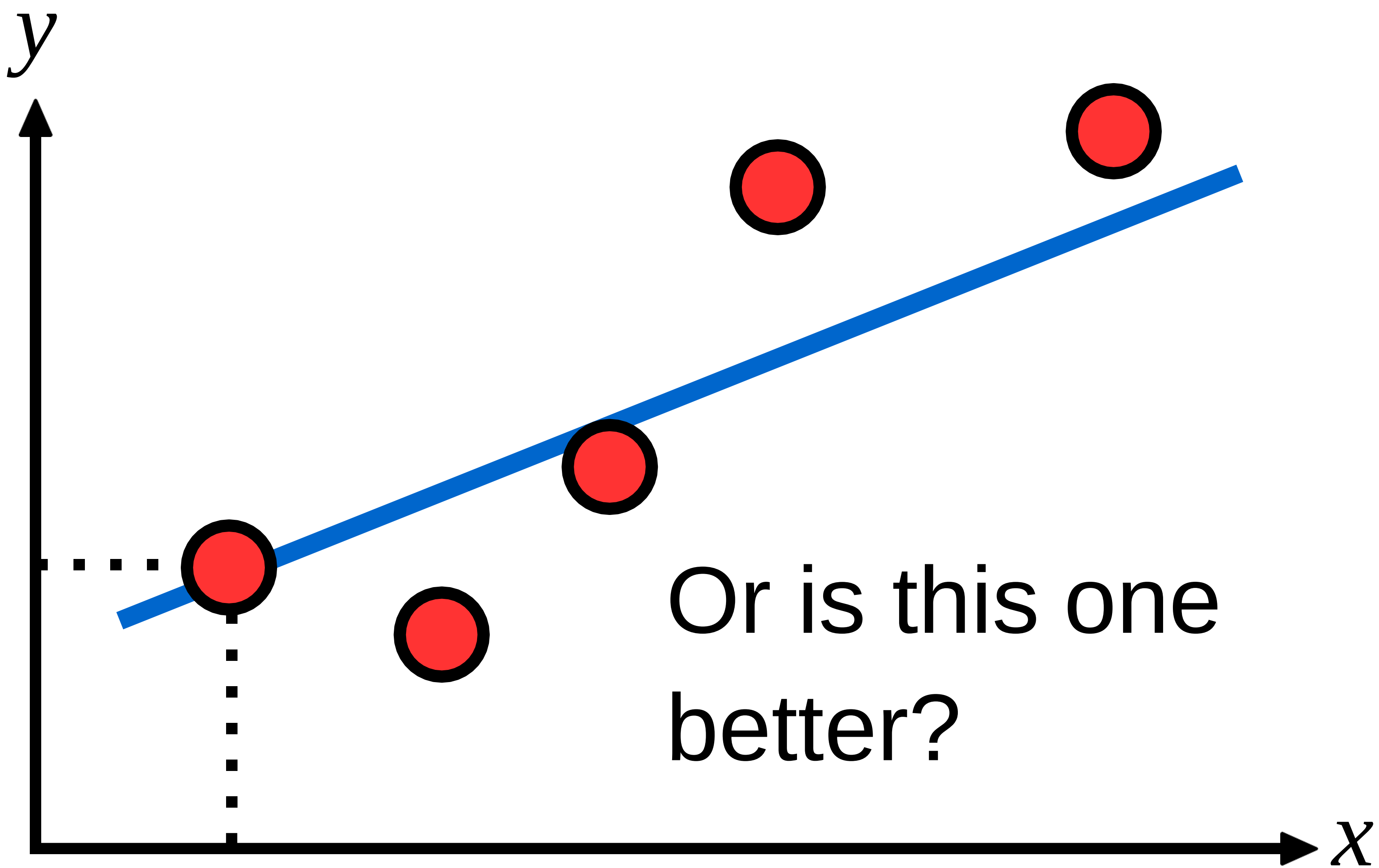
Non-linear Regression/ Curvilinear Regression: If the regression curve is not a straight line then there is a non-linear regression between the variables.

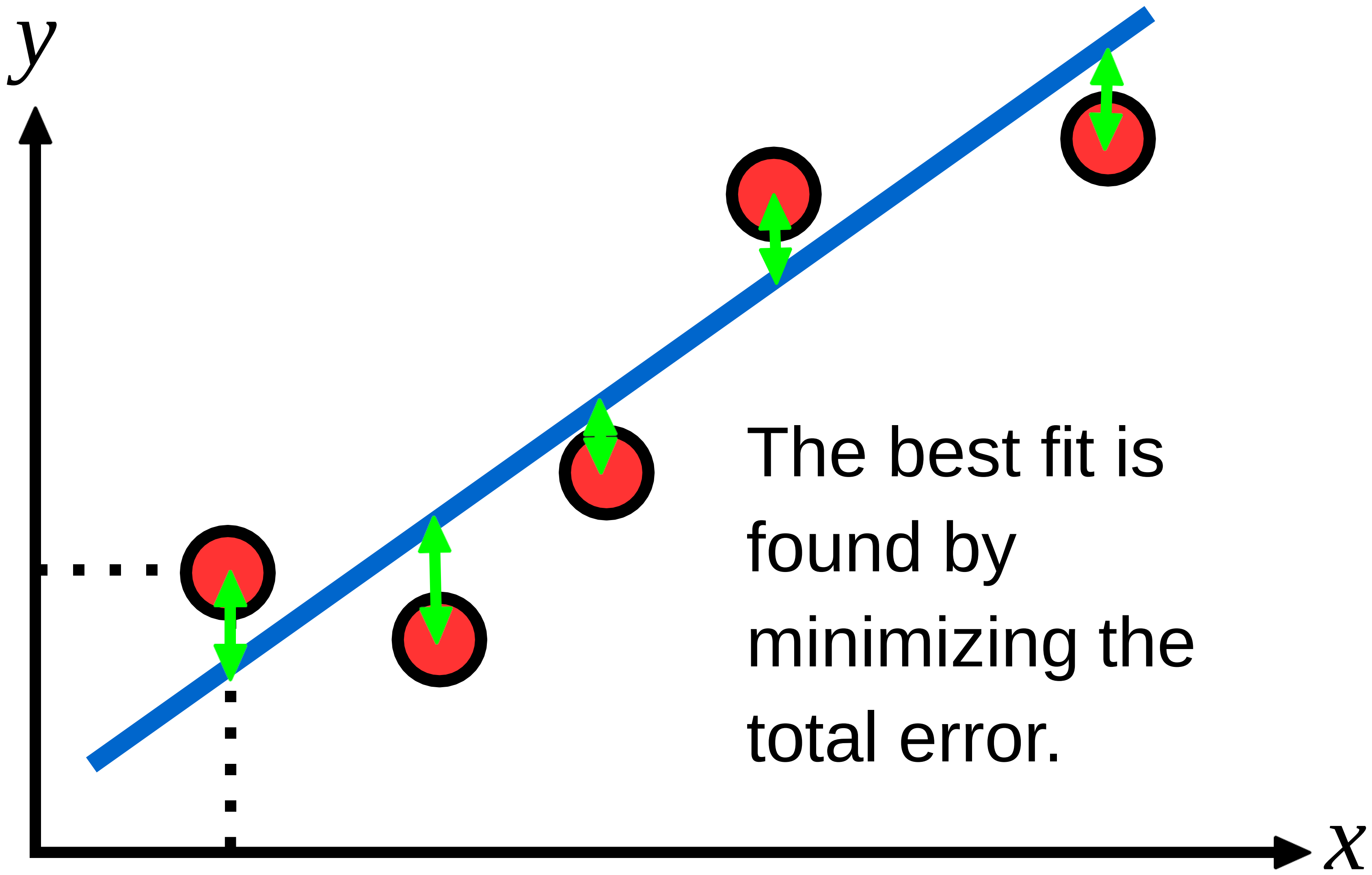
Simple Linear Regression

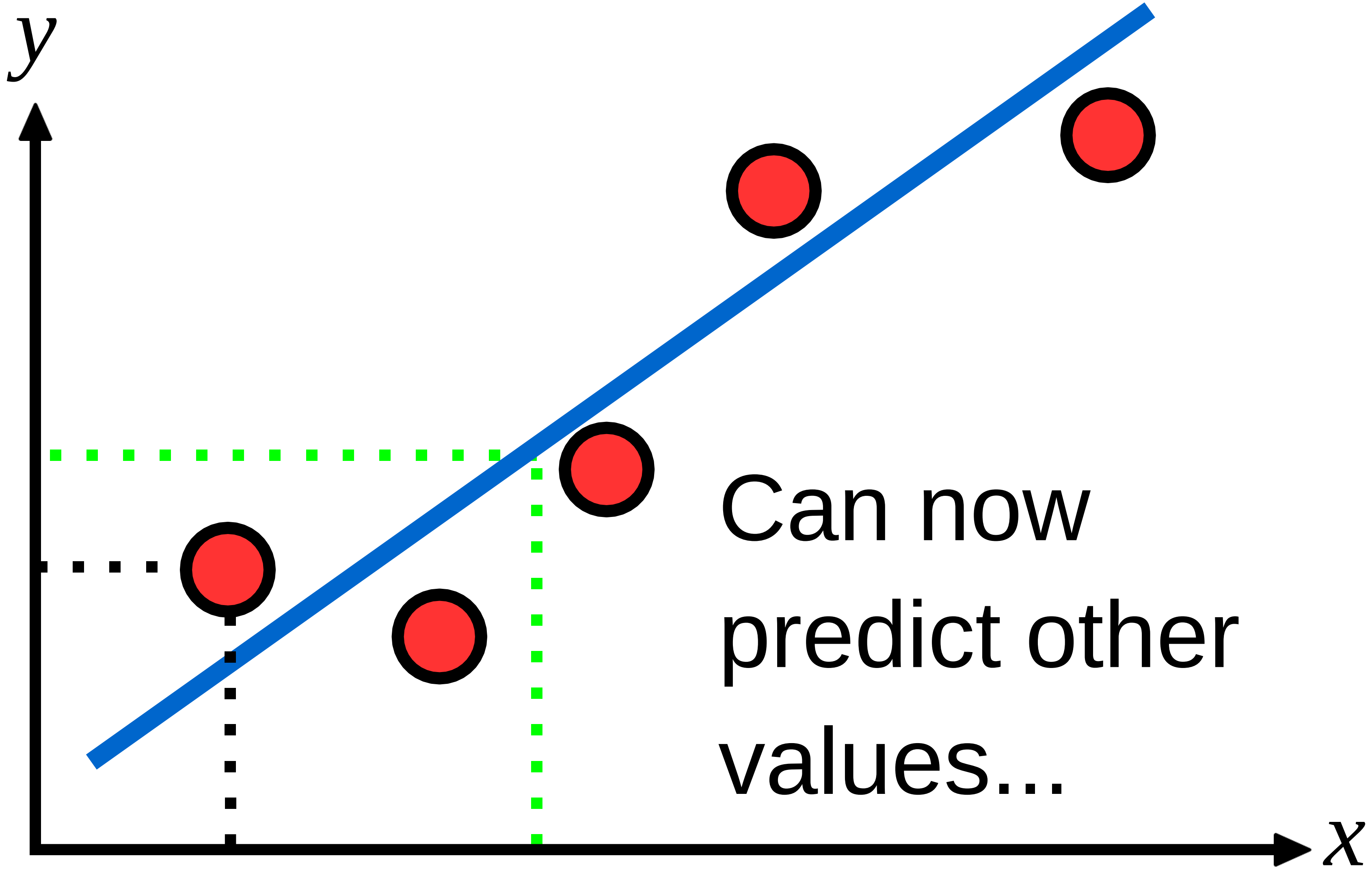

y
x

3

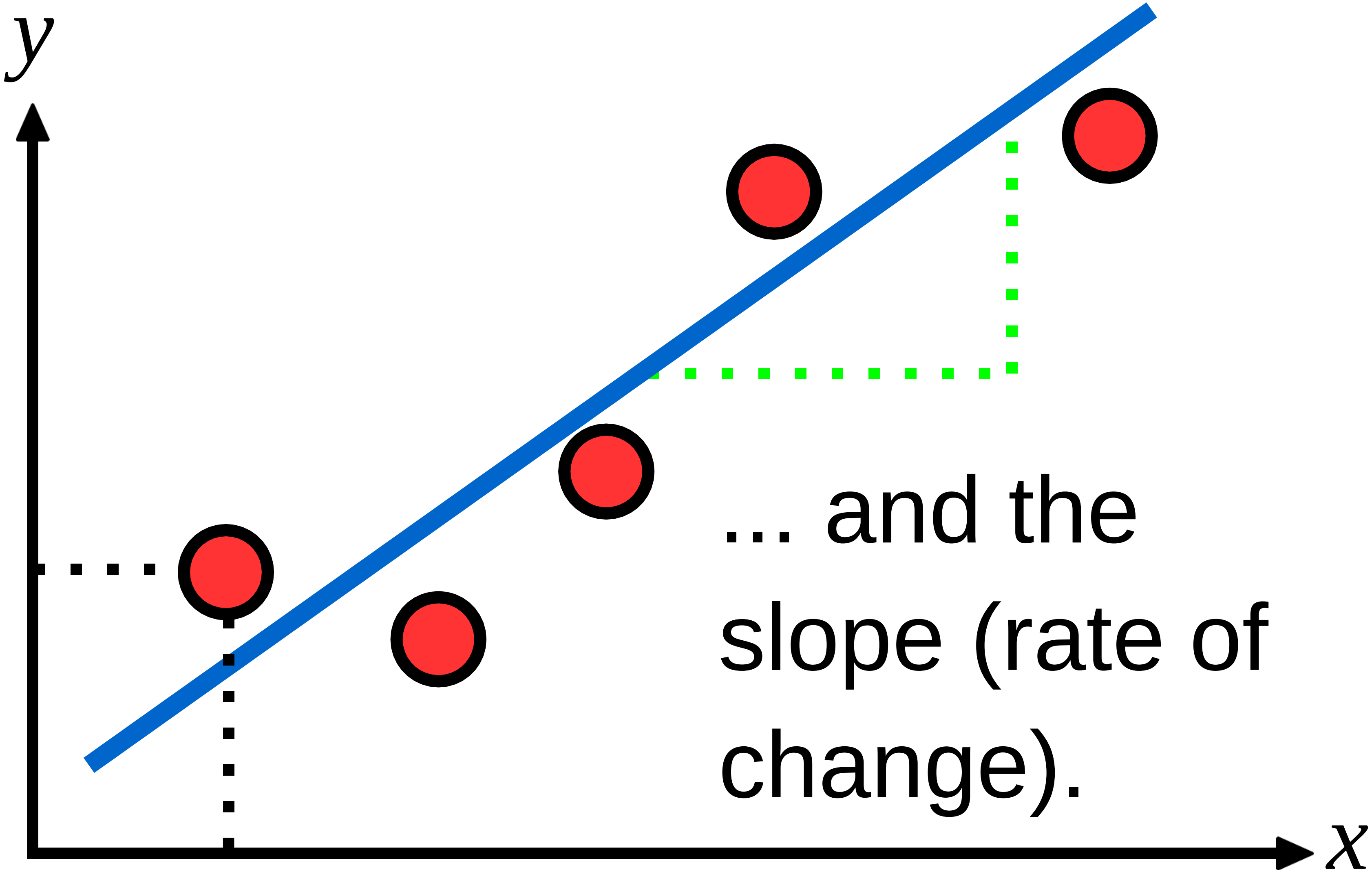


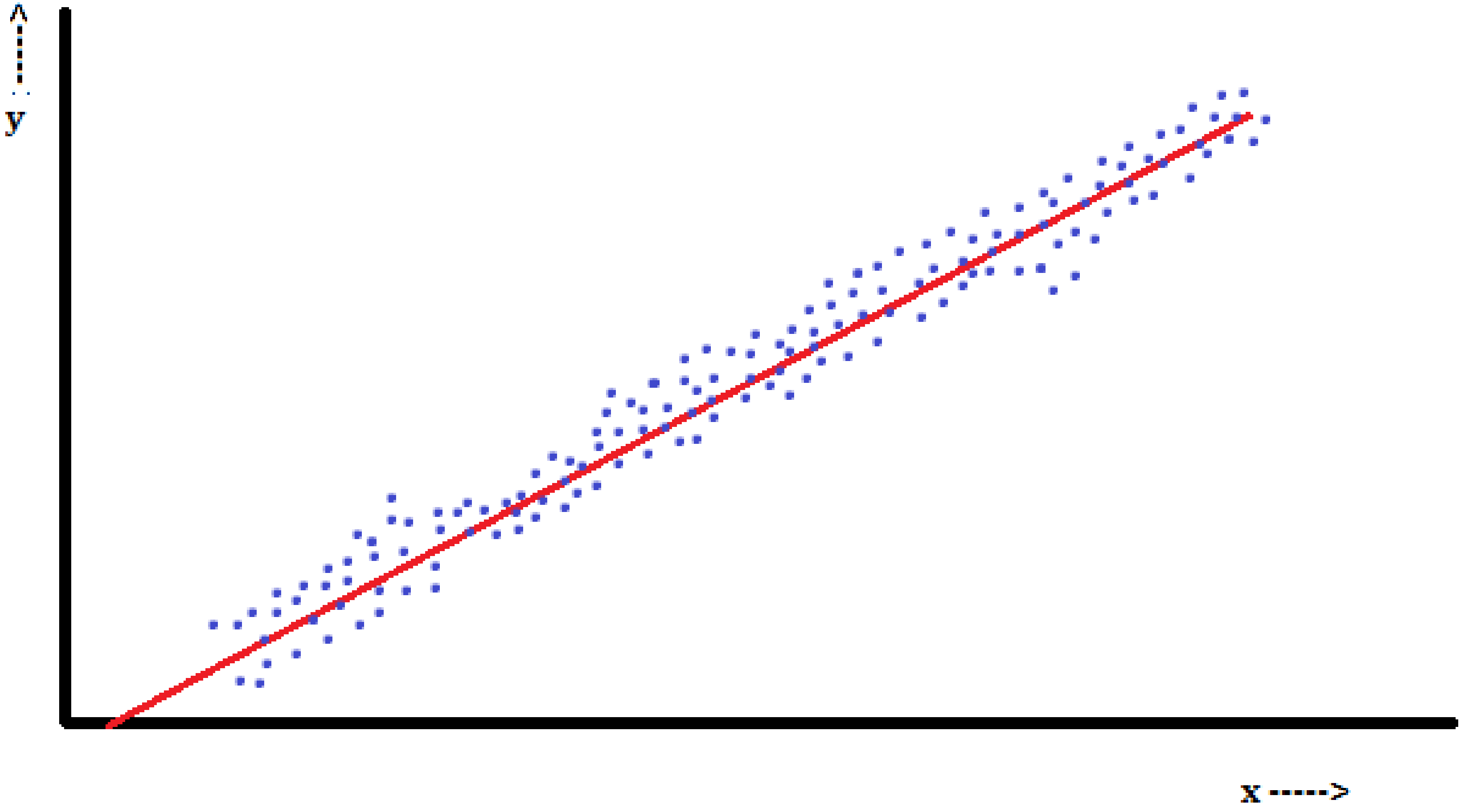

y
x
Or is this one
better?


y
x
The best fit is found by minimizing the total error.



Can now predict other values...


y
... and the slope (rate of change).
x



y
x ------>

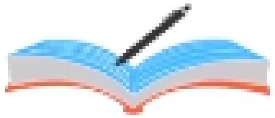
Linear Regression Model

- The regression model is y = b0 + b1x + S, where
- y = output variable, also known as dependent variable
- b0 = constant or coefficient of constant. Graphically, this is the y-intercept or the value of y when x = 0
- b1 = coefficient of x i.e. the slope or rate of change of y for a unit change of x
- x = input variable. X, along with the constant is also known as predictor since they are used to predict the value of y. It is also called the independent variable.
- S = error or residual value. I.e. it is the difference between the actual value of y and the value of y predicted by the regression model.

Regression analysis is used in several situations, such as those described below:

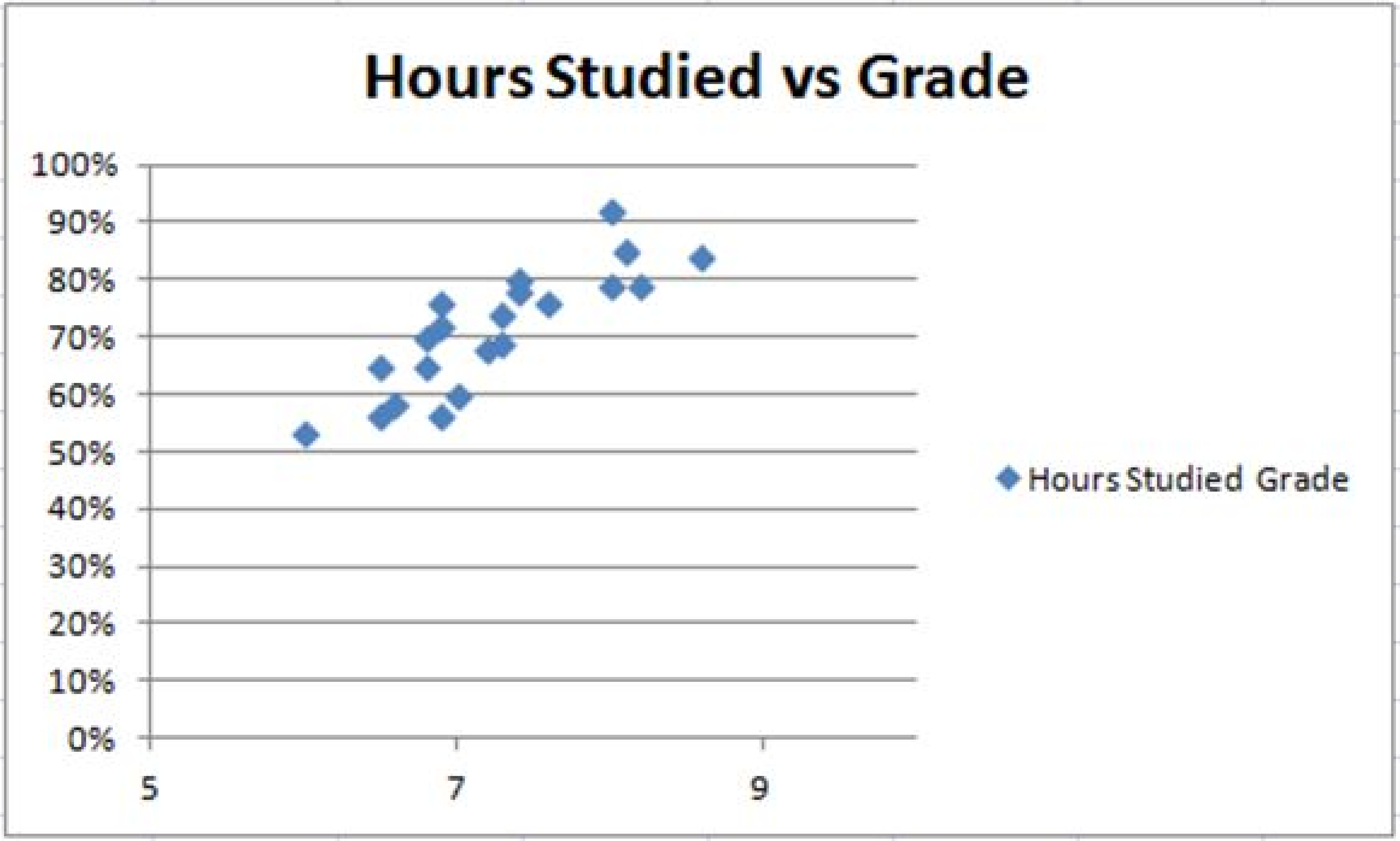
Example 1:
Using the data given below, analyze the relation between the size of a house and its selling price for a real state agent.

Size in Sq. Ft.	Price in $
1400	24500
1600	31200
1700	27800



Example 2:
With the help of the data given below, predict the exam scores of students who study for 7.2 hours.

Hours of Studies	Exam Score
6	53
8	79
7.3	69
7.4	80


Hours Studied vs Grade
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
5
7
9
Hours Studied Grade

You could use regression analysis to predict:

- How supply delivery frequency impacts product assembly time
- How the productivity of one work crew differs from that of another
- The amount of product sales based on time of year
- Future profits based on level of expenses (including investment in research and development and paying talented employees)

THE 5 WHYS

Repeating WHY 5 times…By asking WHY 5 times and answering it each time, we can get to the real cause of the problem, which is often hidden behind more obvious symptoms.

THE 5 WHYS

WHY #1

CAUSE #1

WHY #2

CAUSE #2

WHY #3

CAUSE #3

WHY #4

CAUSE #4

WHY #5

CAUSE #5

WHY #6

CAUSE #6

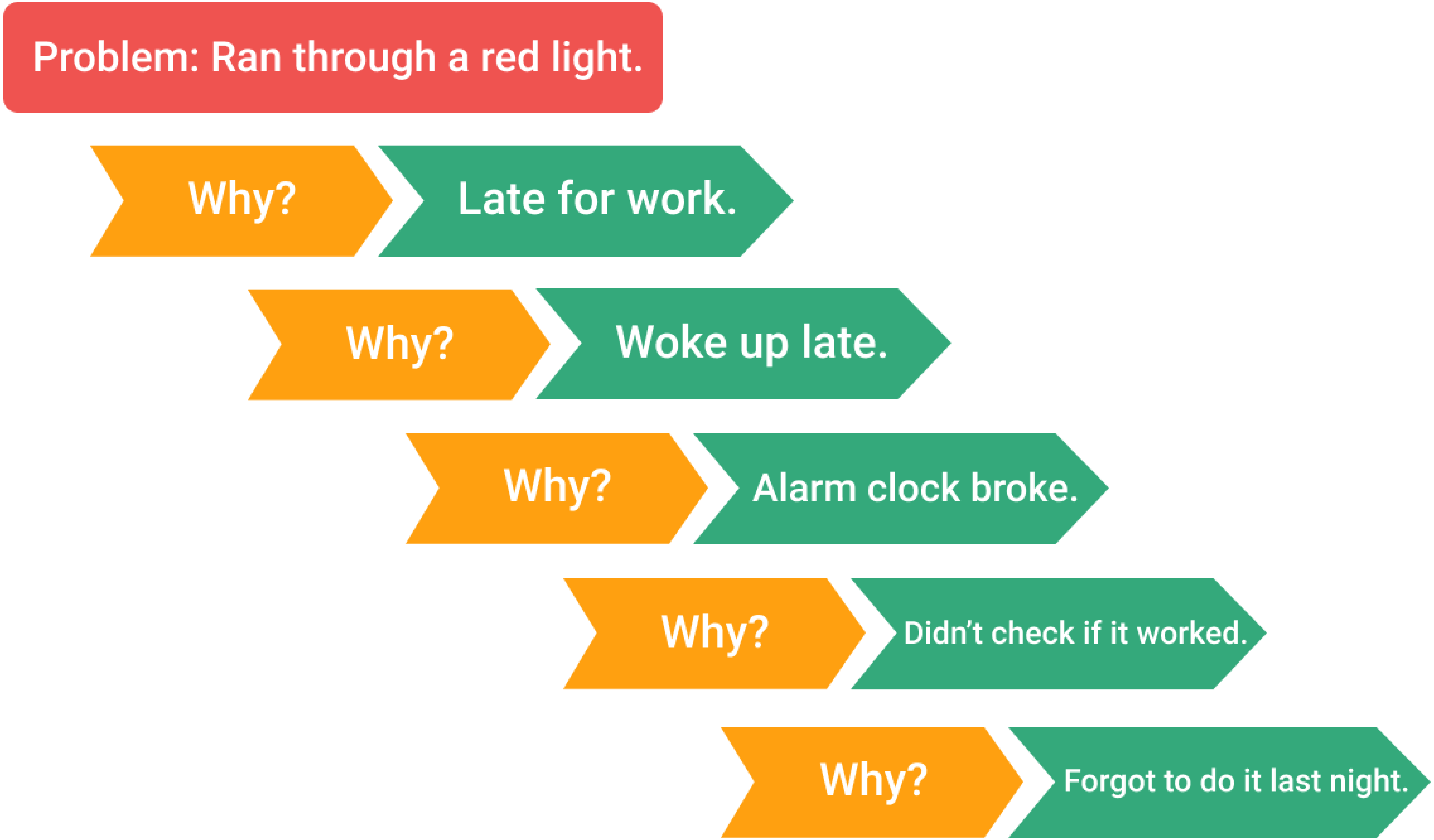
Information is used for Improvement, Not Judgment

WHY #7

Information is used for Improvement, Not Judgment

5 Whys

The 5 Whys is a simple analysis technique that moves past symptoms by asking "why" until reaching the true root cause of an issue.

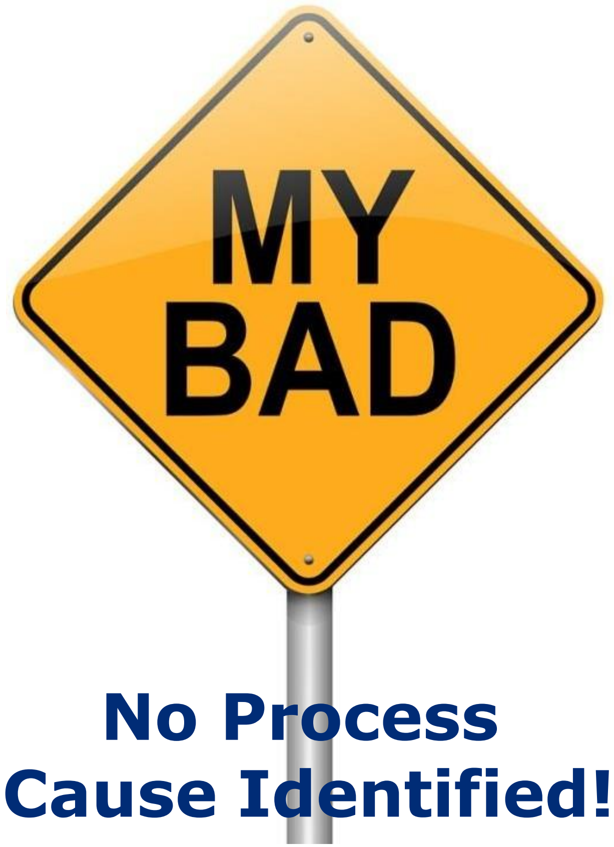

Problem: Ran through a red light.
Why?
Late for work.
Why?
Woke up late.
Why?
Alarm clock broke.
Why?
Didn’t check if it worked.
Why?
Forgot to do it last night.


5 REASONS TO USE 5 WHYS
?
IDENTIFY THE CAUSE, NOT JUST THE SYMPTOMS
Dig deep and find the underlying issues that led to the problem rather than using a quick-fix solution or playing the blame game.
PERFORM AN EVIDENCE-BASED ANALYSIS
Don't assume or jump to conclusions about the source of the problem - make sure you have proof that it's the cause, every step of the way.
ELIMINATE ISSUES IN YOUR SYSTEM FOR GOOD
Be proactive rather than reactive. When issues arise, prevent their reoccurrence to save time and increase the quality of your system.
SEEK IMPROVEMENTS AND WELCOME CHANGE
Encourage your stakeholders to constantly seek ways to improve and adapt your process to ensure its long-term success.
BUILD A CULTURE THAT EMBRACES PROGRESS
Encourage your team to raise issues and concerns without fear or judgement, and to seek long-term solutions rather than the easy way out.

You can be taken for a loop if you don't find the process

Problem: Sales are down

- Because we are not processing enough leads
- Because we don't have enough sales people
- Because we laid off sales people
- Because we had to cut costs
- Because sales are down



No Process Cause Identified!

Benefits

- Change the culture to one of action
  - Get into the rhythm of change
  - Easy small changes lead to bigger harder changes
  - Staff engagement goes up
    - People see real action from customer feedback
- Costs come down
  - Less re-work
  - Fewer resources required
- Improve your customer experiences
  - Customers are happier
  - Net Promoter / Customer Loyalty goes up
  - Profit goes up

Interrelationship Diagram

- An **Interrelationship Diagram** shows graphically the cause-and-effect relationships that exist among a group of items, issues, problems, or opportunities.
- It is particularly useful in helping to identify the potential causal relationships that might lie behind a problem that continues to recur despite attempts to resolve it.
- The basic idea is to count the number of “in” and “out” arrows to and from a particular issue and to use these counts to assist you in prioritizing the issues.

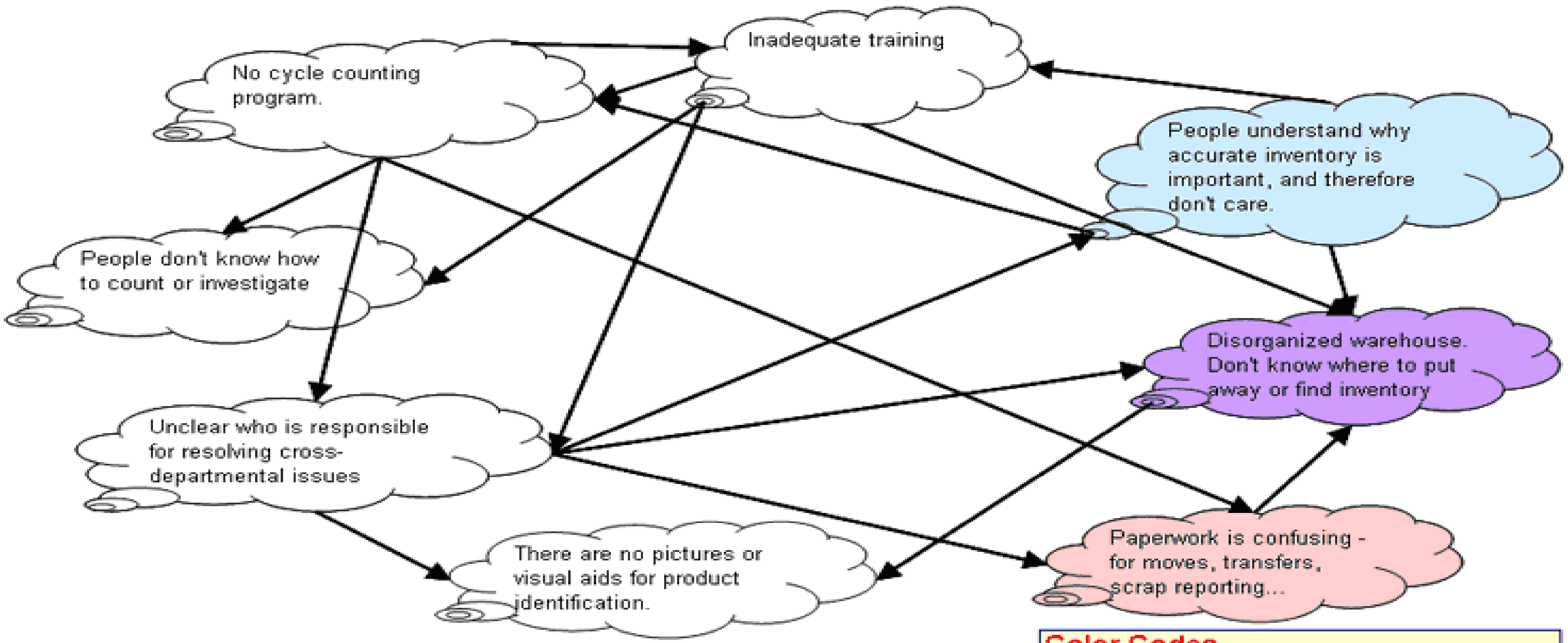
Why is the school drop-off area so congested?

Systems2win
Continuously improving tools for continuous improvement

Relations Diagram

Sample Problem: Inaccurate Inventory

Revised: <date> Author: <name>



Color Codes

You can optionally use different background colors for different types of problems.

Use a text box to provide a Legend of what your colors mean.

Comments Text Box

Comments can be printed or internal - by simply re-setting the Print Area.

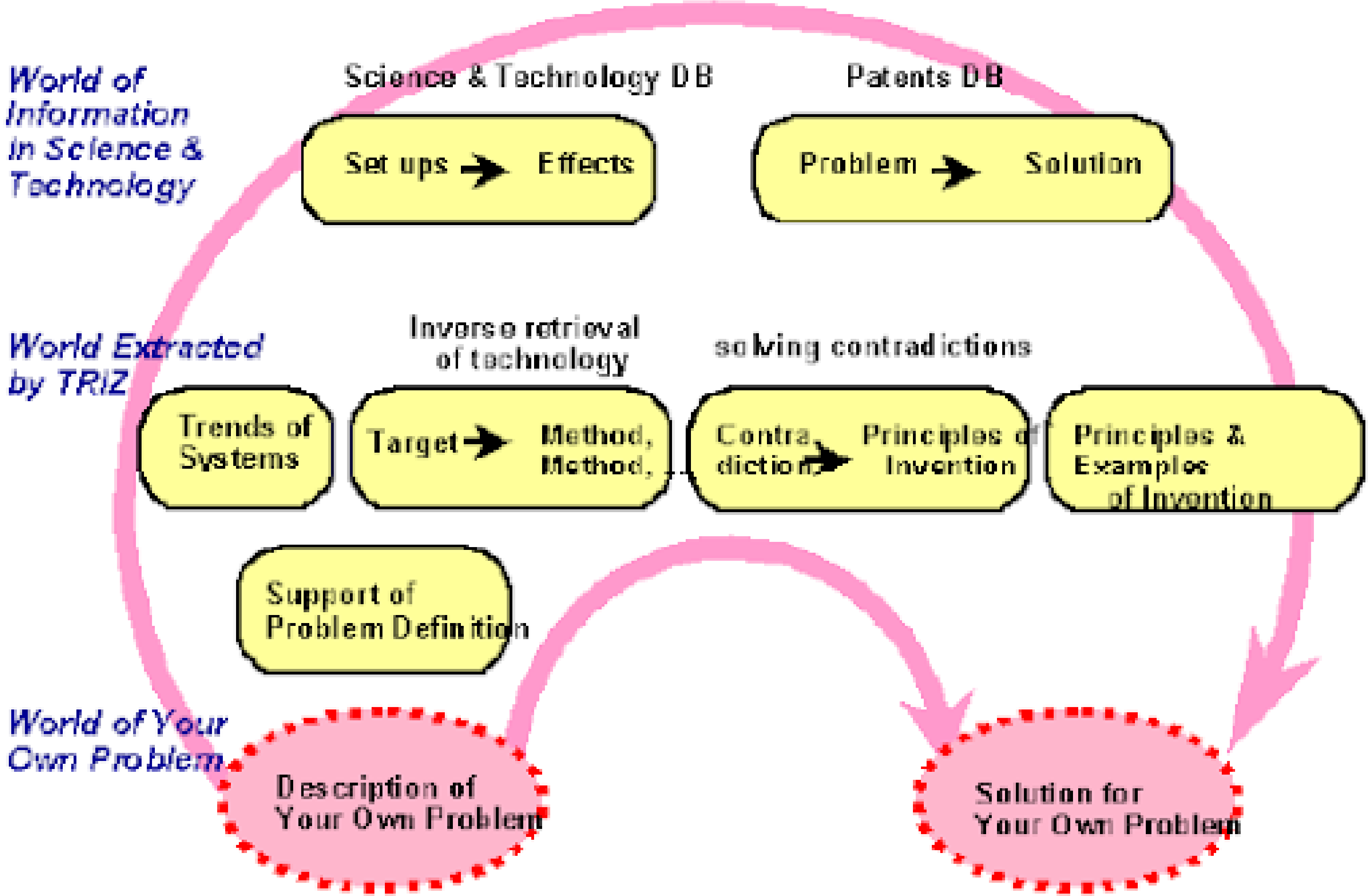
Or add another Comments textbox, and have both printed and internal comments!

PPT

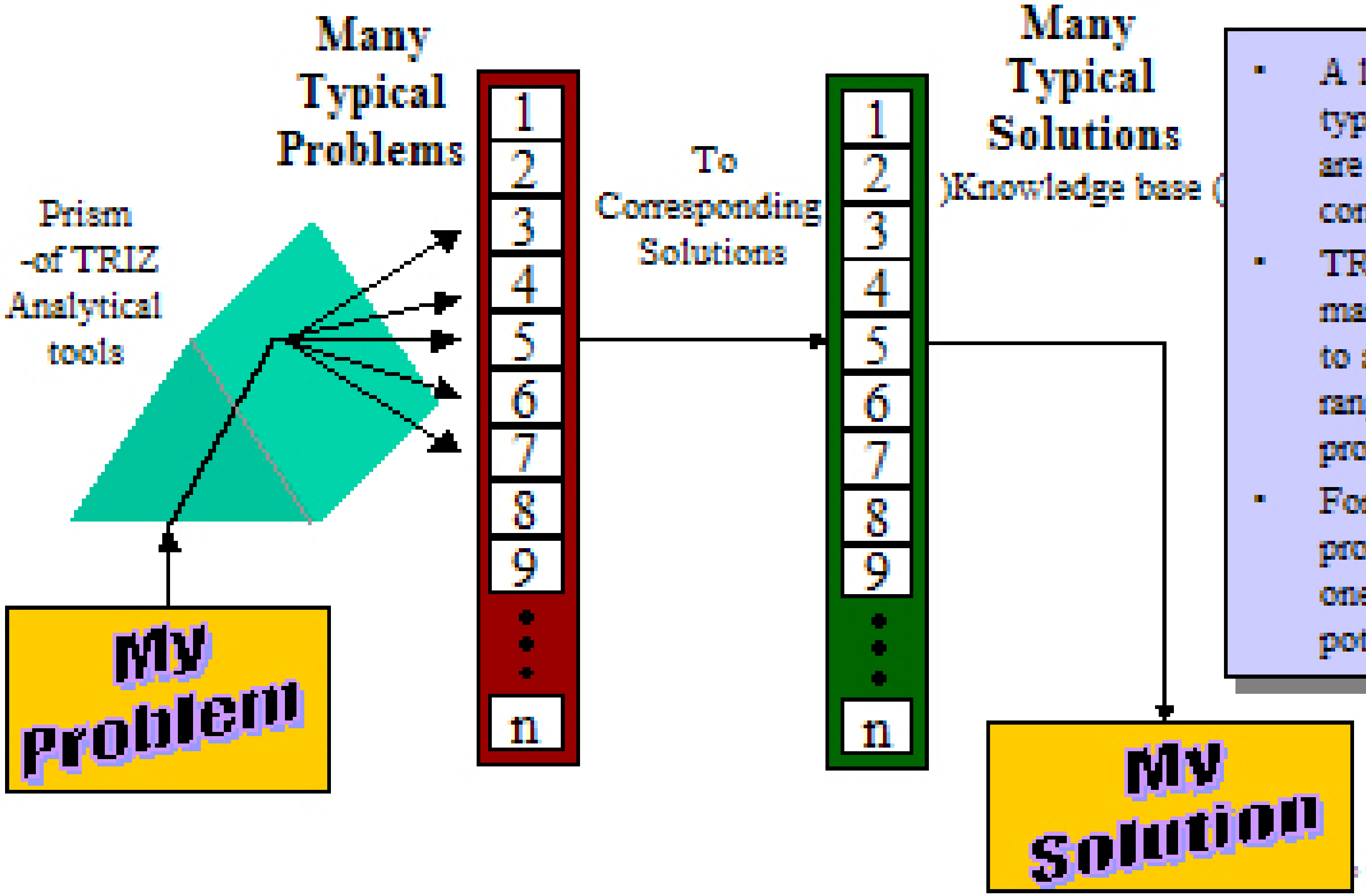
TRIZ

- TRIZ is the Russian acronym for the "Theory of Inventive Problem Solving," developed in the mid-1940s. Of the dozens of TRIZ tools and ideas, a few of the basic ones are particularly useful with Six Sigma: in DMAIC (Define, Measure, Analyze, Improve, Control) and DMADV (Define, Measure, Analyze, Design, Verify).

TRIZ Methodology for Problem Solving



How Ideation/TRIZ Works



- A large number of typical problems are available for consideration
- TRIZ helps to narrow the search to a manageable range of typical problems
- For each typical problem, there are one or more potential solutions

Single Minute Exchange of Dies(SMED)

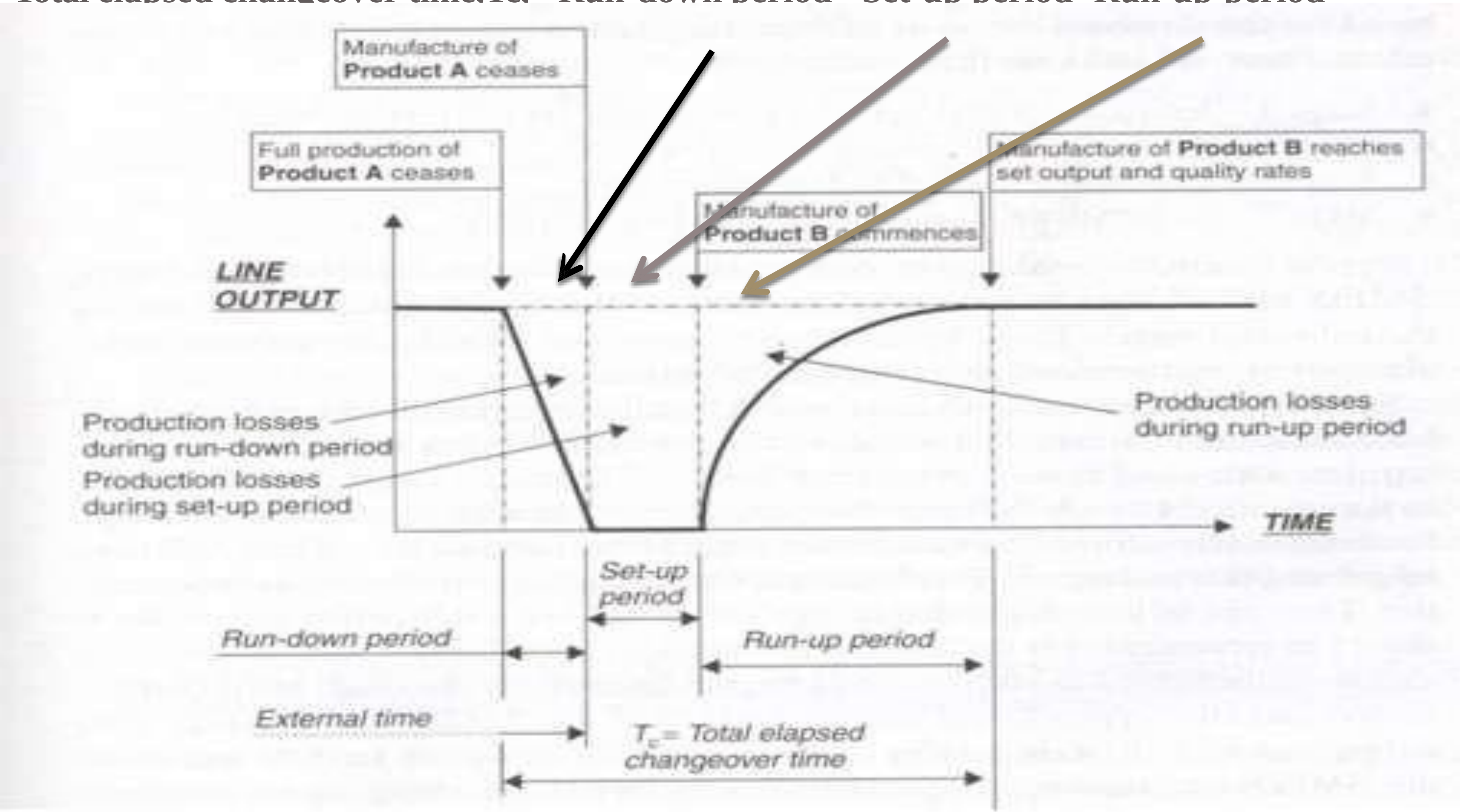
History

The concept arose in the late 1950s and early 1960s, when Shigeo Shingo, was consulting to a variety of companies including Toyota, and was contemplating their inability to eliminate bottlenecks at car body- moulding presses.

Development of SMED by Shigeo Shingo

- **1950**-Forms first stage of SMED : Involves splitting a setup operation into internal and external set ups
- **1956-58**—Worked for Mitsubishi Shipbuildings
  - Invents a new system for hull assembly of 65,000 ton super-tanker
  - Cut time from four months down to three and than two months
- 1970-Originated SMED system at Toyota
- Wrote more than 14 books
  - Including Toyota Production System

Total elapsed changeover time,Tc, =Run-down period +Set-up period+Run-up period



Line Output during Changeover

“SMED = Exchange dies in less than 10 minutes”

SMED Single Minute Exchange of Dies

Single Minute Exchange of Dies is a philosophy where the target is to reduce all setups to less than ten minutes.

SMED helps achieve lower costs, greater flexibility, and higher throughput.

It is one of the key factors allowing JIT to be successful.

Single Minute Means: necessary setup time is counted on a single digit.

SMED Single Minute Exchange of Dies

The analysis and implementing of equipment and process changes to reduce the setup and changeover time of changing tools in and out of machines.

Die exchange is the generic term for removing a drill, cutter, punch, mold or die from a machine & replacing it with another type on machines that are capable of producing more than one part.

SMED Single Minute Exchange of Dies

Intended to reduce lot sizes as larger the lot the more inventory must be purchased and stored, lost, damaged or made obsolete, more space required, more storage materials must be purchased and labor and handling cost increase.

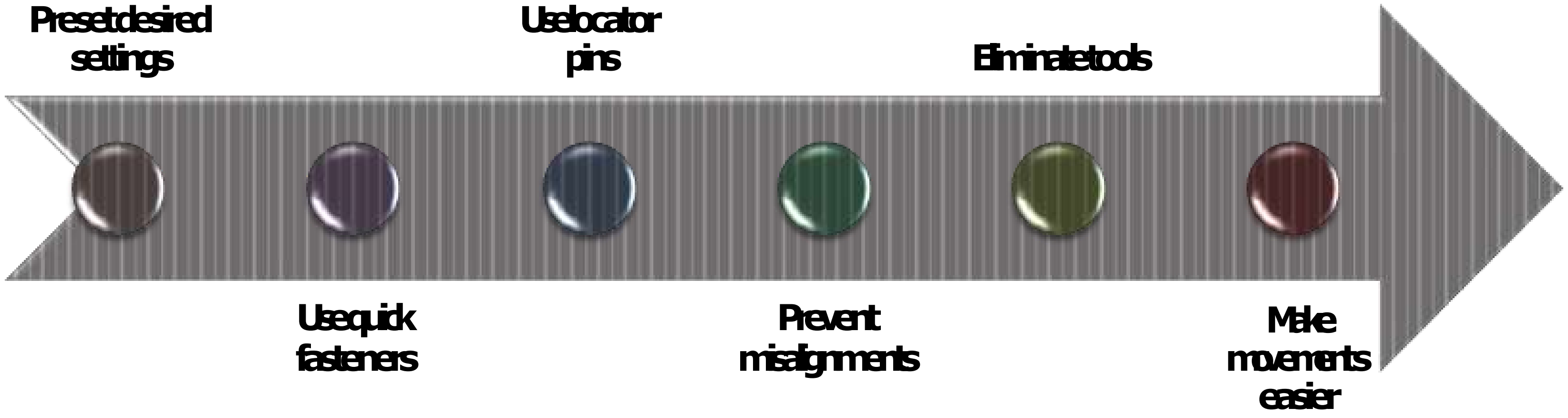
Broken down into internal and external actions and doing the external activities before the tool is actually changed.

Improvements are made using a three stage approach to time reduction.

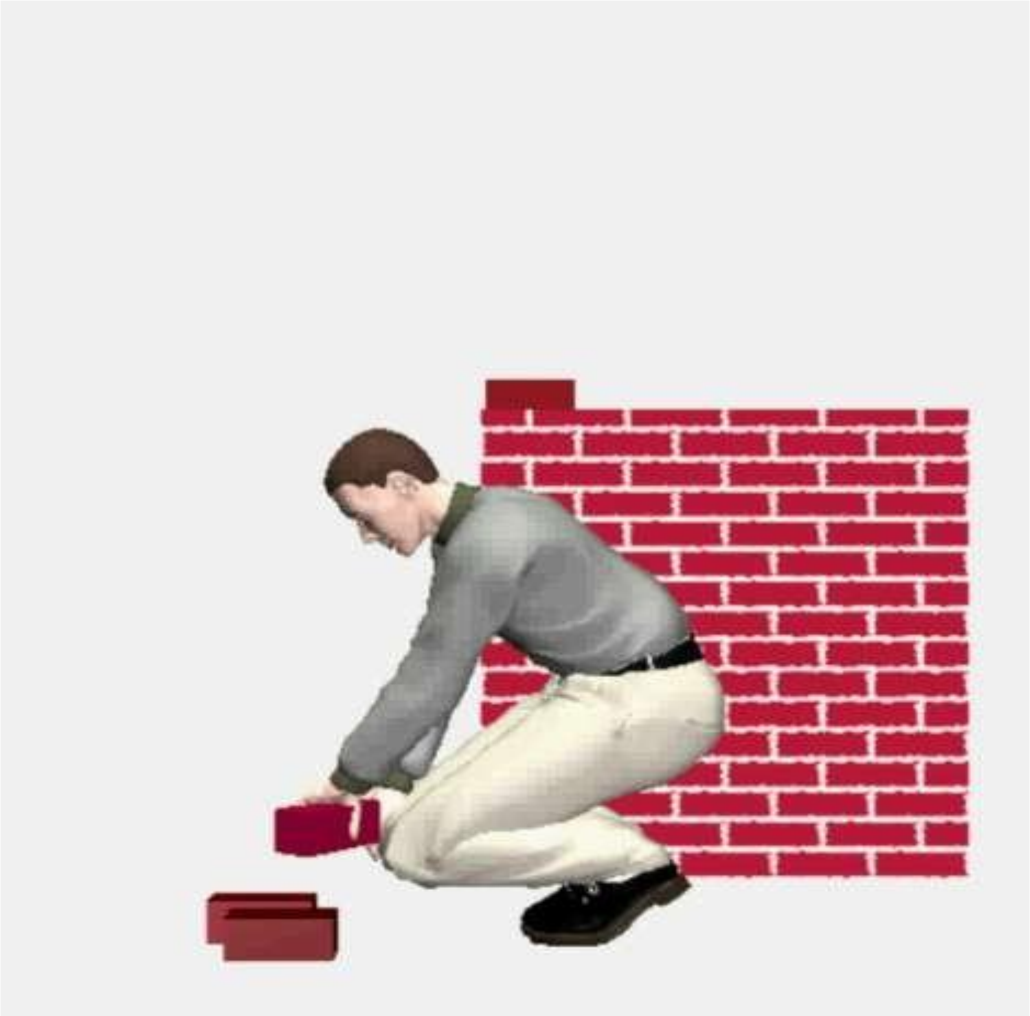
How to reduce Set-Up Cost ?

By reducing setup time → By reducing wastages → By reducing various costs

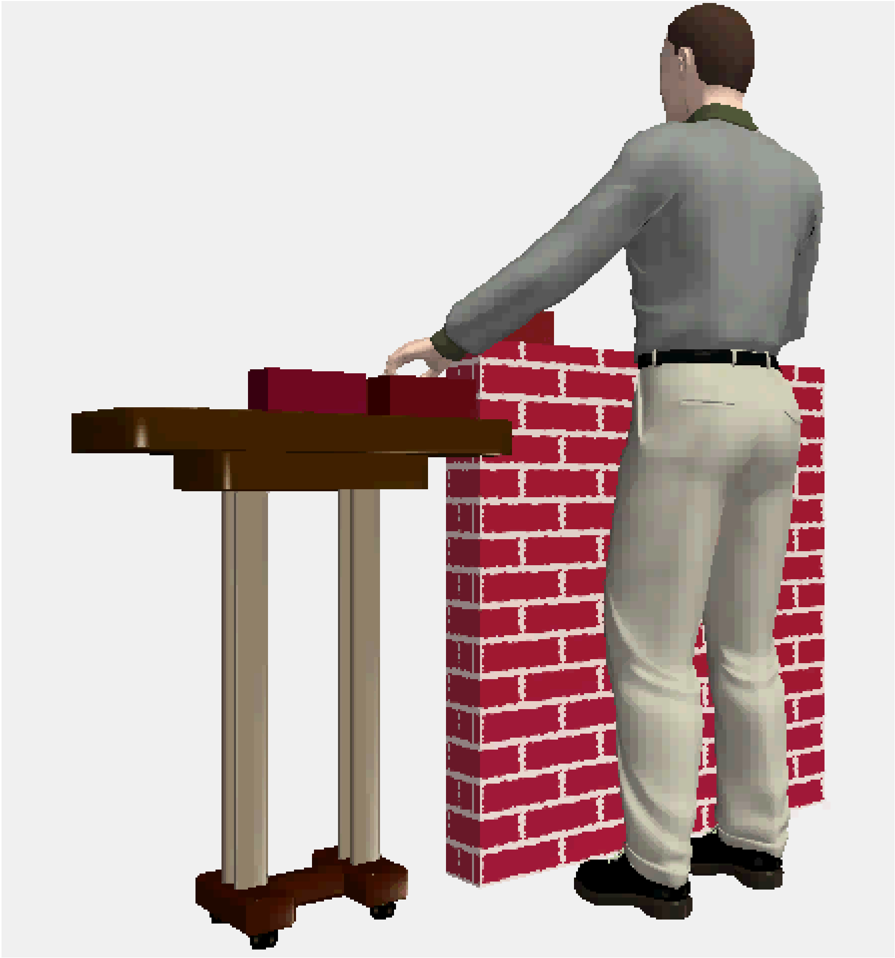
Reducing Set-Up Time



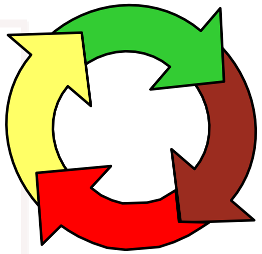
Reducing Set-Up Time



Reducing Set-up Time



SMED is Continuous Improvement



It is a customer driven requirement. Customers are demanding:

- **Product and service diversity**
- **Lower costs**
- **Higher reliability and quality.**

In essence organizations need to become leaner !

So organizations must:

- **Produce smaller lots, more frequently.**
- **Expand the scope and diversity of products and services.**
- **Reduce quality defects.**

Ultimately, SMED focuses on reducing changeover and set-up times, thus enabling organizations to:

Produce smaller lots of products and services more frequently !

Develop a broader scope of products and services !

Reduce quality defects towards zero !

Meet Customer's Expectations !

What Does Set-up/changeover reduction mean for any business?

Increased customer service levels and profits, Via Waste Elimination resulting in :

- Reduced Lead Times-Faster Delivery
- Zero Inventories-Reduced Working Capital
- Improved Quality
- Improved Safety
- Smaller lots of products-flexibility
- Diversified Product & Service Options

Why SMED ?

To eliminate the wastes that result from “uncontrolled” processes increasing inventories and lead times

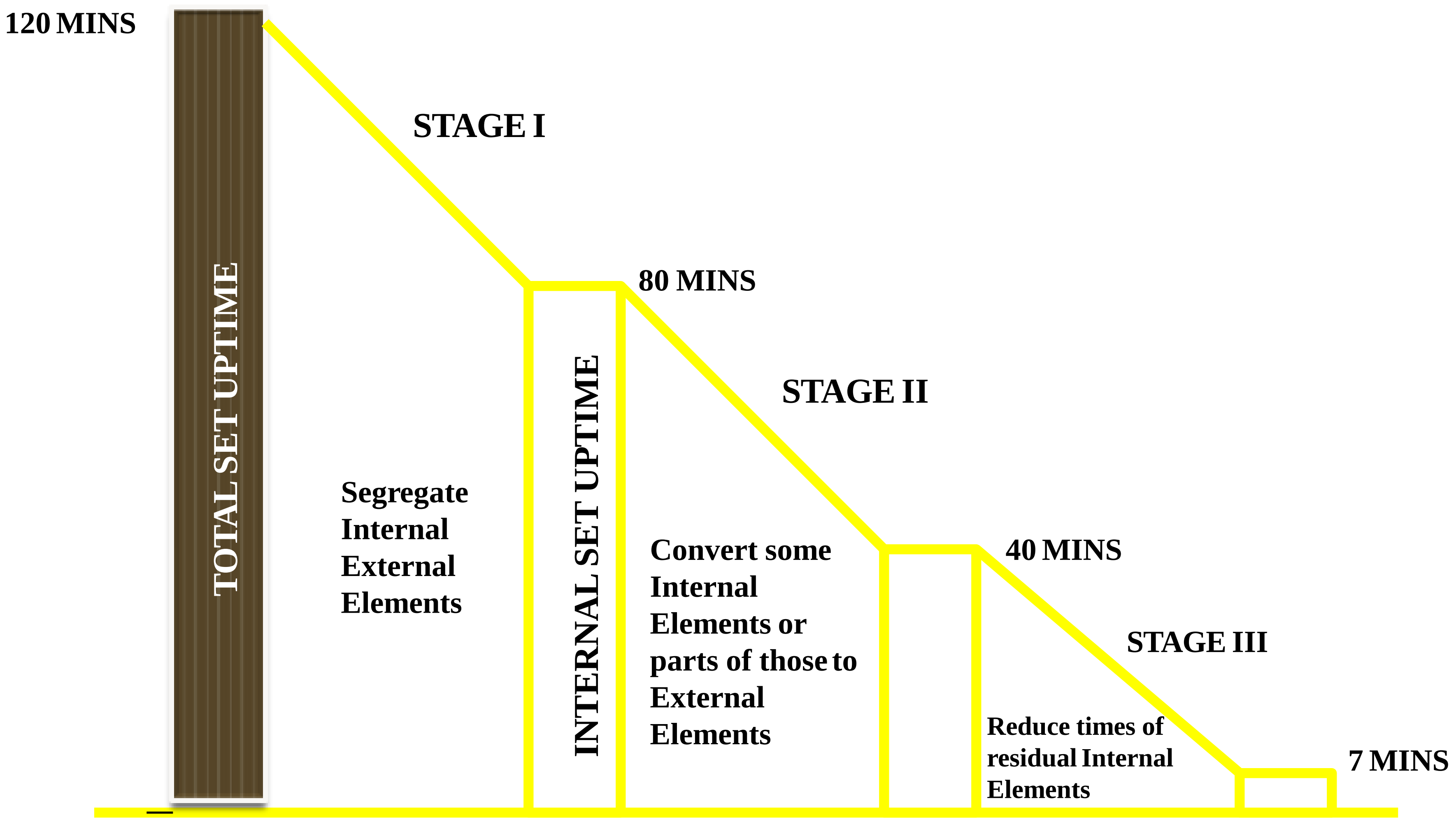
To gain control on equipment, material & inventory.

Apply Control Techniques to Eliminate Erosion of Improvements.

Standardize Improvements for Maintenance of

Critical Set-up Parameters.

Stages Of SMED



The SMED Process

Establish the current changeover time

↓

Identify all the current tasks being done

↓

Identify tasks that can be eliminated

↓

Distinguish between internal and external tasks

↓

Eliminate all unnecessary tasks

↓

Externalise all tasks that can be external

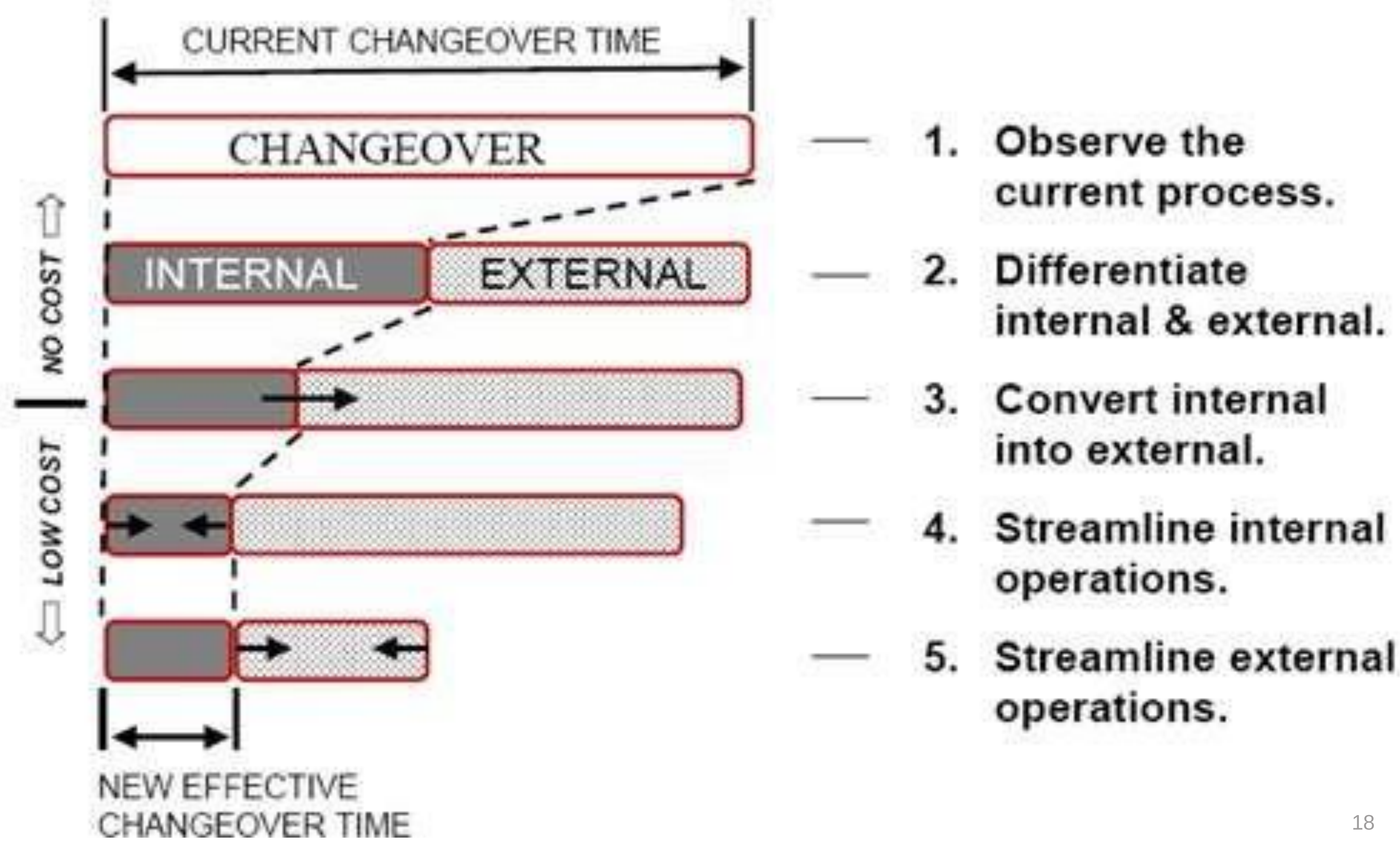
↓

Streamline all internal tasks

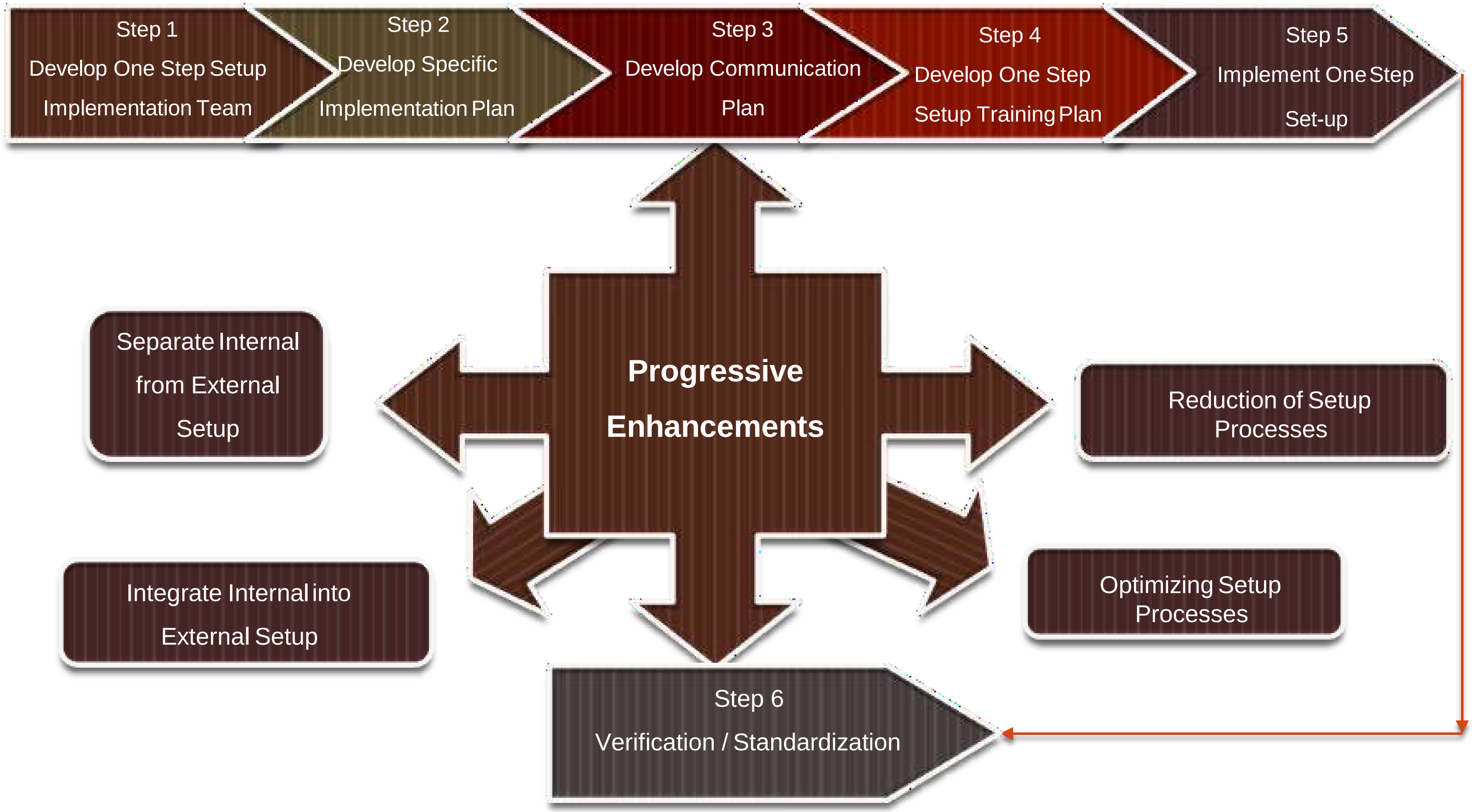
↓

Establish new changeover time

Five Steps to Quick Changeover



One Step Set-up Implementation Plan



Implementation Techniques

- Separate internal from external setup operations
- Convert internal to external setup
- Standardize function, not shape
- Use functional clamps or eliminate fasteners altogether
- Use intermediate jigs
- Adopt parallel operations
- Eliminate adjustments
- Mechanization

Mistake Proofing

Poka Yoke

Normal Group Technique

- This technique provides for issue/idea input from everyone on the team and for effective decisions.

Normal Group Technique (Cont.)

- **Procedure**
  - Generating Ideas: Each individual in the group generates ideas and writes them down.
  - Recording Ideas: Group members engage in a round-robin feedback session to concisely record each idea.
  - Discussing Ideas: Each recorded idea is then discussed to obtain clarification and evaluation.
  - Voting on Ideas: Individuals vote privately on the priority of ideas, and the group decision is made based on these ratings.

Normal Group Technique (Cont.)

- Example: what kind of final test should students have?
(Don't be serious, just for fun:)

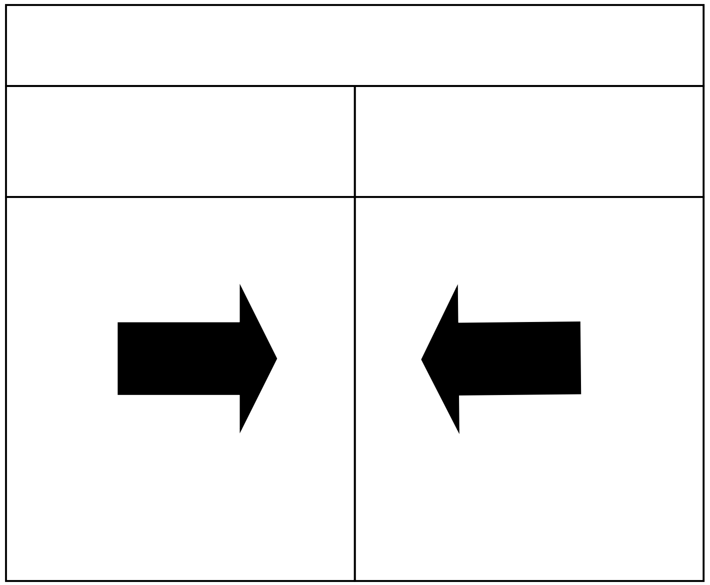
Suggestion	Voting	Decision

Forced Field Analysis

- This analysis is used to identify the forces and factors that may influence the problem or goal.
- It helps an organization to better understand driving and restraining forces so that the positives can be reinforced and the negatives can be reduced or eliminated.

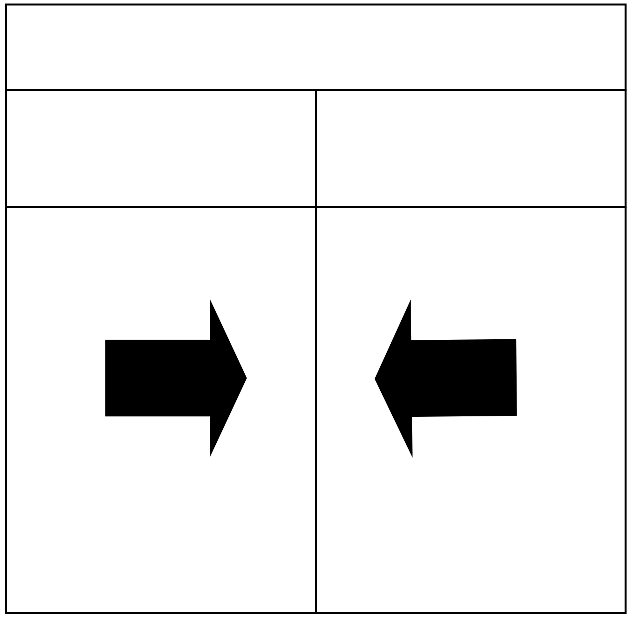
Forced Field Analysis (Cont.)

- **Procedure**
  - Understand current situation.
  - Define a goal.
  - Identify all driving forces which support the implement of the goal. Even if a force has relative lower impact on the goal achievement, it should not be omitted.
  - Identify all restraining forces which inhibit the positive movements in the whole process. The rule of thumb is to find as many forces as you can regardless their contribute to the change.



Forced Field Analysis (Cont.)

- **Procedure (Cont.)**
  - List driving forces in the left column, list restraining forces in the right column.
  - Assign a score to each force based on its level of influence of the goal. For instance: From 1 (extremely weak) to 5 (extremely strong). Computer a sum of each column.
  - Assess whether goal or change is feasible or not.
  - If the conclusion is feasible, then develop a plan to accomplish the goal through increasing the strength of driving forces or decreasing the strength of the restraining forces. If possible, create new driving forces factors to strengthen the positive affect.



Forced Field Analysis (Cont.)

Example: A manager in a manufacture plant is trying to decide whether the company should install new equipment or not.

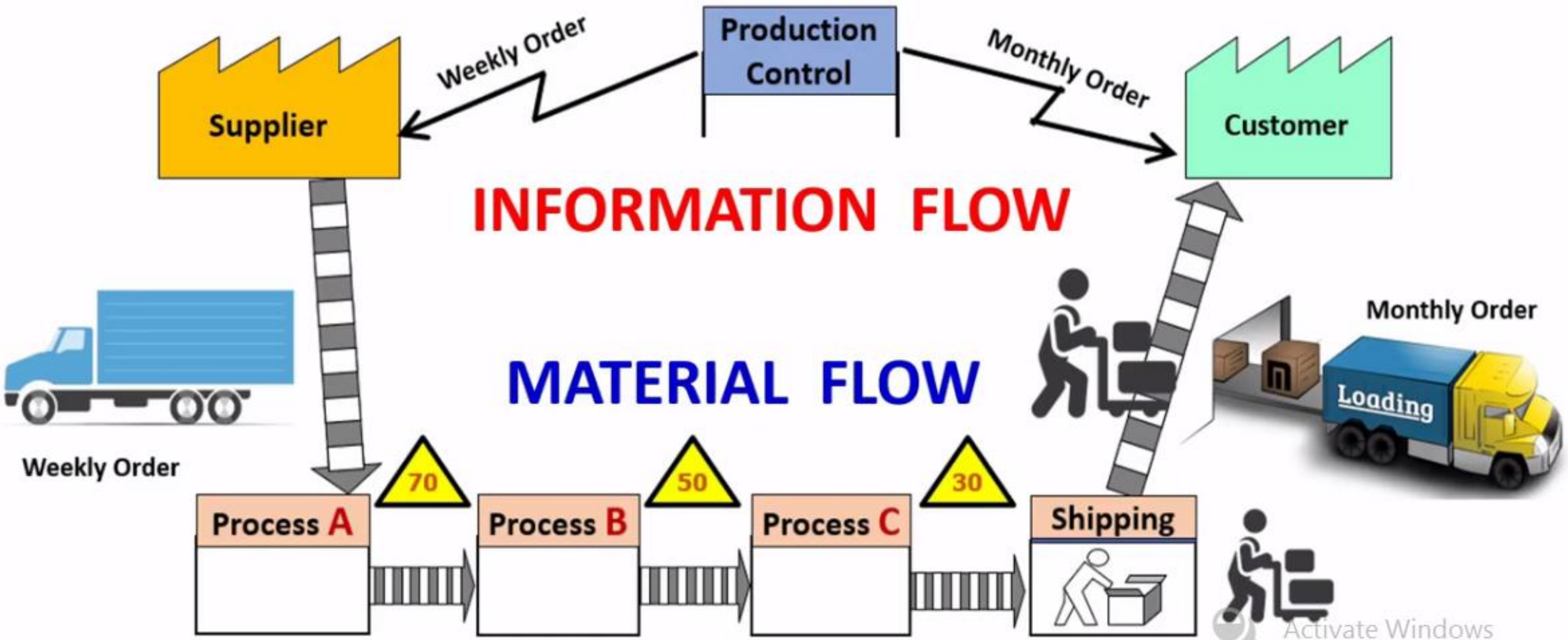
1 (very weak influence), 5 (very strong influence)

Force Field Analysis			
Score	**Driving Forces**	**Restraining Forces**	**Score**
5	Customer's needs	Employees feel uncomfortable of new techniques	4
3	Improve productivity	Employee turnover cost	3
5	Winning more market share	New equipment purchase and installation cost	5
1	Reduce maintenance cost	Disruption	1
14			13

Forced Field Analysis (Cont.)

- Conclusion of the example based on the score (14:13): the plan of new equipment installation is feasible.
- Possible solution for improving the plan:
  - New technique operation training (which will increase cost in restraining force column by 1 point and reduce the feeling uncomfortable item 3 points.)
  - Introducing new technology through employee meeting, listening to employees, and answering their questions about new equipment. (It can reduce 1 point from restraining column.)
  - Raising wage for those stuff who will have to use extra time to master new skill. (This can reduce 2 points from employee turnover item.)
- As a result, those strategies swing the equilibrium from 14:13 to 14: 8, which indicate the possibility of success in this plan increased greatly.

Value Stream Mapping



Value Stream Mapping VSM

What is Value Stream Mapping ?

- Value Stream Mapping is a technique for identifying and eliminating waste from a process by analyze the flow of materials and information currently required to bring a product or service to a consumer.

Value Stream Mapping VSM

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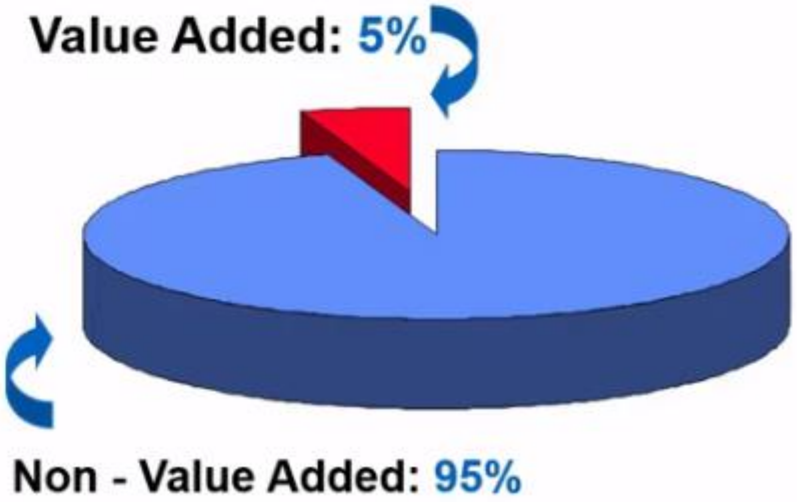
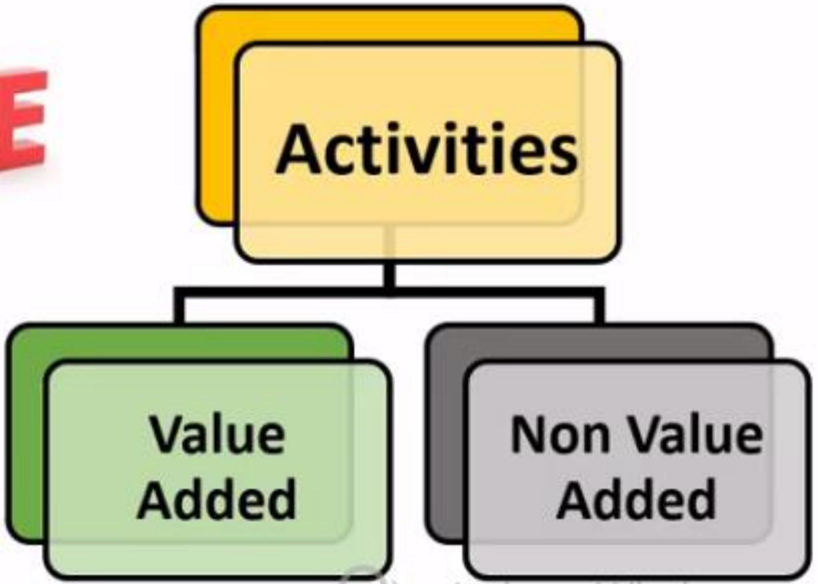
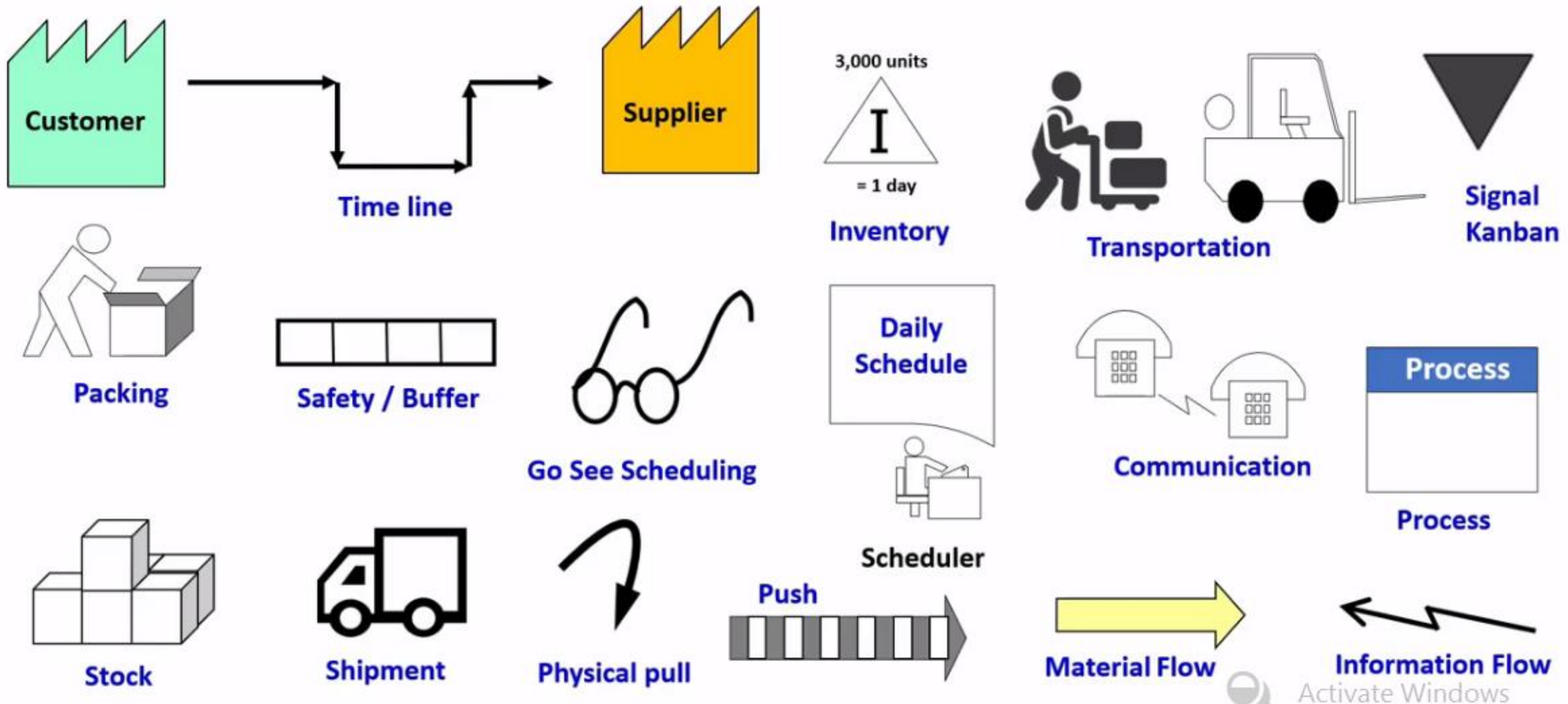
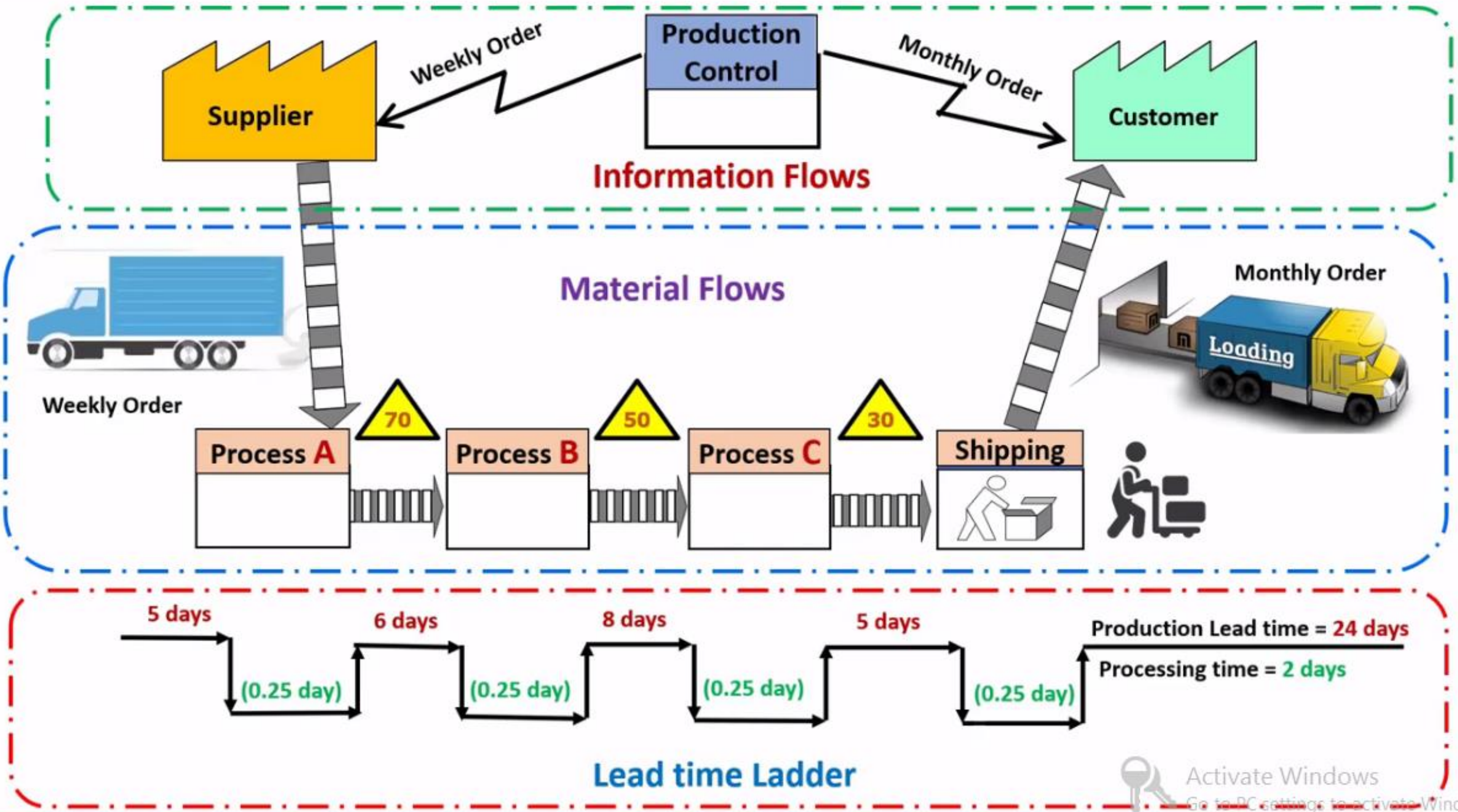




Terminology and symbols and what they mean




Production Control
Weekly Order
Monthly Order
Supplier
Customer
Information Flows
Material Flows
Weekly Order
Monthly Order
Loading
70
50
30
Process A
Process B
Process C
Shipping
5 days
6 days
8 days
5 days
(0.25 day)
(0.25 day)
(0.25 day)
(0.25 day)
Production Lead time = 24 days
Processing time = 2 days
Lead time Ladder