QUALITY

LLA
LEAN LEARNING ACADEMY

QUALITY

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Education and Culture DG

Lifelong Learning Programme

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Learning Objectives

- The purposes of the this module are to:
  - Present the main quality issues related to lean production
  - Explain the meaning of 'quality' and 'value for the customer'
  - Describe the main quality tools used within lean management systems
  - Understand the concept of "Continuous Improvement"
  - Identify the different steps in the PDCA (continuous improvement) cycle

Content

1. Quality

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- Brief Introduction
  - Quality Definition
  - Quality Concept Evolution and Main Quality Experts
  - Quality Perspectives and Dimensions
  - Lean and/or Quality?

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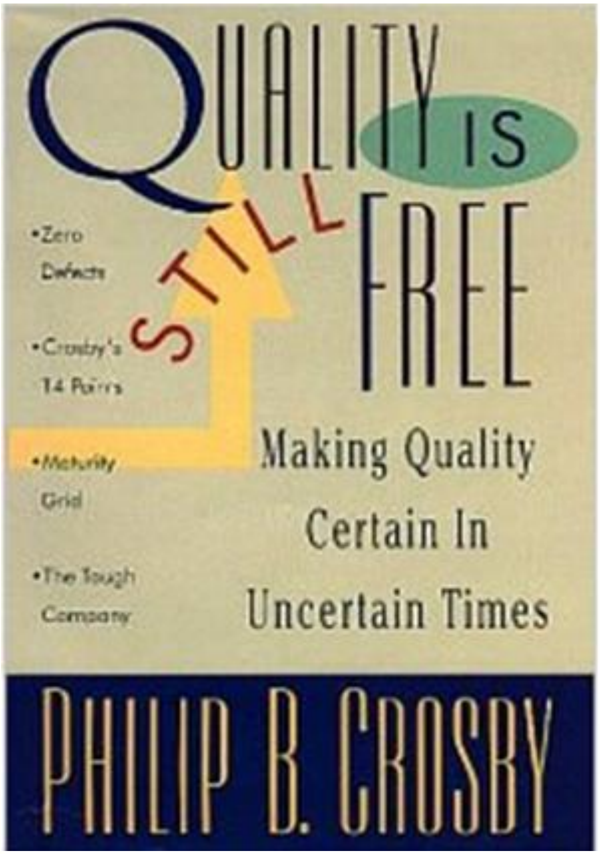
Why Is Quality So Important?

- Quality is no longer just a technical issue, it is a:
  - Business issue:
    - Customers have rising expectations and require low quantity of high quality products at low costs.
    - Quality gives customers satisfaction and differentiates good supplier companies from the competition.
    - Poor quality reduces productivity and increases costs.
  - Cultural issue:
    - Organisational culture based upon the management's commitment to quality and continuous improvement.

The Consequences of Poor Quality

- Loss of business
  - Customers are no longer satisfied and their complaints are not properly dealt with. They do not come back anymore for new orders.
  - Loss of production
  - Loss of customers
  - Loss of jobs
- Reduced productivity
  - Many hours of rework or scrap.
  - More input but less quality output
- Higher costs
- Liability
  - Losses due to damages or injuries resulting from poor quality (design, conformance, ease of use, service)



"Quality is free. It's not a gift, but it is free. What costs money are the unquality things -- all the actions that involve not doing jobs right the first time."

(Philip B. Crosby, 1979)

Quality

- Quality Definition

Quality?

- What do you think that quality is?

Fast response

Fit for use

Compliance with policies and procedures

Good performance

Customer's satisfaction

Value for money

Excellence

Customer's delight

Perfection

Conformance

So, What Is Quality Eventually?

- There is no single and general accepted definition of quality.
- Different people and different organisations have formulated different definitions at different moments in time.
- Some common views refer to quality as:
  - Conformance to specifications (Philip B. Crosby)
    - Does the product/service meet the requirements defined by designers?
  - Fitness for intended use (Joseph Juran)
    - It evaluates the operational performance - how well the product or service does what the consumer thinks it is supposed to do
  - Value for price paid
    - It indicates the usefulness degree vs. price paid
  - Support services
    - Quality depends upon the after sale support
  - Psychological perception
    - e.g. status, ambiance, prestige, friendly staff

Some Definitions

- A product or a service possesses quality if it helps somebody and enjoys a good and sustainable market. (Deming)
- Quality is delivering defect free product with competitive price.
- Totality of characteristics of an entity that bear upon its ability to satisfy stated or implied needs.
- Quality of a product or services is its ability to consistently and continuously satisfy the needs and expectations of the customer.
- A degree or level of excellence – the ability of the product or service to exceed customer expectations
- Quality is determined by what customers want and what they are willing to pay for.
- Quality is inversely proportional to variability.
- ISO 9000:2005 defines quality as:
    - "Degree to which a set of inherent characteristics fulfils requirements."

Remember!

QUALITY IS WHAT THE CUSTOMER SAYS IT IS.

Quality is when the customer returns and the product doesn't!

Quality

- Quality Concept Evolution and Main Quality Experts

Evolution of Quality

- Before the industrial revolution
  - Skilled craftsmanship during middle ages
    - High costs, low volume
    - Custom products built to order, simple tools, highly skilled workforce, quality by repeated adjustments and rework
    - Integrated product development
    - The skilled craftsmen were building quality into their products – a very developed workmanship pride

Evolution of Quality (2)

- After the Industrial Revolution, till the 2nd World War
  - Higher volumes, lower costs
    - Production of interchangeable parts and use of inspection to separate the good products form the bad ones
      - Sorting, grading, reworking
  - End of the 19th century – Development of the “scientific management”
    - Thomas Jefferson and F. W. Taylor emphasized on production efficiency and decomposed jobs into smaller and simpler work tasks.
  - 1920’s – Dr. Walter A. Shewhart studied variation in the production processes and developed the concept of statistical process control charts. He is currently referred to as the father of statistical quality control.
  - 1930’s – development of tables for acceptance sampling and use of statistical thinking outside manufacturing
  - 1940’s – W.E. Deming edits Shewhart’s book and develops the ‘Deming’s 14 points’ and the ‘Plan-Do-Study-Act’ (PDSA) cycle

Evolution of Quality (3)

- During the 2nd World War
  - Quality control
    - Self-inspection, product sampling and testing, basic quality planning, records and analysis to detect and solve any non-conformance product
      - Extensive use of statistical concepts

Evolution of Quality (4)

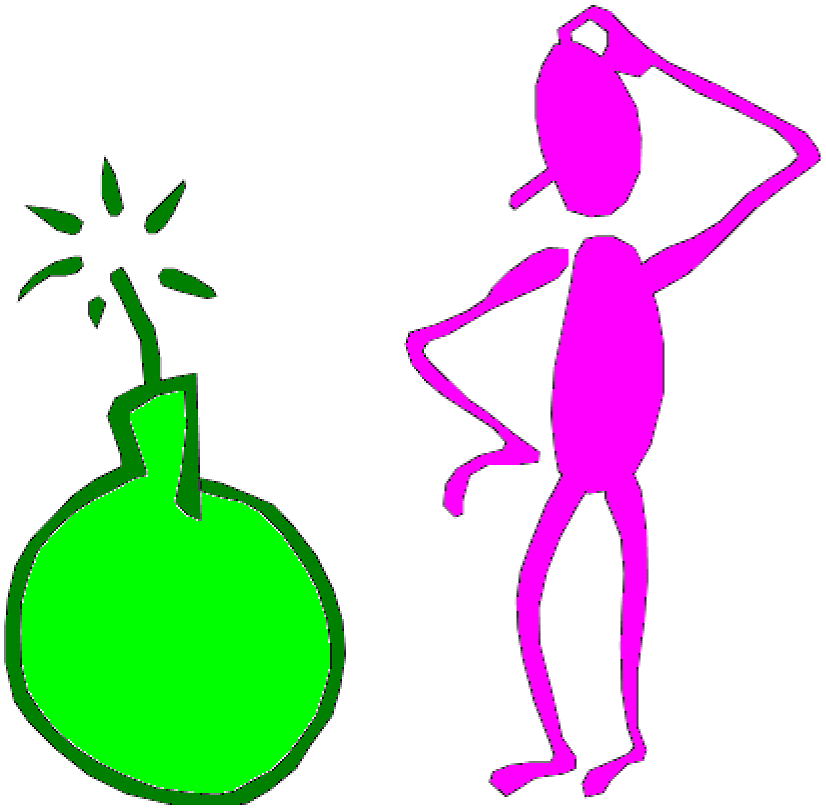
- After the 2nd World War (50-70')
  - Quality management in Japan
    - Joseph M. Juran and W. Edwards Deming were sent to Japan to teach statistical methods and statistical quality control.
  - 1950/60's: Systems of improvement
    - Joseph M. Juran published the first edition of Quality Control Handbook and advocated 3 basic management processes for quality, which are now known as the Juran Trilogy
      - Quality Planning, Quality Control and Quality Improvement
    - P.B. Crosby: Zero defects - do it right the first time
    - A. Feigenbaum develops an integrated view of quality - Total Quality Control (TQC)
    - K. Ishikawa introduces cause-effect (fishbone) diagrams
    - G. Taguchi develops the quality cost function

Evolution of Quality (5)

- After 1980's
  - Quality is no longer seen as the result of sorting good parts during inspection, but as 'built-in' quality into the production processes
    - ISO 9000 series on Quality Management
    - Quality assurance
      - Quality management systems development, advanced quality planning, comprehensive quality manuals, quality costs, involvement of non-production operations, failure mode and effects analysis (FMEA), SPC.
    - Total Quality Management (TQM)
      - Policy deployment, involve all stakeholders and all operations, process management, performance measurement, teamwork, employee involvement

Evolution of Quality (6)

- New trends nowadays:
  - 6Sigma
  - Lean
  - Lean six sigma
  - Design for six sigma
  - BSC
  - TPM
  - QFD
  - TOC
  - Excellence models
  - TRIZ – Creative problem solving

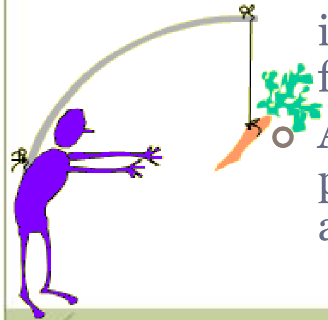


Some of the Main Quality Experts

- Walter A. Shewhart (1891-1967) – 'father' of statistical quality control, statistical control charts
- Armand V. Feigenbaum – Total Quality Control
- W. Edwards Deming – Total Quality Management
- Joseph M. Juran – 'Fitness of Use', the Quality Trilogy
- Philip B. Crosby – 'Zero Defects', Quality is Free
- Kaoru Ishikawa – Cause and Effect Diagram, Quality Circles
- Genichi Taguchi – Total Loss Function
- Taiichi Ohno – Muda
- Masaaki Imai – Kaizen
- Shigeo Shingo – Poka Yoke, SMED

W. Edwards Deming

- W. Edwards Deming (1900 – 1993)
  - Sent to Japan after the 2nd World War
  - Japanese adopted many aspects of Deming's management philosophy
  - The major contributions to the theory of quality
    - Theory of Variation (Statistical Theory);
    - The 14 points for management
    - PDCA/PDSA cycle
    - The theory of profound knowledge
      - The company is a large system including a set of interdependent elements.
      - Every worker has quite infinite potential if placed in a proper environment, that supports, educates, and fosters senses of pride and responsibility. Deming stated that the vast majority (85 percent) of a worker's effectiveness is determined by his environment and the rest of 15% by his own skill and faults.
      - A manager using the system of profound knowledge must understand the psychology of groups and individuals and employ management tools accordingly.



W. Edwards Deming's 14 Points for management

1. Create constancy of purpose towards improvement of product and services. Create and publish a company mission statement and commit to it, provide innovation, investment in research and education, continuous improvement of product and service, maintenance of equipment, furniture and fixtures, and new aids to production.
2. Adopt the new philosophy. It is no more acceptable to work with the same levels of delays, mistakes, defective products, wastes. Lead to promote change.
3. Understand the purpose of inspection. Cease dependence on mass inspection to achieve quality. Require, instead, statistical evidence that quality is built in in the first place. Inspect products and services only enough to be able to identify ways to improve the process.
4. End business practices driven by price alone. Instead, minimise total cost. Move towards single suppliers, based on a long-term relationship of loyalty and trust.
5. Find problems and improve constantly the system of production and service. Improvement is not a one-time effort; management is responsible for leading the organization into the practice of continual improvement in quality and productivity.
6. Institute modern methods of training and retraining on the job. Workers need to know how to do their jobs correctly even if they need to learn new skills.
7. Emphasize leadership. Institute modern methods of supervision of production workers. The responsibility of foremen must be changed from numbers to quality. Manage things, but lead people. Failing organizations are usually over-managed and under-led.

Source: www.deming.org

W. Edwards Deming's 14 Points for management (cont.)

8. Drive out fear and create trust, so that everyone can work well for the company
9. Break down barriers between departments. Optimize cross-functional teams and individual efforts.
10. Eliminate unrealistic numerical goals or slogans, such as "zero defects", for the workforce asking for new levels of productivity without providing improvement solutions. They only create bad feelings between management and workers. Most of the causes of low quality and productivity belong to the system, and cannot be corrected by the workforce alone.
11. Eliminate work standards that set numerical quotas. for the day. Quotas affect quality more than any other working condition, because they emphasise quantity, not quality. Instead, use aids and helpful supervision.
12. Encourage "pride of workmanship," both for hourly workers and management. Give workers respect and feedback about how they are doing their jobs. Stress quality instead of sheer numbers.
13. Institute a vigorous program of education and self-improvement.
14. Create a top management structure to push for change everyday. Put everyone in the company to work to accomplish the transformation. The transformation is everyone's job.

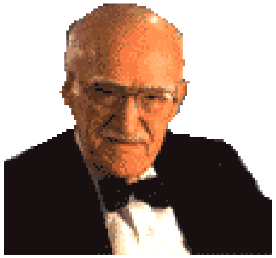
Source: www.deming.org

Deming's Deadly Sins

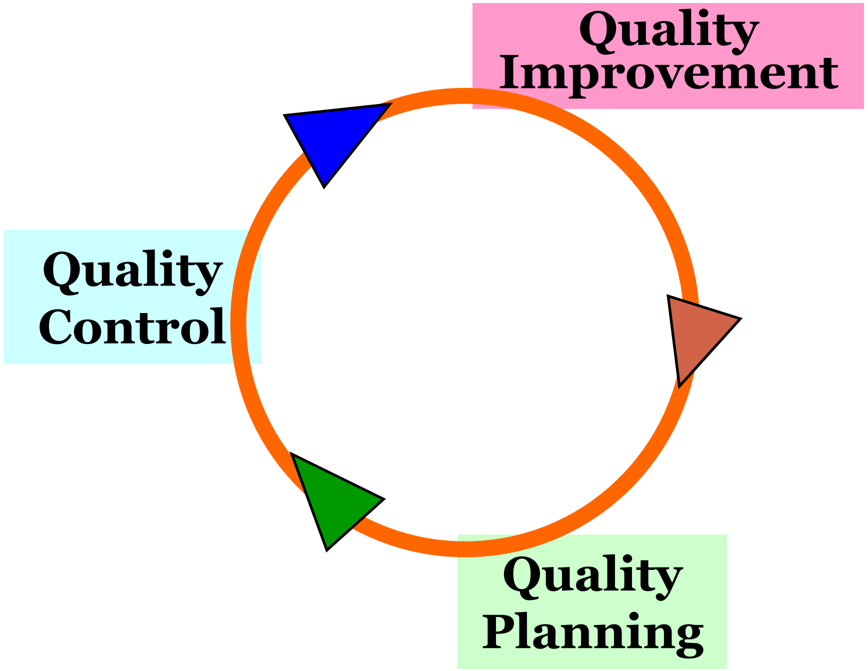
- Lack of constancy of purpose
  - Lots of 'Campaigns of the month'
- Focus on short term financial results
- Over-reliance on performance evaluation, merit rating, annual reviews
- Mobility of management – no real team relationships
- Running a company based only on visible figures
- Excessive medical costs for employee health care
- Excessive costs of liabilities and warrantees

Joseph M. Juran

- Joseph M. Juran (1904 – 2008)
  - Born in Romania, immigrated to the US
  - Quality is defined as “fitness for use” and it incorporates
    - Quality of design
    - Quality of conformance
    - Availability
    - Safety
    - Field use
  - The major contributions to quality management development:
    - Quality Habit
    - The Quality Control Handbook
    - The Quality Trilogy: Quality Planning, Quality Control and Quality Improvement
    - Focus on management
    - Quality improvement based on project-by-project team approach

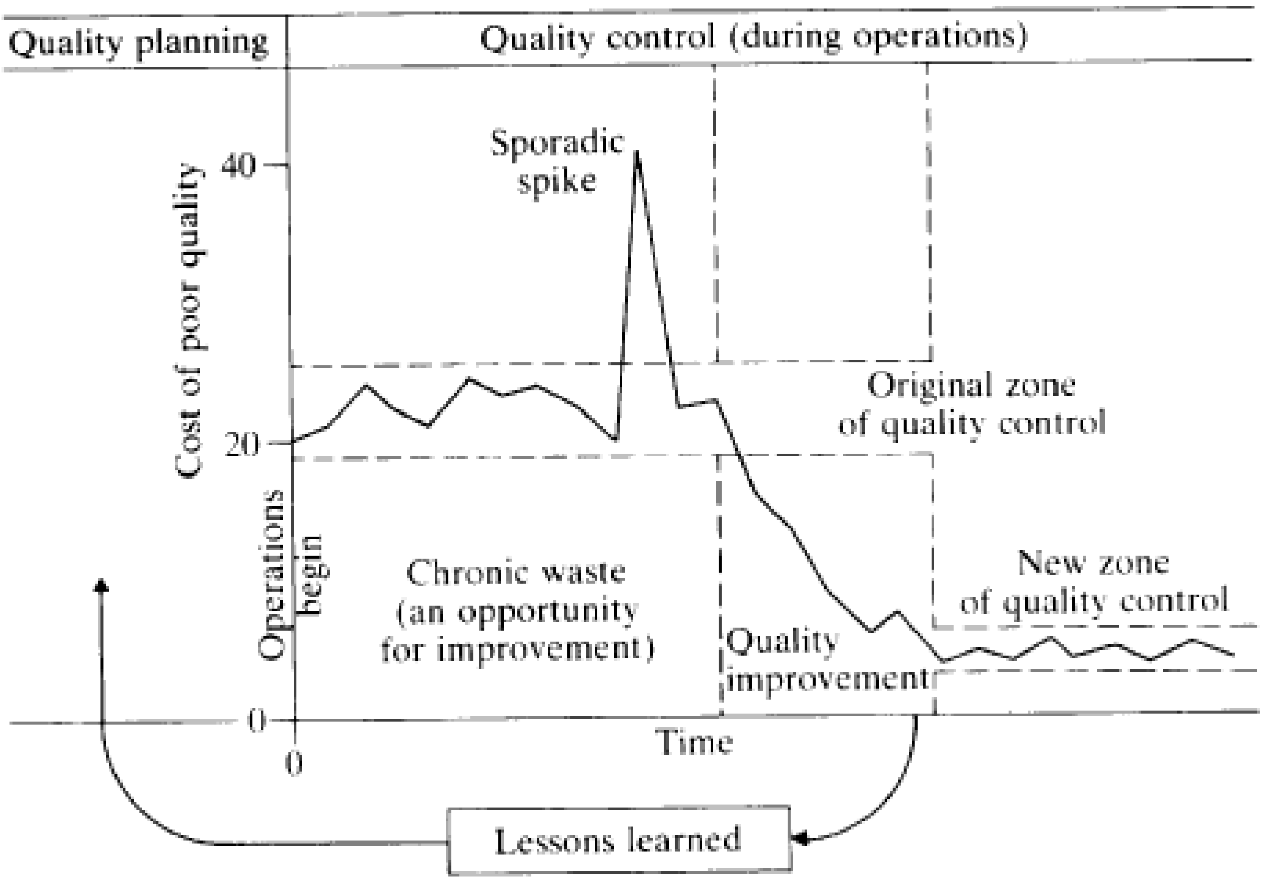


Juran's Trilogy



Juran's Trilogy

(From Juran, 1986.)



Juran's Trilogy (2)

- Quality Planning
  - Establish quality goals
  - Identify customer and discover customer needs
  - Translate needs into technical language
  - Develop a product/service to satisfy these needs
  - Develop a process to realise this product/service
  - Develop process control tools
  - Optimise product features for the customer's needs
- Quality Control
  - Activities and techniques to continuously monitor and improve the conformance of products, processes or services against specifications
  - Analysis of causes of unsatisfactory performance to identify and help eliminating or reducing the sources of variation
  - Review of processes and specifications and improvement actions
- Quality Improvement
  - Seek to optimise the process via chronic problem solving

Philip B. Crosby

- Philip B. Crosby (1926 – 2001)
  - Quality is conformance to requirements.
    - Quality is an essentially measurable aspect of a product or service and that quality is achieved when expectations or requirements are met
  - The major contributions:
    - Focus on prevention, not on inspection – it is always cheaper to do it right the first time
    - The goal of quality is ‘zero defects’ - the only acceptable performance standard
      - There is no optimum level of acceptable defects.
    - Author of ‘Quality is Free’: Measurement of Quality–the price of nonconformance
      - The measurement of quality is the **Price of Non-conformance**, not indices, like the defective ratio or # of non-compliant products.
    - The 14 Steps for Quality Improvement
    - The Quality Vaccine
    - The Quality Management Maturity Grid

Philip B. Crosby's 14 Points

1. Make it clear that management is committed to quality.
2. Form multi-disciplinary quality improvement teams.
3. Establish quality measurements and determine where current and potential quality problems lie.
4. Evaluate the cost of quality and explain its use as a management tool.
5. Raise the quality awareness and personal concern of all employees.
6. Take actions to correct problems identified through previous steps.
7. Establish a committee for the zero defects programme.

Source: www.philipcrosby.com

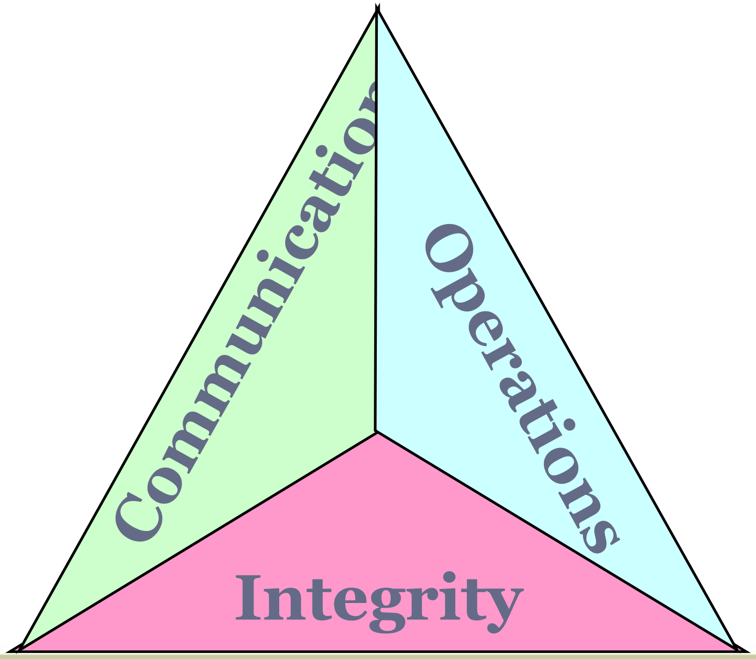
Philip B. Crosby's 14 Points (2)

8. Train supervisors and managers to actively carry out their part of the quality improvement programme.
9. Hold a 'zero defects day' to let all employees realise that there has been a change within the company.
10. Encourage all individuals to establish improvement goals for themselves and their groups.
11. Encourage employees to communicate to management the obstacles they face in attaining their improvement goals.
12. Recognise and appreciate those who participate.
13. Establish quality councils to communicate on a regular basis.
14. Do it all over again to emphasise that the quality improvement programme never ends.

Source: www.philipcrosby.com

Crosby's Quality Vaccine

- The quality vaccine involves:
  - Company-wide policies and operations which support the quality drive
  - Dedication to communication and customer satisfaction
  - Integrity
  - Management maturity



Shigeo Shingo

- Shigeo Shingo (1909 – 1990)
  - The major contributions:
    - Poka-yoke (Mistake Proofing)
      - Shingo considered that '*statistical methods detect errors too late in the manufacturing process*', so he emphasised the need for error prevention, as he believed that humans are fallible.
    - Single-minute exchange of dies (SMED)

Taiichi Ohno

- Taiichi Ohno (1912 – 1990)
  - ‘Father’ of the Toyota Production System
  - The major contributions:
    - Muda – Muri – Mura
    - 7 Wastes

Kaoru Ishikawa

- Kaoru Ishikawa (1915 – 1989)
  - The major contributions:
    - The Cause and Effect Diagram (also known ad the "Ishikawa" or "fishbone" diagram)
    - Showed the importance of integrating the seven basic quality tools in running daily activities:
      - Run Charts, Histograms, Pareto Charts, Cause and Effect Diagrams, Scatter Diagrams, Process Flow Charts, Control Charts
    - Defined the ‘internal customer’
    - Influenced participative approaches involving all workers
      - Quality Circles

Genichi Taguchi

- Genichi Taguchi (born in 1924)
  - Taguchi realized methods of identifying those noise sources which have the greatest effects on product variability.
  - The major contributions:
    - The Loss Function
      - Both non-compliance and over-compliance may cause losses (cost of non-quality, loss of reputation and goodwill).
      - Taguchi devised an equation to quantify the decline of a customer's perceived value of a product as its quality declines.
    - Orthogonal Arrays and Linear Graphs
      - Method used to isolate main outside factors or noise which cause deviations from the mean, based upon the costs induced.
    - The Concept of Robustness
      - Robustness is seen as the ability of a process or product to work as intended regardless of uncontrollable outside factors.
    - Design of Experiments

Quality

- Quality Perspectives and Dimensions

Facets of Quality

- To summarize, quality was defined by different experts, from many points of view, during its evolution.
- So, there have been identified many:
  - Perspectives of quality
  - Dimensions of quality
  - Levels of quality

Quality Perspectives

- Each quality definition is based on a specific perspective. Here there are the relevant five quality perspectives:
  1. Transcendent definition, from a judgmental perspective
  2. Product-based perspective
  3. User-based perspective
  4. Value-based perspective
  5. Manufacturing-based perspective

Quality Perspectives (2)

1. Transcendent quality definition
   - Quality is not something very clear to define, but is equivalent to excellence, “goodness of a product” and is universally recognizable
     - Examples of ‘quality’ products: Rolex watches, Ferrari cars, Ritz hotels
2. Product-based perspective of quality
   - Quality is a precisely defined and measurable variable. Differences in quality reflect differences in quantity of some product attributes.

Quality Perspectives (3)

3. User-based perspective
   - Quality is “fitness for intended use” and refers to product characteristics and features that affect customer satisfaction As individuals have different needs and expectations, quality means meeting customer requirements, hence different quality standards should be met.
4. Value-based perspective
   - It is the perspective of quality vs. price. Quality means best combination of price and product features, namely products as good as the competing ones, sold at a lesser price, or products offering best performance at an acceptable price, or conformance at an acceptable costs.
5. Manufacturing-based perspective
   - Quality is “conformance to specifications” or the degree to which a product conforms to design specification.

Dimensions of Product Quality

- When we think of quality, we are considering many aspects, referred to as the 'dimensions' of quality:
  - **Performance**
    - Primary product characteristics
  - **Special features**
    - Secondary product characteristics, added features
  - **Time**
    - Waiting in line
    - Concept to production
    - Speed of delivery
  - **Reliability**
    - Extent of failure-free operation, meaning that product operates properly within an expected time frame; average time for the unit to fail, probability of failing
  - **Durability**
    - Useful life, including repair time and failure frequency, until replacement is preferable to repair
  - **Conformance and consistency**
    - Meeting specifications, customer's expectations or industry standards
  - **Uniformity**
    - Low variation among repeated outcomes of a process
  - **Serviceability** - service after sale
    - Handling the customer complaints or checking on customer satisfaction, resolution of problems
    - Ease of repair, speed of repairs
  - **Aesthetics**
    - Characteristics that relate to the senses, such as exterior finish, sound, appearance, feel, smell, taste, colours
  - **Perceived Quality**
    - Indirect evaluation of quality (e.g. reputation, past performance and other intangibles)
  - **Responsiveness**
    - Characteristics of the human-to-human interface (speed, courtesy, competence)
  - **Safety**
    - Limited and controlled risk of injury

Dimensions of Service Quality

- Time and timeliness
  - Customer waiting time
- Completeness
  - Is everything provided?
- Courtesy
  - Politeness, respect, consideration, friendliness of contact personnel
- Consistency and accuracy
  - Same level of right service each time
- Accessibility and convenience
  - Easy to reach and obtain service
- Tangibles
  - Physical evidence of the service
- Reliability and dependability
  - Was the problem fixed by the rendered service?
- Responsiveness and communication
  - Willingness/readiness of employees to provide service and information
- Understanding the customer needs and competence
  - Skills and knowledge required to perform service
- Credibility
  - Trustworthiness, believability, honesty
- Security
  - Freedom from danger, risk or doubt

Quality

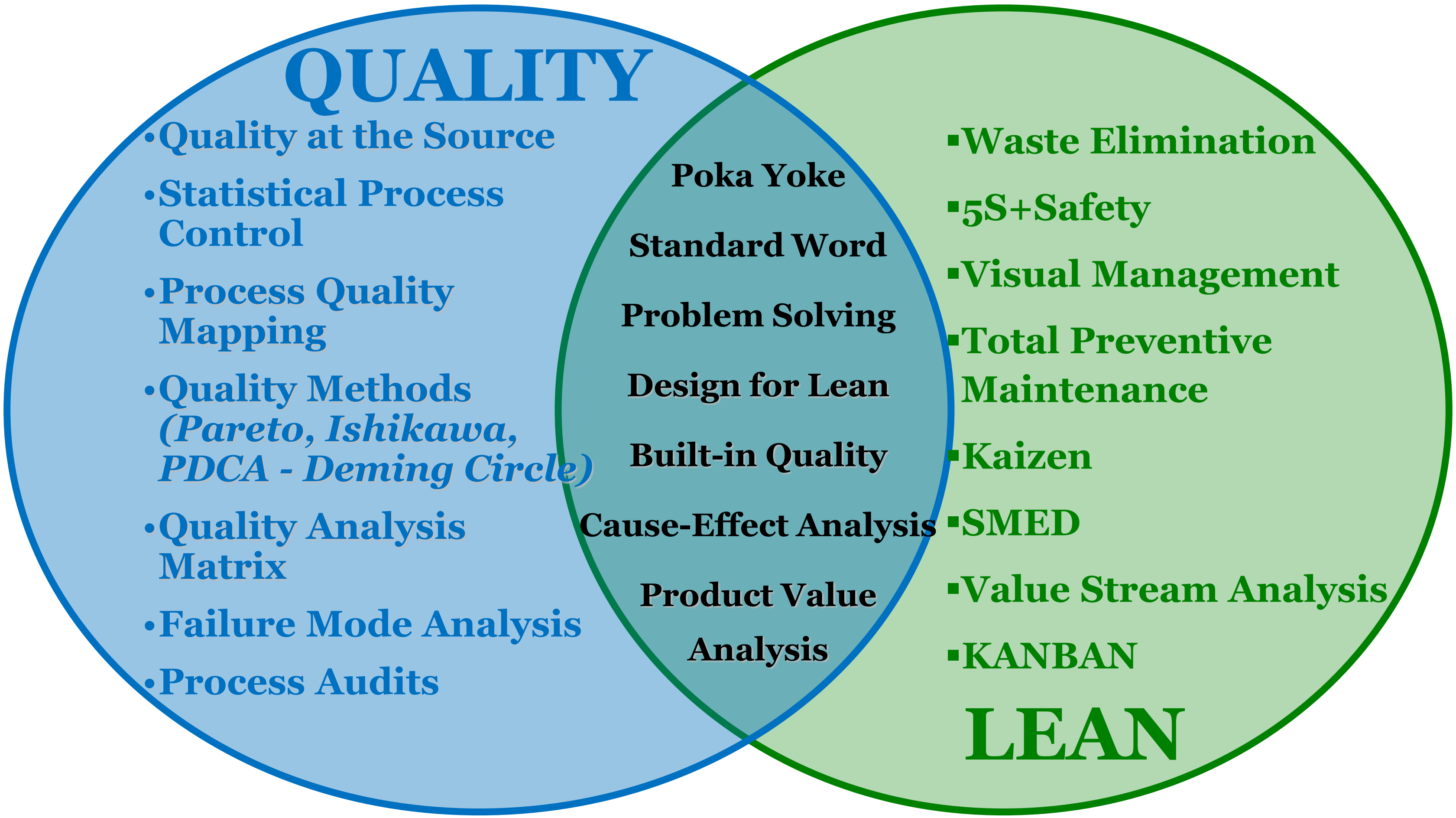
- Lean and/or Quality?

Lean vs. Quality Management

- Lean is a set of concepts, principles and tools used to systematically find and eliminate waste in a production system, as to create and deliver the most value from the customer's perspective while consuming the fewest resources.
  - Success Indicator
    - % of Value Added Activities
  - Method of Achievement
    - Continuous Improvement

- Quality Management is what an organization does to fulfil the customer's quality requirements, and applicable regulatory requirements, while aiming to enhance customer satisfaction, and achieve continual improvement of its performance. (ISO 9000:2005)
  - Success Indicator:
    - % Customer Satisfaction
  - Method of Achievement:
    - Continuous Improvement

Lean and/or Quality?



Lean vs. Quality

- The main similarity of the two approaches is that both quality and lean principles start from the customer's point of view.
- The main difference:
  - Quality aims at customer satisfaction.
    - Satisfaction is not a directly quantifiable indicator; usually it is appreciated the customers' perception of own satisfaction.
    - Nowadays, many companies declare that their quality goal is to satisfy and to go beyond the customers' needs and expectations.
  - Lean is focused on the value added for the customer.
    - The value is seen from the customers' point of view and it usually refers to those activities that help transform a product or service from its raw state into its customer's desired form, done right the first time at the right time and in due time.
    - The value added activities are either the activities that customer thinks as important and willing to pay for them, or required by the law, regulations or ethical considerations.

Lean and Quality

- Lean induces major improvements in overall quality levels:
  - Reduced internal quality costs
  - Better quality during the overall product life cycle.
- Lean tackles many quality chronic problems.
- Lean goes beyond the product specifications and deals with other relevant quality dimensions, such as *responsiveness, on-time delivery performance, and reputation*.
- Lean philosophy, when correctly understood and deployed, enables an environment of continuous improvement.

So, Quality means … ?

Quality Planning

Quality Circles

TQM

Zero Defects

Quality Assurance

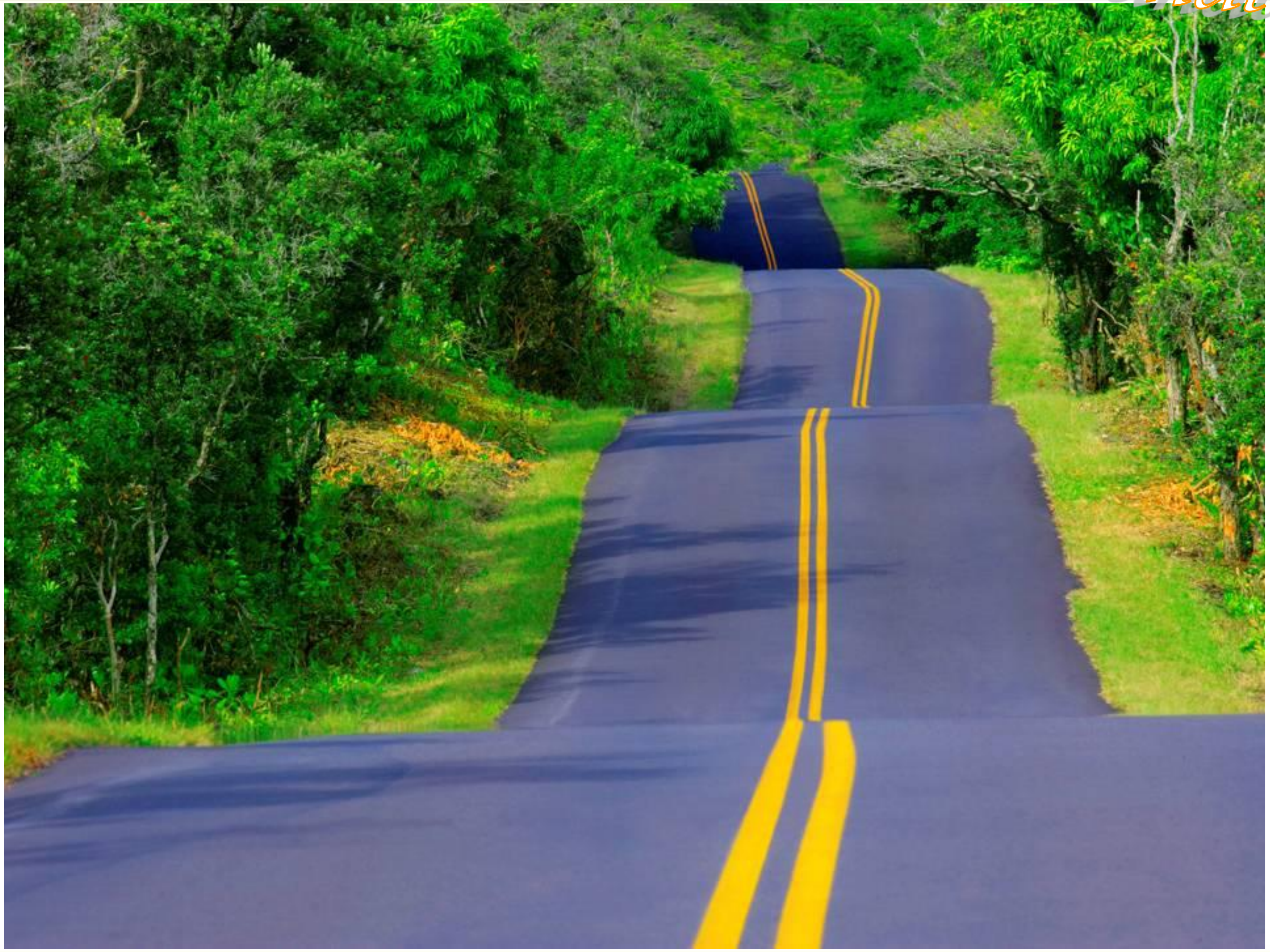
Kaizen

QFD

Six Sigma

SPC

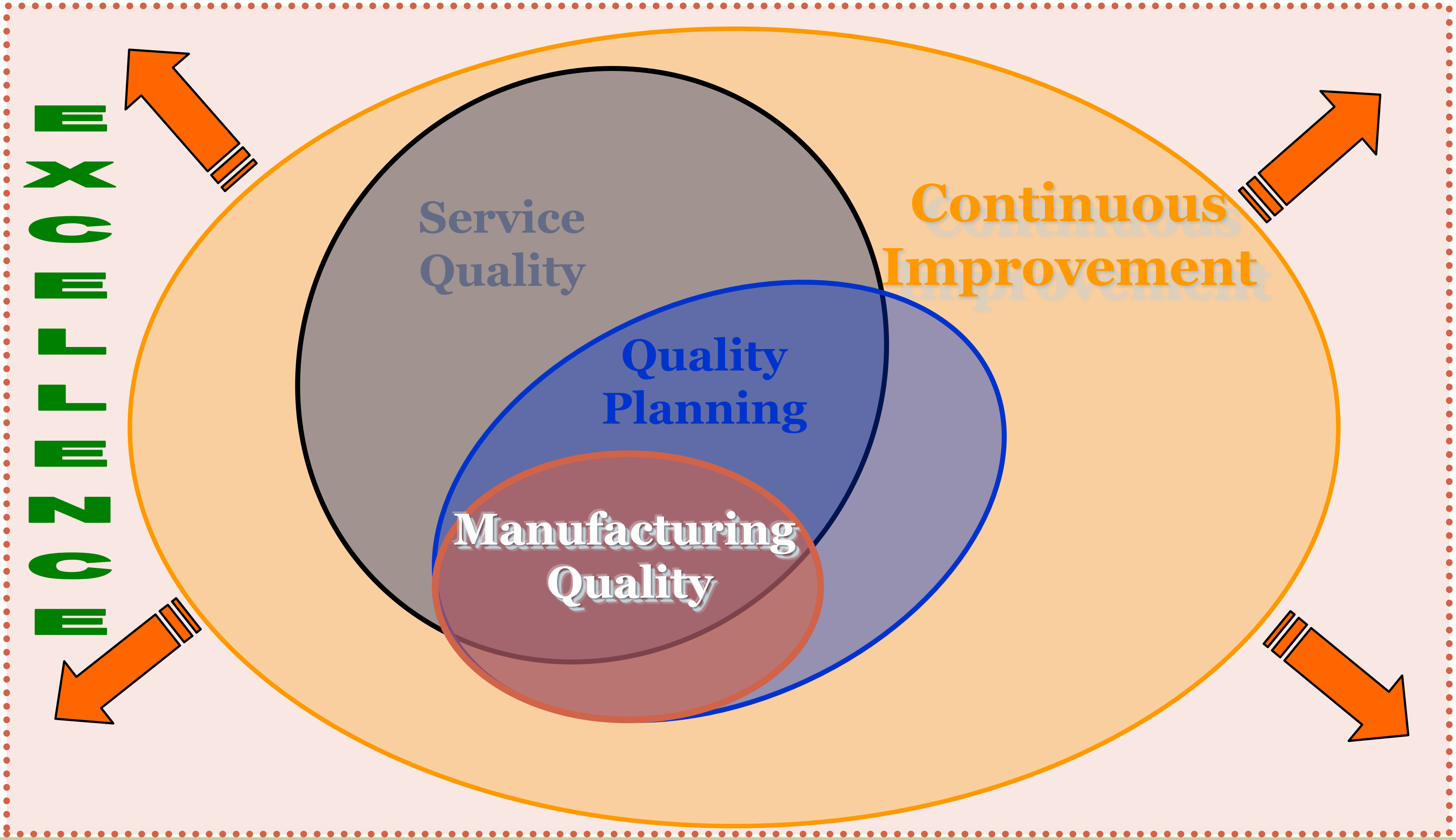
Quality is a Journey, not a Destination.



2. Quality Planning

- 2.1. Built-in Quality
- 2.2. Design for Lean

Current Organisation Management



The Four Determinants of Quality

Built-in Quality

- Quality of design - **Planned Quality**
  - Determining which features to include or exclude in the final product/service design, according to customer requirements

Quality at the Source

- Quality of conformance to specifications - **Executed Quality**
  - Production processes are selected and set up to meet product/service specifications
- Ease of use
  - Instructions, manuals for operations, maintenance, training, safety
- Service after delivery
  - Responsiveness, serviceability, spare parts

2.1. Built-in Quality

- Product and Process Design

Customer Satisfaction

- There are two main drives to provide high customer satisfaction:
  - Built-in-quality
    - During product and process design
      - Product specification
      - Freedom from deficiencies
  - Quality-at-the-source
    - During production and use of the product
      - Quality of conformance
        - Higher conformance means fewer complaints and increased customer satisfaction.

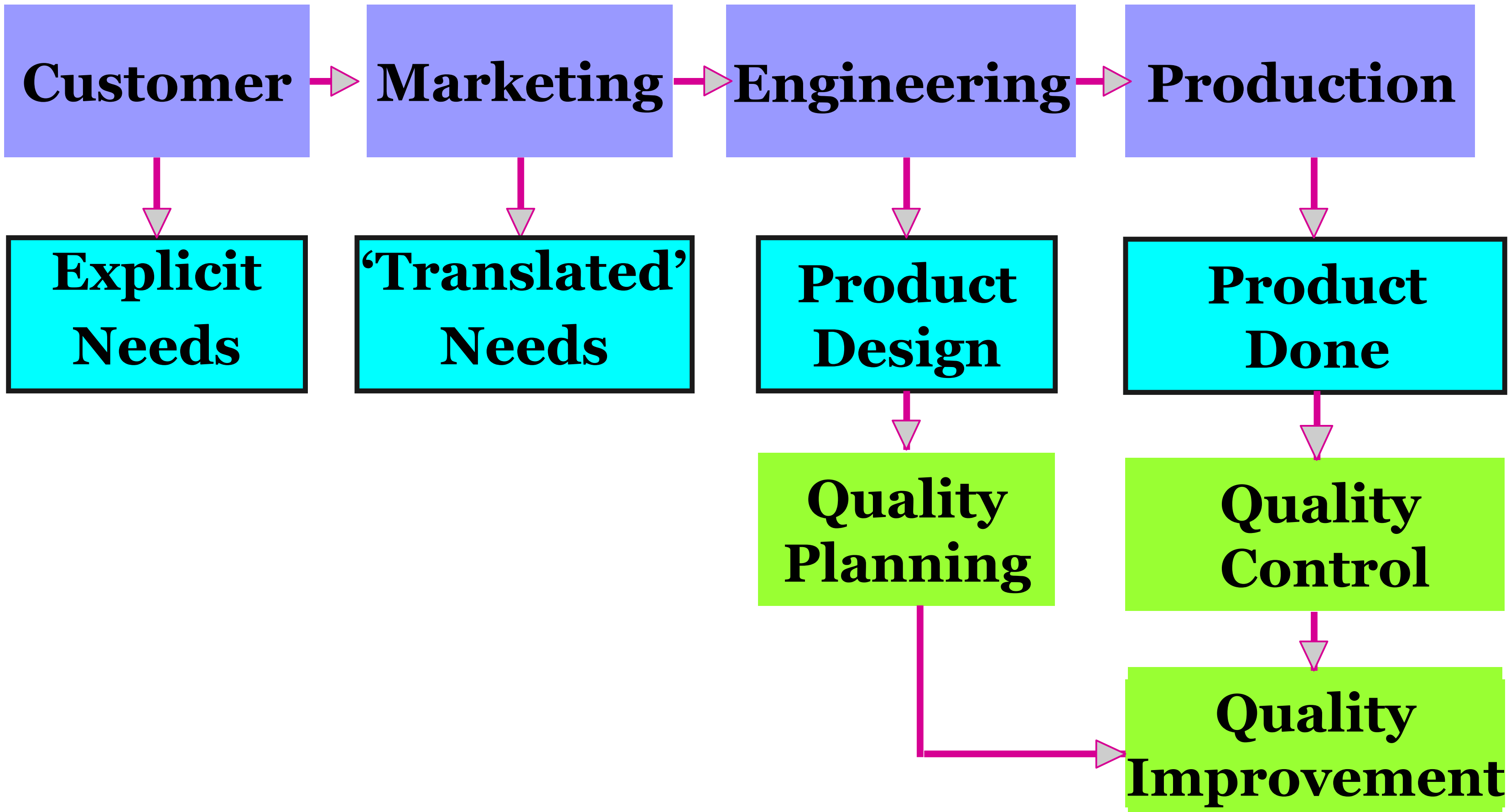
ISO 9001:2008 - Relevant Sections for Quality Planning

- 7 Product Realization
  - 7.1 Planning of product realization
  - 7.2 Customer-related processes
    - 7.2.1 Determination of requirements related to the product
    - 7.2.2 Review of requirements related to the product
    - 7.2.3 Customer communication
  - 7.3 Design and development
    - 7.3.1 Design and development planning
    - 7.3.2 Design and development inputs
    - 7.3.3 Design and development outputs
    - 7.3.4 Design and development review
    - 7.3.5 Design and development verification
    - 7.3.6 Design and development validation
    - 7.3.7 Control of design and development changes

Quality Planning

- Steps:
  A. Identify who are the customers
  B. Find out the needs of those customers
  C. Product/service development
     - Translate the customers' needs and general requirements into product specifications
  D. Product/service design
  E. Process design
  F. Design review and product design improvement, so as to meet:
     - Customer needs
     - Other general needs
       - Internal specific needs – efficiency, profitability, ethics
       - External requirements – laws, regulations

Customer-driven Quality



A. Who Are the Customers?

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Who Are the Customers?

- Customers are:
  - The most important people for any business.
    - They deserve the most courteous and attentive treatment we producers could give them.
  - They are not dependent of suppliers. Suppliers are dependent upon them.
  - Customers are not a bother for producers. They are the purpose of the producers' remaining in business.
    - Satisfying customers is the only reason companies are still in business.
  - Customers have a major input for the producers' processes.
    - They have not been considered just a statistic. They should be seen as individual human beings, with various feelings and emotions.
  - The next employee down the process flow from you is your first customer. At the end of the production line is the external customer.

The Customer

- Customers assign a value to the product or service in accordance with the perception of the degree of satisfaction against own needs and desires, either expressed or implicit.
  - In exchange for this value, they pay and often go into debt, and this constitutes the sole source of income for the business.
- The nowadays trend is to move away from the strategy based on customers' satisfaction to delighting customers, i.e. from satisfying declared needs to exceed customers' expectations in terms of quality, cost and time.

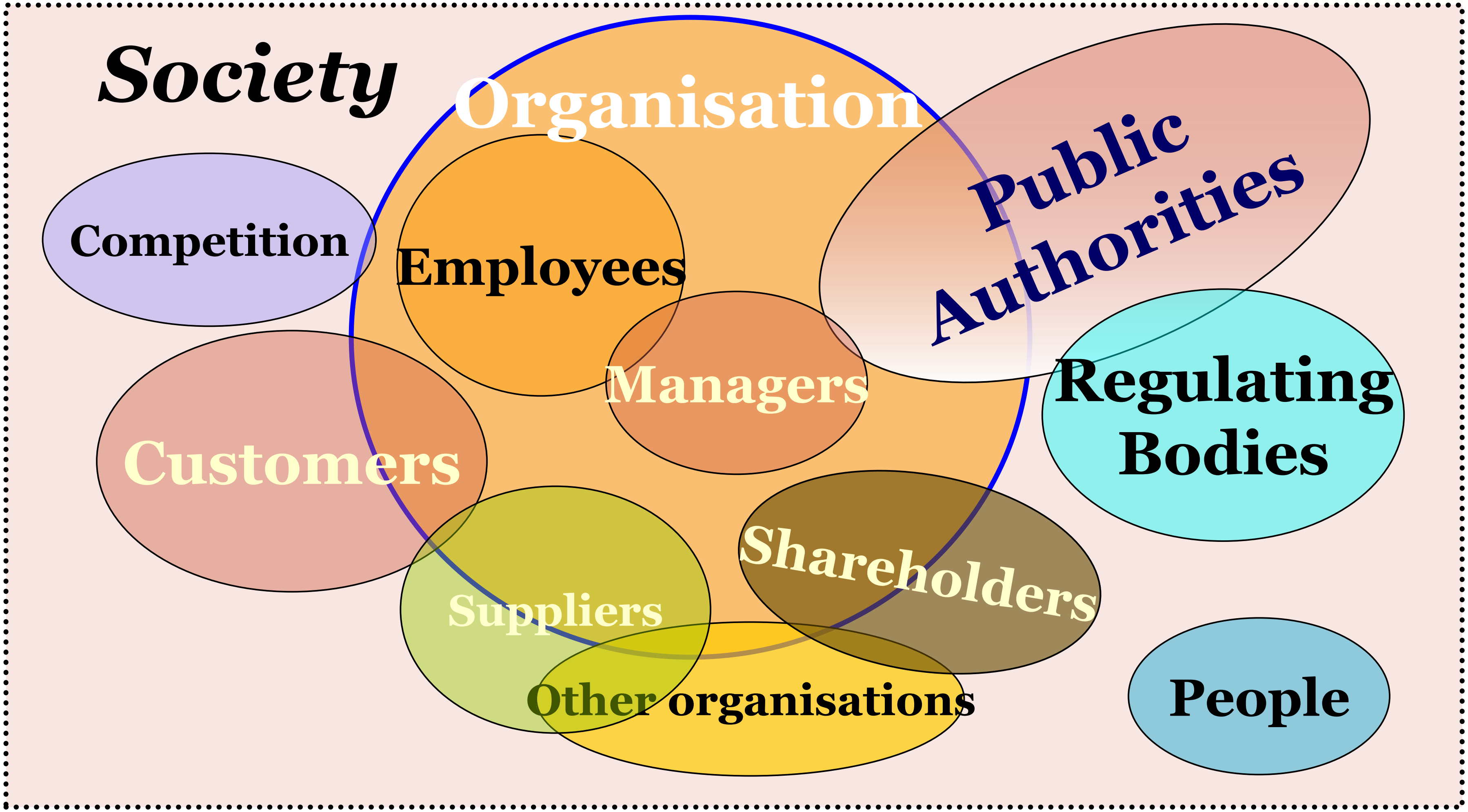
Customer's Needs

- Main concerns:
  - The product/service characteristics should vary according to specific customer needs.
  - The product/service should meet customer requirements in the simplest and most cost-effective manner
    - Shortest time to market
    - Limited number of revisions needed
- A customer can be defined as one who purchases or patronizes for the purpose of receiving products or services. There are two major categories of customers:
  - External customers
  - Internal customers

Internal Customers/Suppliers

- The internal supplier is the product, service or advice, which represents the end-product of one stage in the process.
- The internal customer is the office, shop or service which carries out the next stage.
  - Each worker on a process flow acts both as a supplier and a customer with respect to and for the other.
  - Main principle: The relationship between internal customer and internal supplier has a key role to satisfying the external customer.

Different Customers / Stakeholders



B. What Do the Customers Need?

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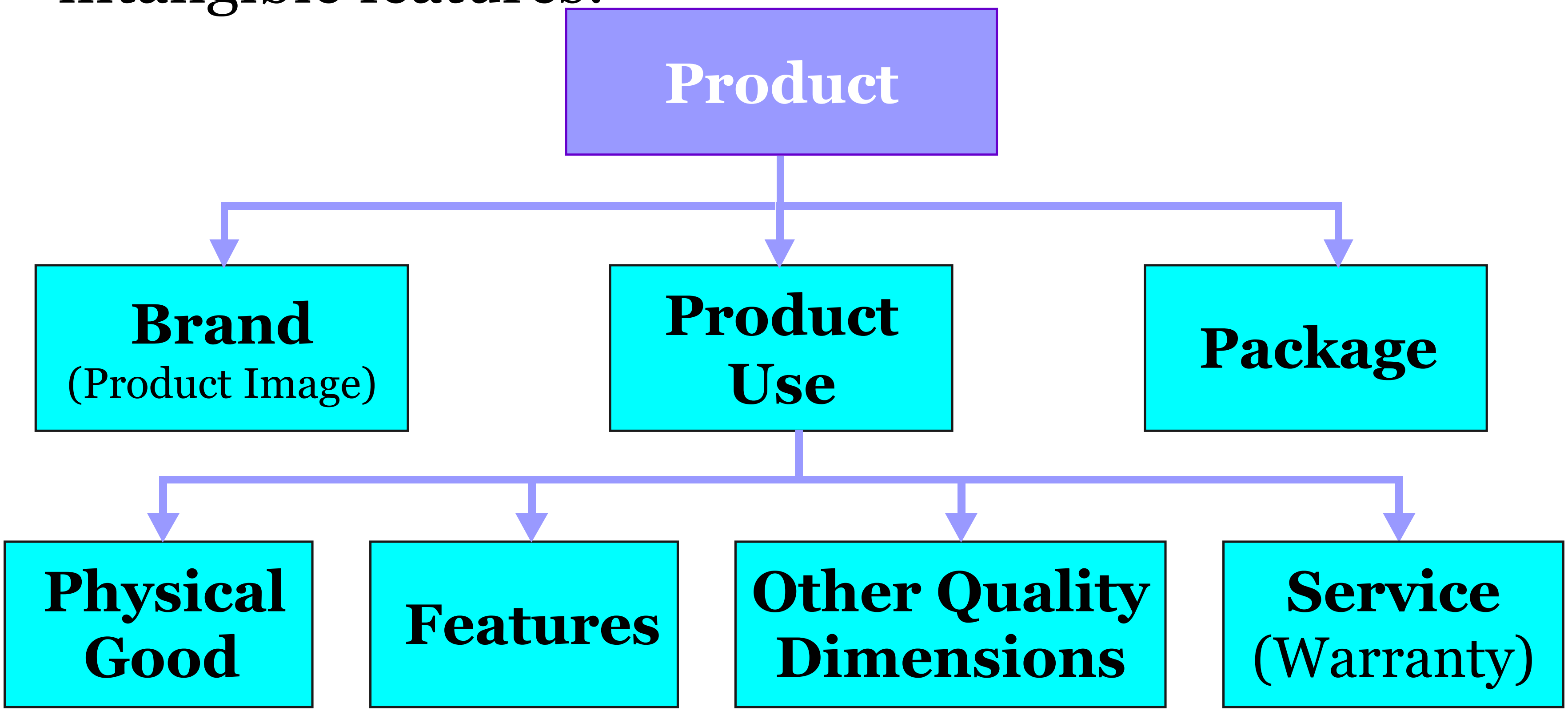
What do Customers Buy?

- Customers buy satisfaction, not merely goods or services.
  - Examples:
    - Producers of cleaning products sell the benefits of clean and nicely perfumed clothes or surfaces
    - Producers of cosmetics sell youth hopes for adult women
- Customers pay for need-satisfying supplies
  - The buyer decision is based on value for the customer
  - Lately, goods are no more sold for their inherent features, if not accompanied by suitable services
    - Examples:
      - Furniture is bought not only for its current use, but for the designer' reputation, because it is transported and fixed on place, because there are disposal provisions in the sale offer, etc.

Product Components

- Customers buy not only a product, but also several intangible features:



Customers' Values

- Customer satisfaction and delight
- Quality at low cost
- Quality is multi-dimensional for customers
  - Garvin identified the following quality dimensions:
    - Performance
    - Extra features
    - Reliability
    - Conformance
    - Durability
    - Serviceability
    - Aesthetics
    - Perceived quality
  - In addition, Schonberger has added 4 new dimensions:
    - Quick response
    - Quick-change response
    - Humanity
    - Value

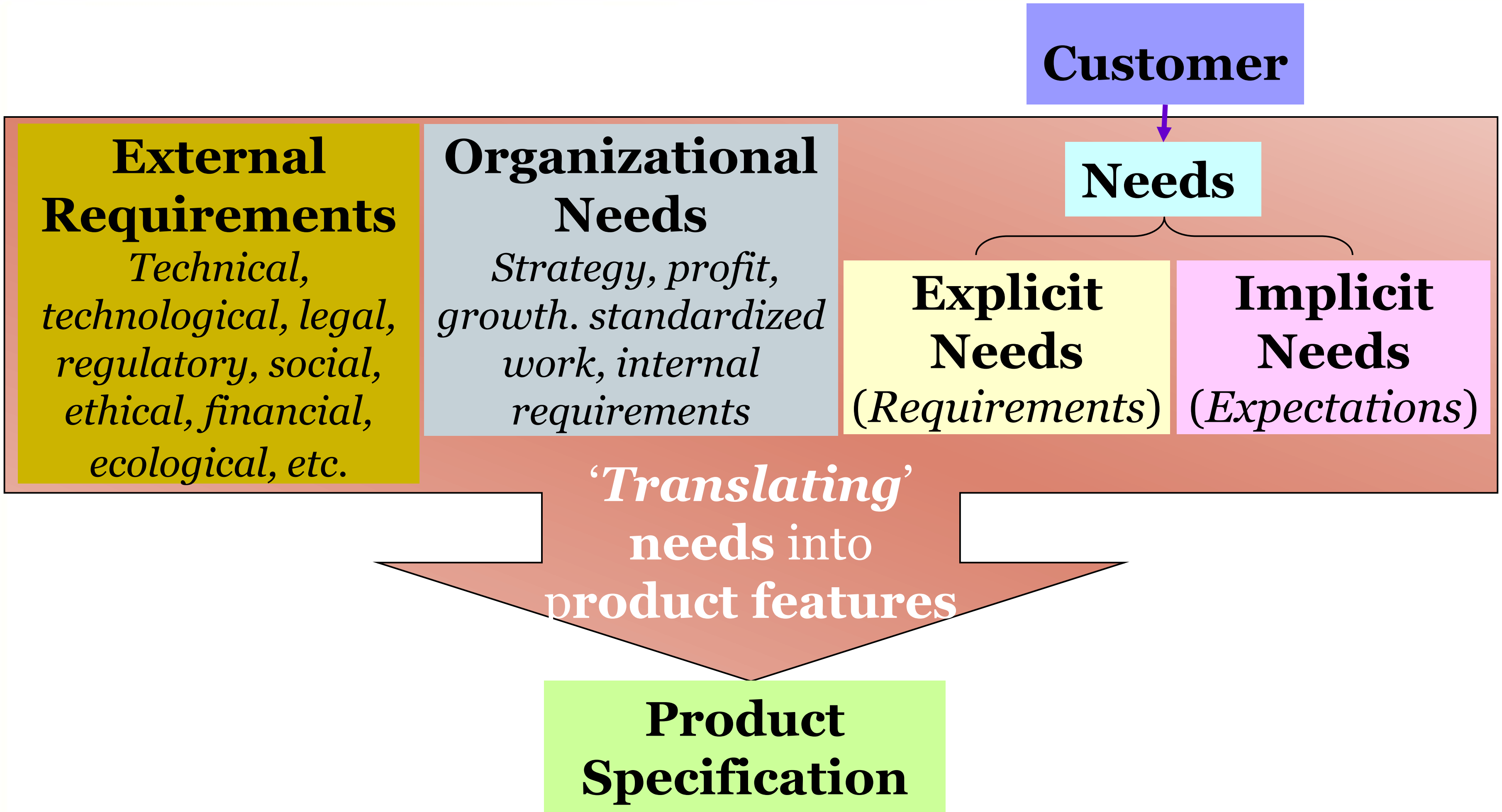
Customer Feedback Methods

- To obtain information from the customers involves a certain range of useful tools:
  - Comment Cards
  - Surveys
  - Focus Groups
  - Toll-free Telephone Numbers
  - Customer Visits
  - Report Cards
  - Internet
  - Employee Feedback

C. Product Development

- Product Specification

Customer's Needs vs. Product Specification



Some Definitions

- Need
  - Need means a lack of something requisite, desirable, or useful.
    - Necessity, desire, expectation, requirement, demand
  - A need may be:
    - Explicit
      - A clearly formulated request
    - Implicit
      - A latent, non declared desire or expectation
        - Current implicit need
        - Future implicit need

Some Definitions (2)

- Product/service
  - A product/service is something provided to a customer, to satisfy the customer's need.
- Product/service specification
  - A set of requirements to be satisfied by a product or a service
    - Functions
      - What the product is intended to do
    - Features (quality dimensions)
    - Costs

Exercise

- You have just been employed by a manufacturing company to be a member of the design team.
  - The company has asked their customers and received the following input, in different configurations:
    - The new product should include an AM-FM radio, a CD player, a telephone with an answering device, a clock with alarm and a timer, a flashlight, a smart screen, smoke and fire detection device;
    - As implicit needs, the customers had in mind a small and light portable device, low price, high fidelity performance, low energy consumption, long-lasting battery, easy to use, ...
  - The company is trying to decide whether or not to include everything in one single product, and also if to include additional functions: *a remote control for turning on/off the electrical house appliances, an external 2" TV screen and a device to synchronize communication with laptops.*
- Your job is to:
  - Recommend the main features for the new product to build
  - Explain how you would validate the specification against the customers' needs.

Designing for the Customer

- Simultaneously dealing with the many dimensions of quality demanded or expected by customers is a major design challenge.
- Translating customer's needs – the "***voice of the customer***" – into product specification – the "***voice of the engineer***" – means setting the proper features for the required product.
- Designing for the customer should cover the product life cycle.

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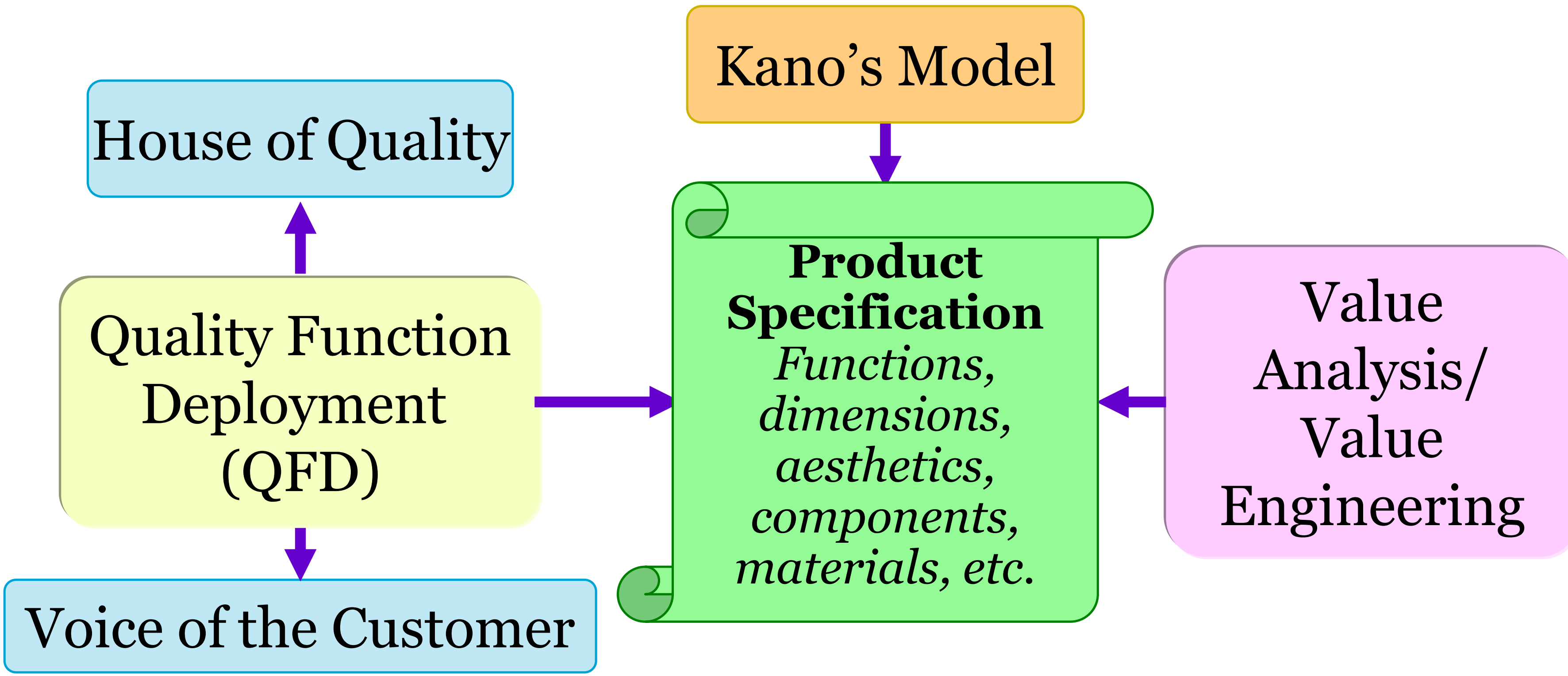
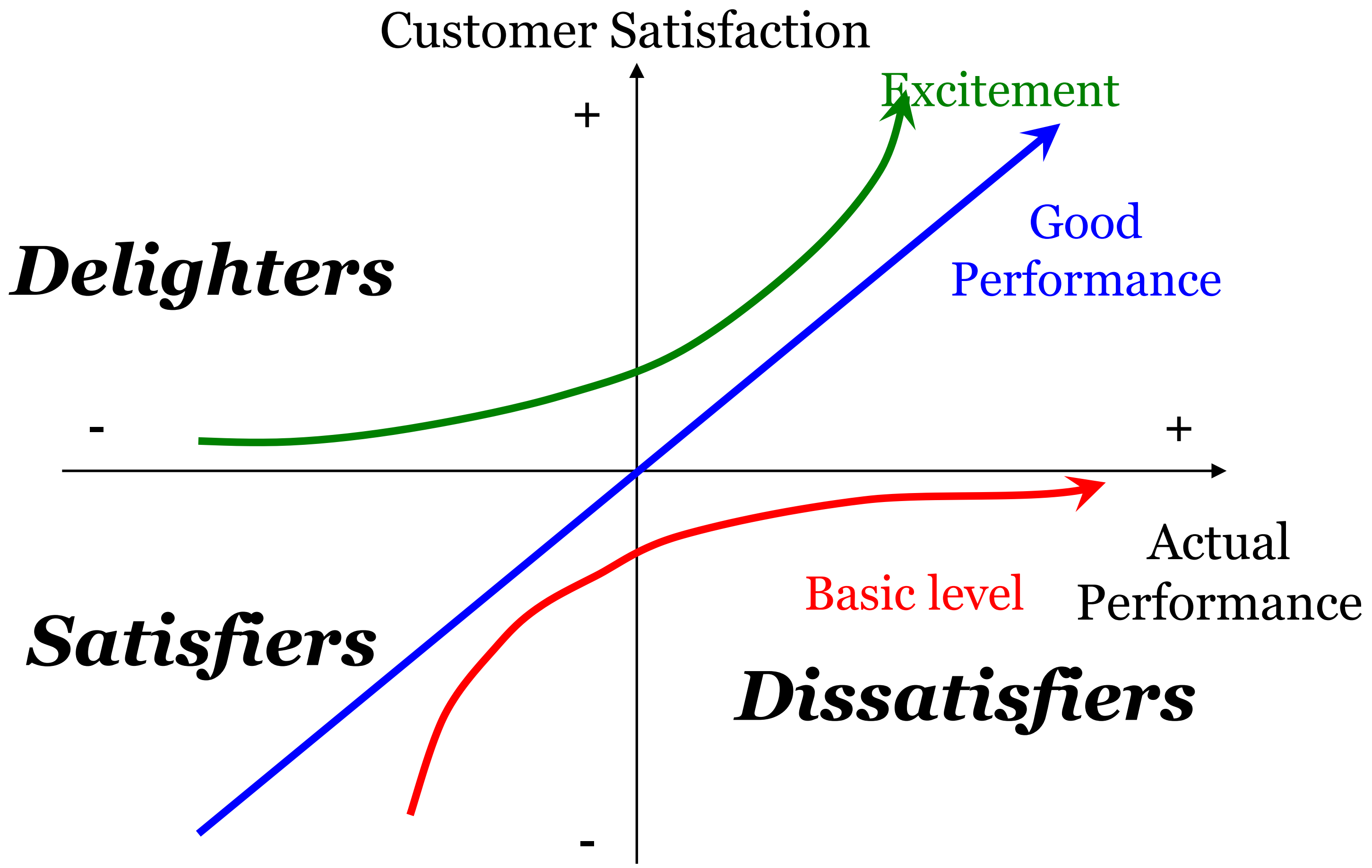
Designing for the Customer (2)

- It involves several tools:



Kano's Model


Customer Satisfaction
Excitement
+
Good Performance
Delighters
-
+
Actual Performance
Basic level
Satisfiers
Dissatisfiers
-

Use of Kano's Model - Example

Expected Quality	Dissatisfiers
Smooth surface	Rough surface, scratches, blemishes
All parts work	Broken parts
Clear instruction	Vague instruction
Normal function	Function not provided
Safe to use	Insecure product
Compliance to specification	Non-conformities

Use of Kano's Model – Example (2)

- Satisfiers:

Desired Quality	Performance Measure	Desired improvement
Dimensions	mm	↗
Price	EUROs	↘
Reliability	MTBF	↗
Energy consumption	kW per h	↘

Use of Kano's Model – Example (3)

- Delighters
  - Extra product features, pleasantly surprising the customers
    - Examples of delighters - when firstly provided:
      - Redial button on telephone
      - One-touch recording
      - Cup holder for drivers
      - Automatic car lights
      - Self-sharpening knife blades

Quality Function Deployment (QFD)

- Product quality is measured by customer satisfaction and customers are satisfied if their needs or requirements are met. QFD is a cross-functional team-based management tool for translating customer requirements into functional design.
  - The cross-functional team should include at least marketing, engineering, manufacturing.
  - QFD provides a systematic approach to identify which requirements are a priority for whom, when to implement them, and why.
    - Customer requirements are grouped and interpreted into a visual dynamic document, so as to identify the important requirements to be met by the product features. These in turn are translated into organisational processes and production requirements.

Classical Model of QFD

Matrix	What	How
House of Quality	Voice of Customer	Technical Performance Measures
Subsystem Design Matrix	Technical Performance Measures	Piece/Part Characteristics
Piece/Part Design Matrix	Piece/Part Characteristics	Process Parameters
Process Design Matrix	Process Parameters	Production Operations

QFD

- It includes several components:
  - Voice of the Customer
    - Helps to translate the 'Voice of the Customer' into technical design requirements
  - A series of four related matrix diagrams, breaking down the product design into increasing levels of detail
    - Customer Requirements Planning Matrix – the 'House of Quality'
      - A conceptual map that translates customer requirements with product characteristics and helps the company to focus effectively on the most important product features
    - Technical Features Deployment Matrix
      - Translation of the technical product features into design requirements for the product components
    - Process Plan And Quality Control Charts
      - Translation of the design requirements for product components into critical processes and product parameters
    - Process Design Matrix
      - Translation of critical processes and product parameters into specifications for operations for plant personnel

The Phases of QFD

- There are 4 main phases of QFD, and there are some basic rules:
  - Each phase requires internal iteration before proceeding to the next one.
  - Once a phase is completed, the method requires not to go back again.

The 4 Main Phases of QFD

Customers' Requirements

I. Product Planning

Technical Specifications

II. Product Design

Detailed Product Design

III. Process Design

Methods
Tools

IV. Process Control

Working Procedures

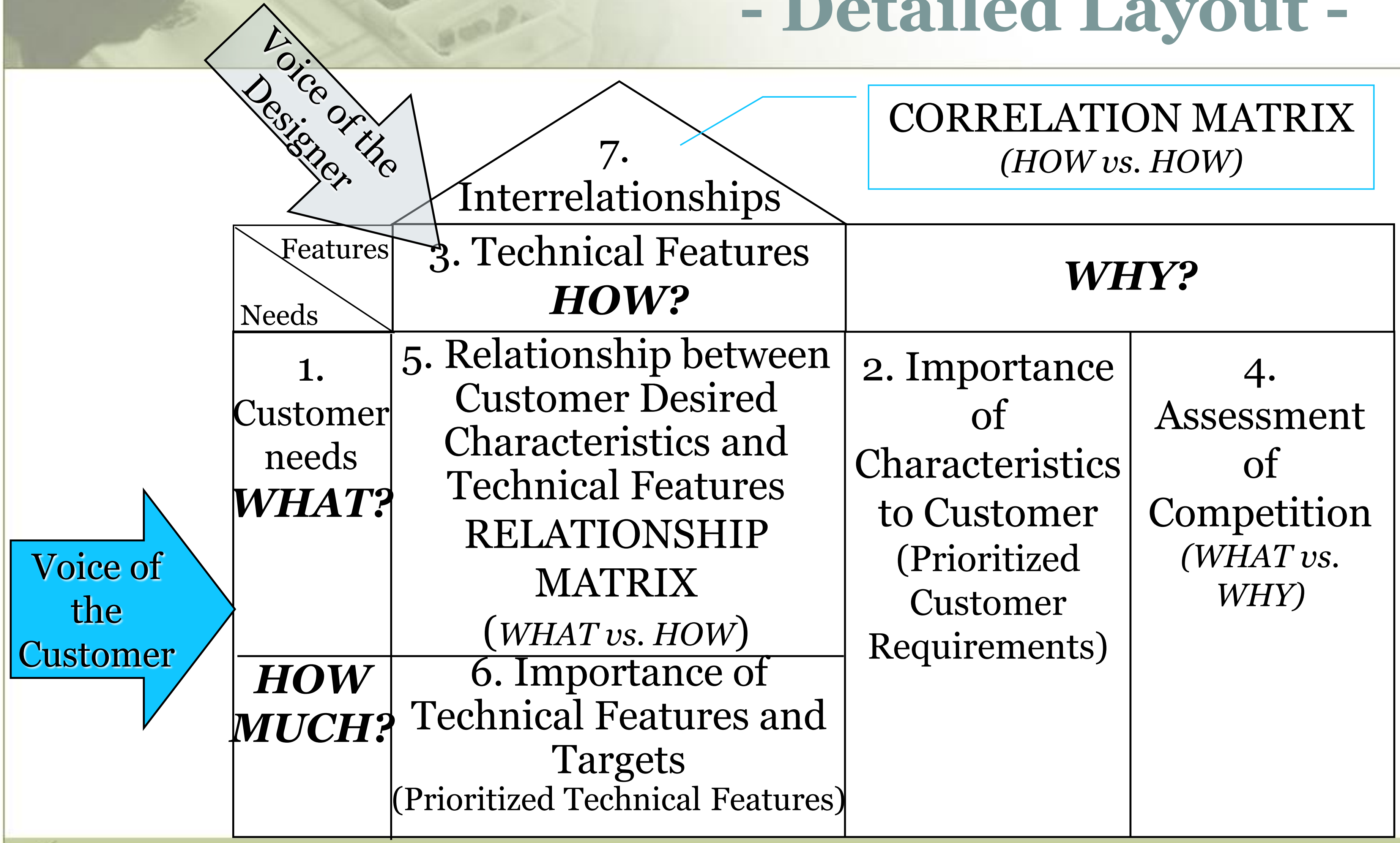
QFD - I. Product Planning

- Phase I is the most relevant part for the product quality, because it is the phase where needed information is devised.
  - Getting good data is critical for customer satisfaction. Any mistakes in identifying and translating requirements in this phase will produce major problems in the following phases.
- Key items in the product planning phase:
  - QFD team members selection
  - Who are the customers?
  - What are their requirements?
  - How important is each requirement?
  - How will each requirement be achieved?
  - Relationship Matrix between what and how
  - Which features are the most important?
  - Correlation Matrix between the product features
  - What target values should be established for each feature?

House of Quality

- The "House of Quality" is main working chart of QFD.
  - The chart documents clearly the translation of customer needs (referred to as the "***What?***"), which are often vaguely formulated or even implicit ones, into technical requirements (also referred to as target requirements or the "***How?***") of the product to be developed.
    - The left wall of house of quality lists the customer requirements.
    - The roof of the house shows if the technical requirements interrelate with each other and the strength of any.
    - The relationship matrix in the middle of the chart shows the interrelationship between the customer requirements and the technical requirements.
      - Weighting factors can be added to the customer requirements, as well as an estimation of competing products from the point of view of the customer.
    - Underneath the central matrix, target values for the technical requirements are plotted along with a technical assessment of competing products (benchmark).
    - At the bottom the weighted values (priorities) of the technical requirements are listed.

House of Quality
- Detailed Layout -



Steps for Building the House of Quality

1. Identify customers and their needs
2. Prioritize the customers' identified needs
3. Identify how the product/service will satisfy customers' needs
4. Evaluate competing products
5. Relate customer needs to product features
6. Set importance ratings for the product features
7. Identify relationships between the product features

House of Quality – 1st Step

- Identify customers and their needs (WHAT?)
  - "Voice of Customer"
  - Detailed list of product attributes desired by customer, expressed in customer's own language, usually as qualitative, vague, ambiguous, incomplete, or inconsistent declarations
  - Methods used:
    - Focus groups, 1-on-1 interviews, direct observation, market analysis, the seven quality tools

House of Quality – 2^{nd} Step

- Prioritize the customers' identified needs
  - Assign priorities to customer requirements, so as to focus the later analysis on the most relevant ones
    - Each requirement relevance is usually rated from 1 to 5, by consulting the customers, so as to illustrate their point of view
  - Methods used:
    - Surveys, market analysis

House of Quality – 3rd Step

- Functional Specification Step (HOW? and HOW MUCH?)
  - Voice of the Engineers or Designers
  - The product is defined in terms of how the product would meet the desired attributes and the product technical characteristics are identified, to be further deployed in the final product design
    - Each customer requirement is translated into designers' language
      - For example, if the customers require an "easy to use" product, how is it to be built? Should it be a simple product? Or an "easy to use" product by teenagers? Should we provide a comprehensive set of user's instructions?
    - Usually there are several potential choices for each product feature, but they have to be clearly quantifiable or measurable.
  - Targets are to be set for each technical feature selected.
    - 'How much' of each feature is good enough to satisfy the customer?
    - Even if the targets are not known at the time when the features are selected, they have to be determined through analysis and clearly stated in a measurable way, so as to describe how customer requirements are met.
  - Methods used:
    - Brainstorming, TRIZ, Taguchi methods, the seven quality tools

House of Quality – 4th Step

- Evaluate competing products
  - A competitive assessment analysis is performed to compare the new required product with the key competitors' products, to identify the extra features needed - providing a competitive edge
    - The main question raised is: "Why the product is needed?"
  - The customer should be involved to evaluate relevant existing products, by comparing each requirement and giving ranks from 1 to 5. The results help to position the product on the market.
  - Methods used:
    - Benchmarking, the seven quality tools

House of Quality – 5th Step

- Relate customer needs to product features
  - Correlate customer attributes with the technical product features (WHAT vs. HOW) and the strength of each relation
    - A weight of 1-3-9 or 1-3-5 is often used
    - More "strong" relationships are ideal
  - Methods used:
    - A relationship matrix chart, used to demonstrate the intensity of the relation for each pair of customer requirement – technical feature
      - Use marks or symbols to show weak, medium, and strong relationships

House of Quality – 6th Step

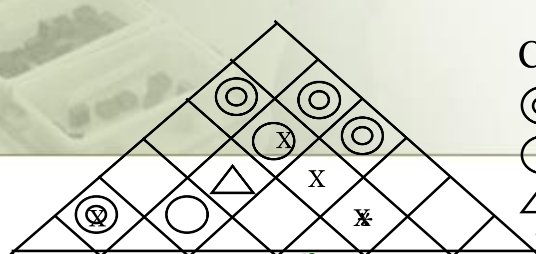
- Set importance ratings for the product features
  - Establish priorities of the product technical features
  - Methods used:
    - Priorities are set based on several criteria:
      - Overall importance ratings
      - Degree of technical difficulty
      - Technical competitive relevance

House of Quality – 7th Step

- Identify relationships between the product features
  - Show the correlations (positive or negative) between design features, in the roof of the house
  - The relative and absolute weights for technical features are required to choose the best fit engineering decisions for including the customers' requirements into the product design.
    - Features with a strong positive may be combined, to reduce product development effort
    - For features with negative correlation, it is required to find solutions (usually by changing targets or rankings), otherwise customer requirements will not be fully satisfied.
  - Methods used:
    - The intensity of the influence each feature has on the others is presented through the use of symbols in a correlation matrix.

House of Quality - Example

Product: **Umbrella**



Correlation:
- ◎ Strong positive
- ○ Positive
- X Negative
- * Strong negative

Customer Needs \ Engineering Characteristics	Importance to Customers	Force to open/close	Reliability	Colour Resistance	Dimensions / wight	Handling force	Water resistance	Competitive evaluation (X = our company, A = Comp. A, B = Comp. B, 5 is best; 1 2 3 4 5)
Easy to open/close	5	◎	○			◎		X AB
Stays open in the wind	5		◎			◎		X AB
Easy to transport it	3		○		◎			XAB
Doesn't leak in rain	5		◎				◎	A X B
Nice colours	2			◎				X A B
Importance weighting		9	9	3	3	9	3	
Target values		Reduce force with 20%	Improve with 20%	Min. for 500 using cycles	200 g., 60 cm radius, 80 cm length	Maintain current level	Maintain current level	
Technical evaluation (5 is best)	5 4 3 2 1	B A X	BA X	B A X	B X A	BXA	BA X	

Relationships:
- ◎ Strong = 9
- ○ Medium = 3
- △ Small = 1

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QFD Phase I - Output

- Product Technical Specifications, to be used as input in Phase II of QFD
  - Usually a review conducted by the technical team is made after completing the House of Quality, to ensure the feasibility and realization of each technical feature, and to point out any:
    - Technical advantages or disadvantages over competitor products
    - Conflicts between customer evaluations and technical team evaluations
  - Final overall importance ratings are calculated, function of relationship ratings and customer prioritization ratings.
  - Final ratings are used to determine the set of technical specifications / requirements needed for the next phase – product design.

QFD - II. Product Design

- It is the phase in which the product is designed:
  - How the product will be made, based on the technical specification
    - Materials, component parts, detailed drawings

QFD - III. Process Planning

- It is the phase in which the key processes needed to actually make the product are established:
  - How each part of the product and the product itself will be obtained, based on the product design
    - Processes, process characteristics, equipment and tools needed

QFD - IV. Process Control

- It is the phase in which it is established how to transfer into production the results of the design phase:
  - How each key process should be operated and controlled to ensure the designed results, based on customer’ input
    - Work standards and instructions

Key Benefits of QFD

- Focus on customer needs, leading to increased customer satisfaction
  - Improved formulation of requirements lists through a better understanding of customer requirements
  - Identification of critical product functions (customer-oriented function structures)
  - Definition of critical technical requirements and identification of critical components
- Reduction of the total product design costs, by avoiding trial and error cycles during the product life cycle
  - Design costs reduced by 30% to 60%
  - Engineering changes cut by 30% to 50%
  - Design time reduced by 30 to 50%
  - Start-up costs reduced by 20% to 60%
  - Warranty claims cut by 20% to 50%

Disadvantages of QFD

- QFD is very resource consuming – it requires a lot of time, energy, and patience to achieve the benefits.
- QFD requires full management support
  - Cross-functional QFD team
  - Resources available to perform the QFD phases
  - QFD does not reduce product development costs. Moreover, initial costs will be higher compared with traditional designing techniques, even if on long term, savings are to appear during the product life cycle.
- The extensive effort needed to complete every stage of QFD is only justified only for major long-term product development projects or for very complex and expensive products.

VALUE METHODOLOGY

- "The systematic application of recognized techniques which identify the functions of the product or service, establish the worth of those functions, and provide the necessary functions to meet the required performance at the lowest overall cost." *(John M. Bryant, VM Standard, Society of American Value Engineers, Oct. 1998)*

- Value means: $\dfrac{\textbf{Function}}{\textbf{Cost}}$

Value Engineering (VE)

- VE is an intensive, interdisciplinary problem solving activity focusing on improving the value of the functions required for a product / process / service / organisation.
- Benefits:
  - Reduced complexity of products
  - Additional standardization of products
  - Improved functional aspects of product
  - Improved job design and job safety
  - Improved maintainability of the product
  - Robust design

The Six Steps of VE

Phase	Description
1) Information Phase	Problem(s) to be solved, information gathering on the functions and requirements of the product / process / system
2) Creativity Phase	Brainstorm ideas on how to reduce the high costs, broken or inadequately performed key functions
3) Evaluation Phase	Screen ideas for acceptance, rate and rank ideas, group ideas into categories, develop design scenarios, set selection criteria
4) Planning Phase	Plan how to sell ideas to management, identify key recommendations, plan management presentation
5) Reporting Phase	Give oral or written presentation to management
6) Implementation Phase	Get management approval for starting the implementation, make management plan, perform assignments, follow-up.

Value Analysis (VA)

- VA aims at achieving equivalent or better performance of a product, at a lower cost, while maintaining all functional requirements defined by the customer.
  - Does the product have any design features that are not necessary?
  - Can two or more parts be combined into one?
  - How can the weight or material consumption be reduced?
  - Are there nonstandard parts that can be eliminated?
- It is more used for design improvement during production phase:
  - Lists products in descending order of their individual sales income
  - Lists the total annual sales income for the analysed product
  - Helps management evaluate alternative strategies.

D. Product/Service Design

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Product/Service Design

- Product Design
  - Specifies structure, components
  - Specifies materials
  - Determines dimensions and tolerances
  - Defines appearance, aesthetics, ergonomics
  - Sets performance standards
- Service Design
  - Specifies what the customer is to experience
  - Determines setting and degree of customer involvement
  - Defines physical items, physiological benefits, and psychological benefits the customer receives
  - Sets standards for delivery

Product Design Phase Output

- Design Documents
  - Engineering drawings
    - Showing dimensions, tolerances, and materials
  - Bill of Material
    - Product detailed structure
    - List of components, quantities and where used

Design Methodologies

- There are many approaches and several tools possible to be used:
  - Design for the customer
    - The last three phases of QFD, as previously discussed
  - Design for quality
    - Functional design
      - Design for reliability
        - Fault tree analysis
        - FMEA
      - Design for maintainability
    - Robust design
    - Configuration management
    - Reverse engineering
    - Design for manufacturability
    - Modular design
  - Value analysis, as discussed previously
  - Environmentally friendly design (Green design)

Design For Quality

- Achieving product quality is equivalent to building-in quality starting with the design process and to maintaining it throughout the production process and the product life cycle.
  - Up to 80% of all faults can be traced back to insufficient product planning, design and development.
  - Up to 60% of all breakdowns that occur within the warranty period are caused by incorrect or incomplete product development.

Functional Design

- Design for Reliability
- Design for Maintainability

Functional Design

- Functional design approach focuses on finding the best suitable product configuration for meeting best product operation objectives, knowing that no product is 100% certain to function properly during its life cycle. The issues addressed during the functional design:
  - Product availability
    - Availability: the proportion of time in which a system is in a proper functioning condition; free of failures status
  - Product reliability
    - Reliability: the probability that the product, service or part will function as expected for a specified length of time
  - Product maintainability
    - Maintainability: ease of maintaining the product in function or of repairing the product
  - Product safety
    - Safety: the state of being "safe“ against different types or consequences of failures, damages, errors, accidents, harms or any other events which could be considered as non-desirable.
- It includes also the design for recycling after completing the product life cycle.

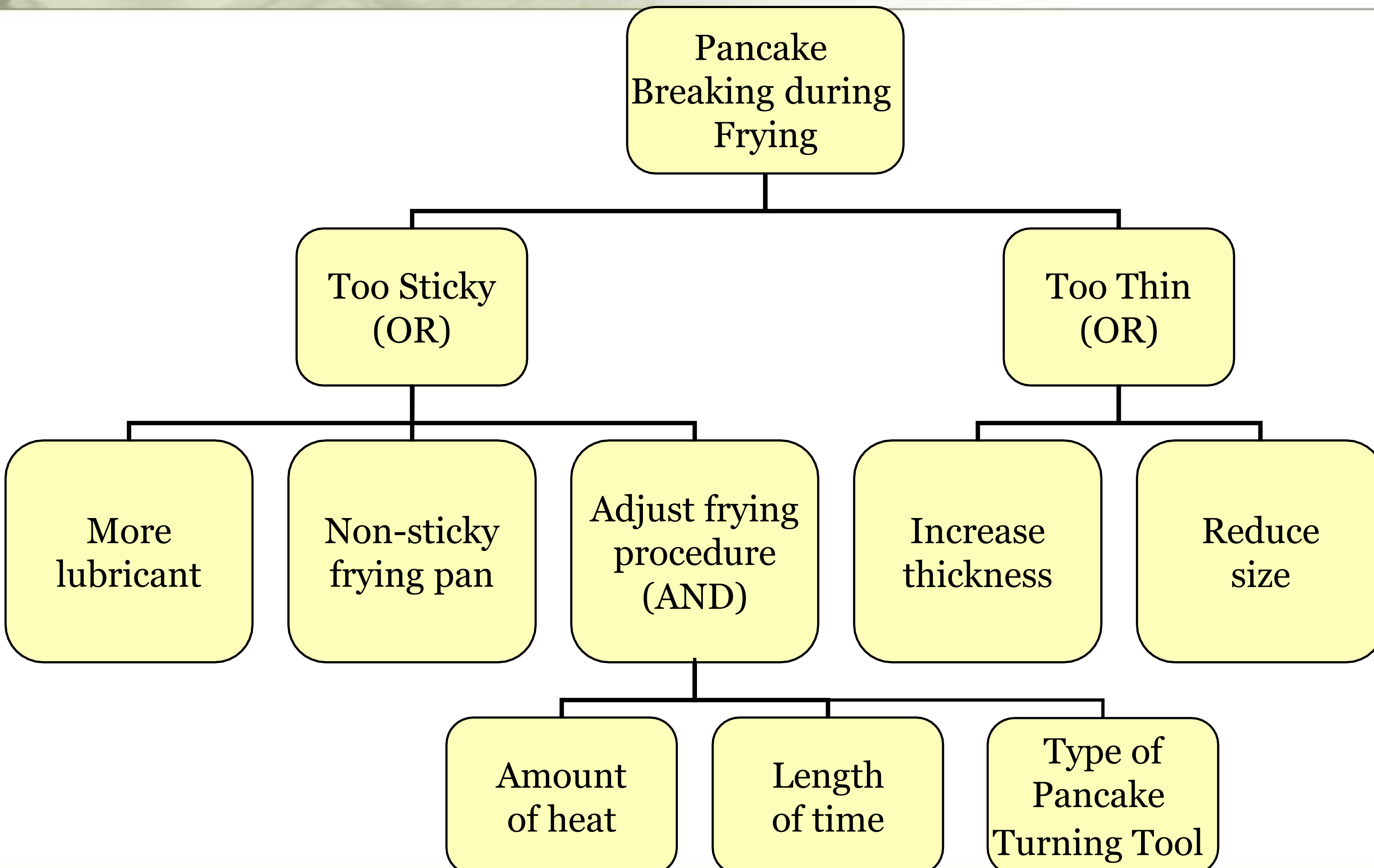
Design for Reliability

- Reliability means fault free design
  - Failure reduction through design measures such as:
    - Compensating the action of the disturbing factors (principle of balanced forces)
    - Selecting working principles and structures in which the properties are largely independent of the disturbing factors
    - Choosing interfacing elements that do not require close tolerances.
- There are two main tools used to analyzing potential failures:
  - Fault tree analysis(FTA)
    - A visual chart showing the interrelationship between failures, assisting designers in the refining of the product design
  - Failure Mode and Effects Analysis (FMEA)
    - A systematic approach for analyzing the causes of failures, prioritizing the effects of failures and attempting to find solutions to eliminate causes of all critical and major potential failures
    - Apart from evaluating possible malfunctions caused by failures and disturbing factors, FMEA encourages early cooperation between the various departments involved in product development. It also functions as a means of handing over to production and supporting the overall quality management process.

Fault-Tree Analysis (FTA)

- FTA systematically explores the influence of faults, disturbing factors and possible failures on the proper functioning of a system.
  - FTA is based on causality, i.e. every undesired event is considered to have at least one cause, and that event only occurs when its cause is manifesting.
  - The established function structures can thus be used to identify all the functions to be checked. Considering these functions failing one by one, designers seek out the possible causes of these potential failures.
    - An identified cause may be associated with further causes with which it has an OR or an AND relationship. These causes and their effects can then be examined.
    - Grouping the remedial measures according to the departments involved simplifies their execution.
  - On the basis of the information gained from a fault-tree analysis, designers are able to improve and complete the product design before they proceed to the process design phase, and, if necessary, re-examine the solution concept or modify production, assembly, transport, operation and maintenance procedures, in later phases of the product life cycle.

Fault Tree Analysis - Example



Failure Modes and Effects Analysis (FMEA)

- FMEA is a structured approach used to analyse possible failures - to identify, estimate, prioritize, and evaluate risk of possible failures at each stage in the product life cycle, in a more extensive way than can be done with Fault-Tree Analysis.
  - It involves a direct analysis of failures and their consequences and causes.
  - FMEA may be used for:
    - Products, during the product design phase, to verify whether the functions set out in the requirements list are possible to be fulfilled.
    - Processes or production, to verify whether the planned production process can produce the required product characteristics and to eliminate risks of failures.
- It requires a cross-functional team, including members from design, development, production planning, quality control, purchasing, sales and customer service.

Use of Product FMEA

- FMEA implies creating a matrix listing possible failures, their consequences, causes, risk numbers (RN), proposed remedial solutions.
- The steps of FMEA:
  - Risk analysis of each component (or process step)
  - Risk assessment:
  - Risk number calculation
    - RN > 125 is usually considered critical
  - Risk minimisation

FMEA Steps

1. Risk analysis of each component (or process step) regarding:
   - Potential failures and failure types
   - Failure consequences
   - Failure causes
   - Planned measures to detect failures
   - Planned measures to avoid failures
2. Risk assessment:
   - Estimation of the probability of occurrence
   - Estimation of the effects of the failure on the customer
   - Estimation of the probability that the failure can be detected before delivery
     - A high probability of detection implies a smaller risk for the customer, therefore a smaller numerical value.
3. Risk number calculation (RN), based on:
   - The probability of occurrence (O)
   - The severity of failure (S)
   - The difficulty of detection (D)

RN = O x S x D

3. Risk minimisation
   - Development of measures to improve the design of the product (or its production process).

FMEA - Example

Product: an **outside fresco** (paint onto wet plaster on an outside wall)

Failure Mode	Causes of Failure	Effects of Failure	Corrective Action
Discoloration	Environmental factors – light, humidity, heavy rains, freeze/heat cycles	Shades, stains, spots, traces, colour unevenness	Add coatings in several layers, change paint formulas, protect the surface against environmental factors
Fissured paint layer	Layer too thin or too brittle, improper painting technique, improper paint storage or handling	Falling paint strips, deteriorated appearance, rough texture	Change paint recipe, change painting process, change paint packaging or storage conditions
Fading image 	Paint colours too faint, limited contrast, shapes too small to be seen from distance	Unclear visual appearance, difficult to discriminate shapes and colours	Change colours used, change paint recipe to increase resilience, use better painting techniques

Design for Maintainability

- A concept that states that products should be designed in a way that makes them easy for consumers to maintain them in use and to readily repair them, if needed.
  - Concepts
    - Components easily replaceable
    - Components easily removable with standard tools
    - Adequate access to perform maintenance activities
    - Non-destructive disassembly
    - Safe maintenance
    - Available manuals and documentation for users
    - Ease of delivery of maintenance

Robust Design

- The product should be designed so as small variations in production or assembly or operation do not adversely affect the product.
  - A product or service demonstrates robustness if it performs with same results, regardless of the operating conditions.
  - Designers must consider both controllable factors (design features) and uncontrollable factors (operating conditions) when designing for product robustness.

Configuration Management

- In the product design phase it is better to define also recommendations for configuration management:
  - A system by which a product's planned and still under changing components are accurately identified and for which controls and accountability of change are maintained.
- Configuration management provisions are needed for complex products or services, more than ever when the customers requirements evolve very rapidly.

Reverse Engineering

- A design approach used to dismantling and inspecting of a competitor’s product, as to discover useful product improvements.

Design for Manufacturability

- Manufacturability
  - It means the ease of fabrication and/or assembly, which has relevant consequences during the product life cycle, on:
    - Costs
    - Productivity
    - Quality

Design for Manufacturing and Assembly

- A design approach focusing on the simplification of the product, by reducing the number of separate parts, an easy and economical production:
  - During the operation of the product, does the part move relative to all other parts already assembled?
  - Must the part be of a different material or be isolated from other parts already assembled?
  - Must the part be separated from all other parts to allow the disassembly of the product for adjustment or maintenance?
- Some of useful solutions of designing for manufacturability:
  - Use recommended parts and strategic suppliers
  - Products are designed to be consistent with internal and external process capabilities
  - Modular designs/ease of configurability
  - Concurrent Product and Process Design

Modular Design

- A design approach used to create products made by easily segmented components.
  - It adds flexibility to both production and product development

Environmentally Friendly Design (Green Design)

- There are several design approaches, considering some of the following aims:
  - Design for Reuse
    - Designing products so that some of their parts to be used in later generations of other products.
  - Design for Disassembly
    - A method for developing products so that they can easily be taken apart.
  - “Green” Design
    - Make products recyclable
    - Use recycled materials
    - Use less harmful ingredients
    - Use lighter components
    - Consume less resources: energy, materials, water, etc.

E. Process Design

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Lifelong Learning Programme

Process Design

- There are several steps to be performed:
  - Make-or-buy decisions for each part of the product
    - Decide whether or not is better to produce or purchase each part of the product to be built
  - Selecting the ‘right’ processes
  - Create workable instructions for production processes
  - Select tooling and equipment
  - Prepare job descriptions
  - Determine operation and assembly order
  - Planning to network all systems needed for actually making the product

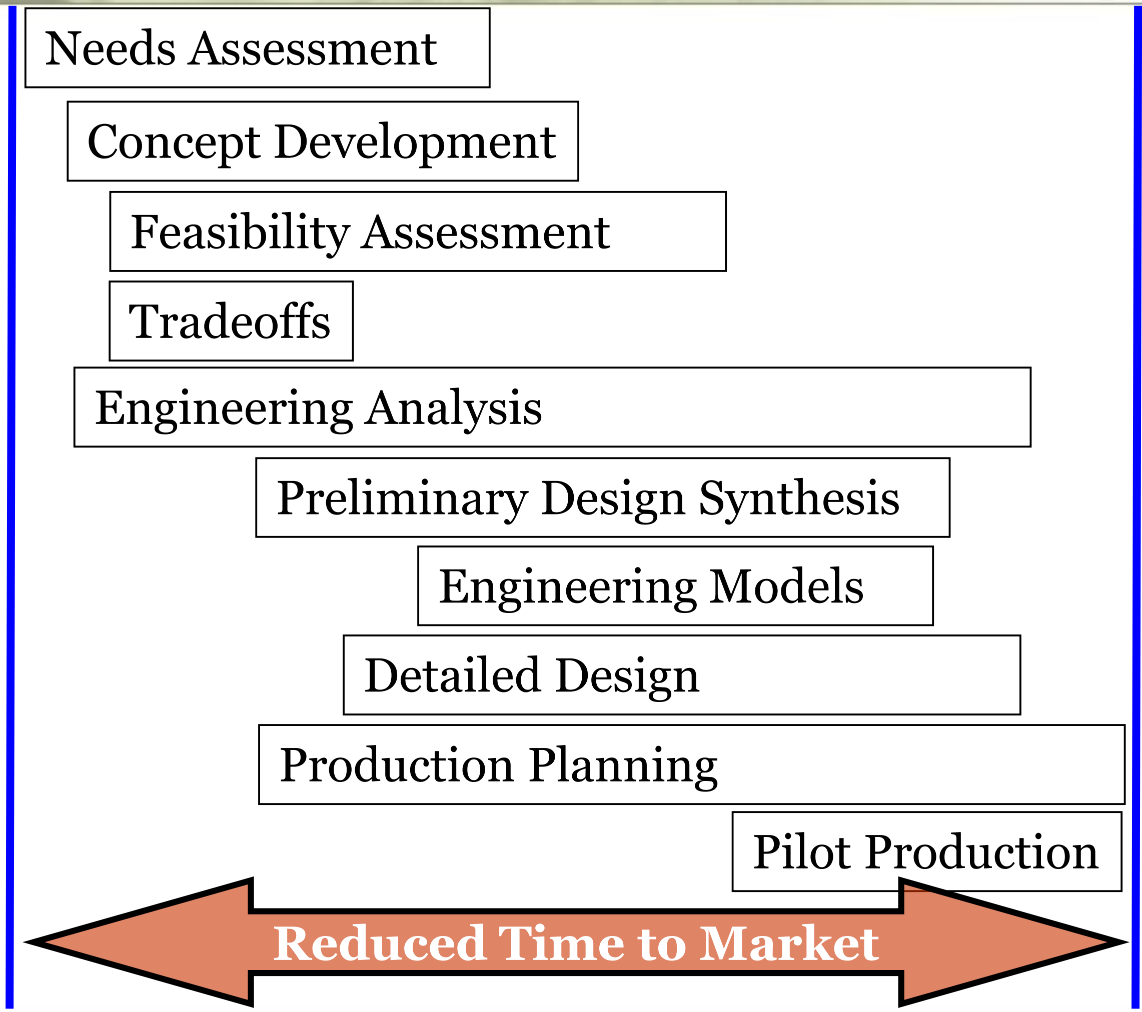
Selecting the Processes

- Finding the 'right' production processes
  - An effective production process must be
    - Executable
    - Structured
    - Applicable
    - Providing follow up mechanisms
    - Focus upon measurable outcomes
    - Apply to every level of product
- Some actions are needed for smoothing the transfer from R&D towards Production
  - Concurrent design
  - Fail-Safe Design
  - Analyzing functional design (design for reliability and for maintainability)
  - Measuring design quality
  - Utilizing QFD
  - Designing for robustness

Concurrent Design

- Also known as simultaneous or concurrent engineering
  - Cross-functional design teams
    - Customers, design, production, marketing, engineering, suppliers
  - Simultaneous development of project design functions, with open and interactive communication among all team members for joint decision making
    - Aims to completing as many tasks in parallel as possible, even if some individual tasks are completed with lower efficiency
  - It integrates product design and process planning
  - Details of design more decentralized
  - Encourages price-minus, not cost-plus pricing
  - Needs careful scheduling because tasks are done in parallel

Concurrent Engineering Development Model



Source: Clausing, D., *Total Quality Development,: A Step-By-Step Guide to World Class Concurrent Engineering*, ASME Press, NY 1994, pp. 35

Fail-Safe Design

- Shingo observed that SQC methods do not prevent defects, which arise when people make errors. So he recommended to include in the process design phase the concern to prevent possible defects by providing workers with rapid feedback on errors or abnormalities emerged during production processes.
- Shingo developed the Poka-Yoke methodology, also known as Mistake–proofing, which includes:
  - Checklists
  - Special tooling that either prevents workers from making errors, or provides rapid feedback on abnormalities, in time so as the worker could correct them

Process Design Phase Output

- Process Design Documents
  - Assembly drawings
  - Assembly charts
  - Route sheets
  - Work orders

F. Design Review and Product Design Improvement

- Before transferring the product design towards the production area, a final design review is required, as to validate the chosen solutions and to make improvements, if needed.
  - Methods used:
    - Quality engineering
    - Quality Loss Function
    - Robust Design

Quality Engineering

- Quality engineering is an approach originated by Genichi Taguchi
  - It combines engineering and statistical methods to reduce costs and improve quality by optimizing product design and manufacturing processes.

Quality Loss Function

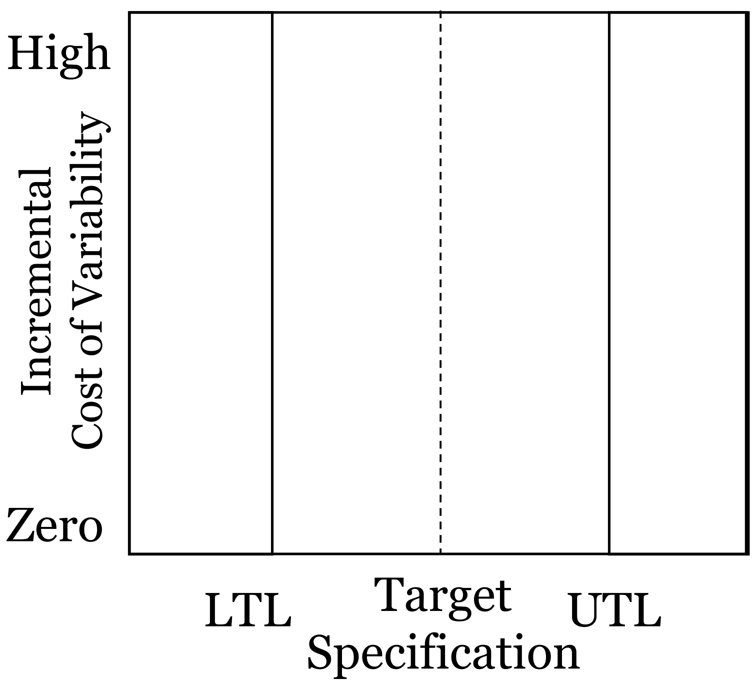
- Quality Loss Function starts from the basic idea that quality is measured through customer satisfaction and states that a service or a product that barely conforms to the specifications is more likely to be a defective service or product, than a perfect one.
- Quality Loss Function is optimum (zero) when the product's quality measure is equal to the target measure.
  - All variation (+/-) from optimal measure results in a loss.
  - The method defines the Quality Loss as 'Loss to Society' and it quantifies it through the "Quality Loss Function".

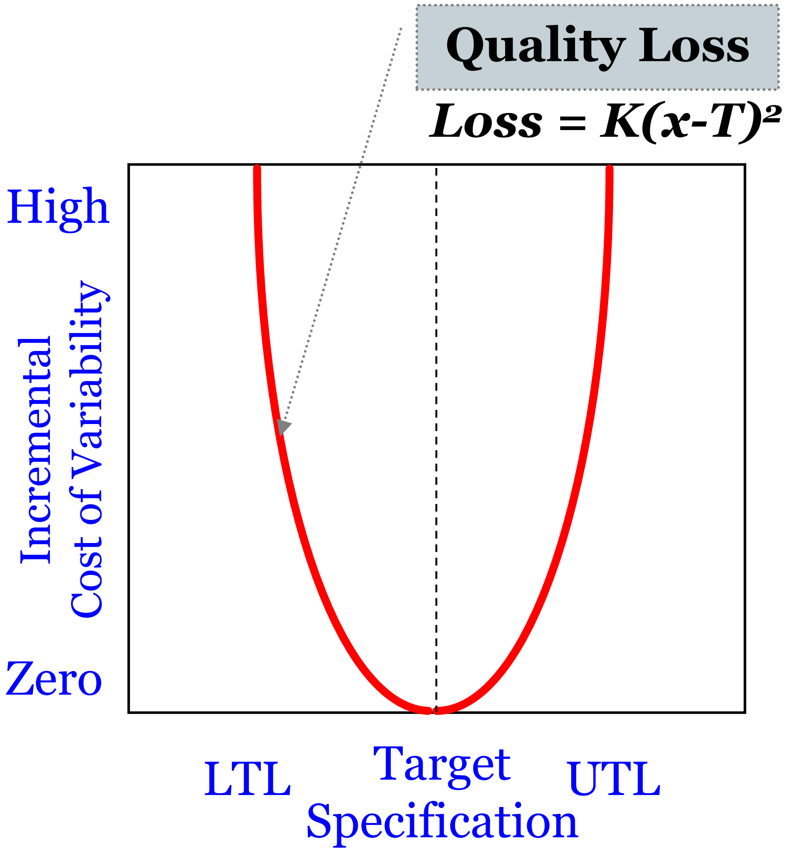
Quality Loss Function (2)

- The Loss Function
  - Quantifies the decline of a customer's perceived value of a product as its quality declines
  - Tells how much revenue is lost because of variability of the production process
  - It is a powerful tool for projecting the benefits of a quality improvement program
- Taguchi's View of Variation
  - Traditional view is that quality within the lower tolerance limit (LTL) and the upper tolerance limit (UTL) is good and that the cost of quality outside this range is constant.
  - Taguchi's view is that costs increase as variability increases, so minimizing quality costs means achieve zero defects level.
    - Any deviation from target involves a loss, no matter how small it might be!

Quality Loss Function (3)

Traditional View





Taguchi's View

The Loss Function – Example 1

- The specifications for a product have LTL= 8 and UTL=14, with a target of 11. If 10% of the products are produced at exactly 8, 50% on target and 40% at exactly 12, what is the loss function value?
  - Solution:

$$L=0.1 \times K \times (8-11)^2 + 0.5 \times K \times (11-11)^2 + 0.4 \times K \times (12-11)^2$$

$$L = 0.9K + 0.4K = 1.3K$$

(where K is an arbitrary constant)

The Loss Function – Example 2

- A company issued an average of 10 wrong invoices per month last year. In March they had 15 wrong invoices (x). Management sets an acceptable level at 2 per month (tolerance).
- It is known that the costs to correct one invoice is 50 Euro. They determined the cost in delayed payable accounts to be 100 Euro.
- Total cost per wrong invoice: 150 Euro.
- What is the loss function value?

k = 150 Euro / 22 =37.50 Euro

L(x) = 37.50 (15-10)2
= 37.50 (5)2
= 37.50 (25)
= 937.50

- The loss for the month of March is of 937.50 Euro.

2.2. Design for Lean

- Lean Product Design
- Design for Lean

Product Design
Traditional vs. Lean Approach

- Designing activities are performed as soon as possible.
- Decisions are made sequentially by specialists who then pass them over downward on the flow
  - Product design is completed, then process design begins.
- Not all product life cycle stages are considered in design.
- Designers build up large knowledge inventories to protect their own interests.
- Stakeholder interests are not aligned.
- Learning occurs sporadically.

- Activities are planned to be performed at the last responsible moment.
- Downstream players are involved in upstream decisions, and vice-versa.
  - Product and process are designed together.
  - Systematic efforts are made to optimize supply chains.
- All product life cycle stages are considered in design.
- Buffers are sized and located to perform their function of absorbing system variability.
- Stakeholder interests are aligned.
- Learning is incorporated into the design process.

Lean Design

- Lean design involves both
  - Simple, standardized, efficient, robust product development and design processes, with maximum value added and minimum waste, including:
    - Integrating events instead of quality checks
    - Late concept selection with more knowledge
    - Managing organizational capacity versus demand
    - Project teams "own the business"
    - Team leadership, team design, supplier integration
    - Simple technology to fit team needs and processes
      - Tools used:
        - Knowledge management, Target Costing, Value Engineering, Six Sigma, Brainstorming, TRIZ

AND

  - Design for Lean Manufacturing
    - Planning for Lean production process

Key Principles of Lean Design

- Well-integrated basic elements of product development
  - Highly skilled and well organized cross-functional design teams
  - Processes that minimize waste and maximize the capability of people using them
  - Technologies that enhance the performance of people and processes
- Customer first philosophy
  - Understand customer defined values
  - Strive to give defined values to customer

Source: Superfactory™

Key Principles of Lean Design (2)

- Knowledge based organization
  - Learning and continuous improvement as part of job
- Standardization
  - Skills
  - Design standards
  - Processes/milestones/deliverables
- Reuse
  - Knowledge/experience
  - Design/design alternatives
  - Parts/configuration

Source: Superfactory™

The Six Step of Lean Design

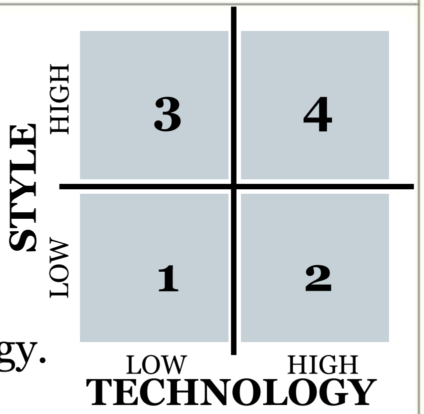
1) Cross-Functional Teams	Involve downstream players in upstream decisions , create and exploit opportunities to increase value in every design phase
2) Set Based Strategy	Select from alternatives at the last responsible moment, share incomplete information, share ranges of acceptable solutions
3) Structure Lean Design	Simultaneous design of product and process, decisions for making or purchasing the components, detailed engineering, and design
4) Minimize Negative Iteration	Pull scheduling, Design Structure Matrix, strategies for iterative loops
5) Process Control Planning	Set quality controls for the processes, measure deviations from target, identify risks and act for improvement
6) Technologies Fit for **Lean Design**	Technologies enabling simple, standardized, efficient, robust processes

Lean Concepts in Design

- Value
- Value added activities
- Waste
- Pull and flow
- Workcell
- Team empowerment and ownership

Defining Value

- Value is broken down into specific attributes required by the customers, i.e. the quality dimensions.
  - Method used: a matrix relating product style and technology.



1. Typically generic, well established technologies. Minimal lifestyle impact, features, and technology. These products provide price driven functionality. Profit is made by high volume and low margin per item.
2. Technology driven products. Higher features, but less concern for lifestyle ergonomics. Often first product of their type, so advantage comes from novelty and high performance. Profit is made by early adopters who will pay for new technology, but is typically not sustainable.
3. Products driven by style, typically focus on aesthetics but ignore ergonomics and features. Profit comes from consumers seeking new fads.
4. Products that integrate style and technology in order to add value to the consumer. These products differentiate themselves from the competition and define the state of the art. Possible to cost more to design and produce, but consumers are willing to pay more.

Value Added Activity

- Finding waste in product design process is difficult, because the main flow is of immaterial 'products':
  - Sometimes there are physical outputs: drawings, reports, lists, sheets, but the aim of the design process is not to produce a bunch of written documents, but to document the relevant knowledge needed to produce the product able to satisfy the customers' needs.
    - Knowledge about customers, about technologies and process capabilities, integrated into specific knowledge about how to make the designed product
    - The relevant knowledge often resides only in the minds of the design team members and finding waste is rather a 'creative' task and requires open minded designers.
- Knowledge is the medium through which value is added during design
  - Value added activities include relevant knowledge into the design.
  - Waste (even if necessary) does not add value to the design.
    - Waste usually concerns knowledge acquisition and management activities.
    - All activities referring at compliance will invariably not add value to the design

The 7 Wastes in Product Design - Examples

- Defects: *misidentified customer needs, bad or obsolete data, drawing or code errors, misfit features to customer needs*
- Overproduction: *future proofing design, feature inflation, poor synchronization, working with incomplete requirements, not using standard parts*
- Waiting: *waiting for data, people, machines, specifications; more workload than capacity, excessive multi-tasking, delays due to reviews/approvals/testing/deployment/staffing over workloaded*
- Excessive processing: *lack of design for reuse, unnecessary features, unnecessary items specified, too many approvals required, too much "paperwork"*
- Transport: *dispersed design teams, excessive data transfer, excessive approvals and controls, repeated task switching on multiple projects*
- Inventory: unnecessary data storage, work-in-process exceeding capacity
- Motion: *dispersed design data (data hunting), excessive engineering changes, requirements changes moving info from one person/group to another*

Other Types of Wastes in Product Design

- Common Waste in Product Design Process:
  - Reinvention
    - Lean product design teams appreciate the value of knowledge, and ensure that knowledge is easy to capture, easy to reuse and always used to make decisions. Traditional product design teams prefer to 'reinvent' knowledge when access to already existing one is not obvious.
  - Excess Requirements
    - Lean product development teams recognize that every extra feature or performance enhancement must be designed, produced, maintained and supported – and customers pay the price in greater complexity and greater risk of failure.
  - Overloaded Resources
    - Lean product development teams know that overloading resources makes them slower and less flexible, and that task-switching costs engineers valuable time. Traditional product design teams work as hard as possible, sometimes only from pure passion.
  - Un-integrated Design
    - Lean product development teams strive to understand and then manage their designs as an integrated system, so that they can focus innovation on areas that improve the market performance of their entire portfolio of products. Traditional product design teams raise walls between functional departments and sometimes prefer to be in competition with people from Marketing or Production.

Source: Superfactory™

Pull and Flow in Lean Design

- Lean design includes process definition and production value streams
  - Pull systems:
    - Activities performed according responsibility based planning
      - Everyone starts when they must to meet the gates, seeks information as needed
    - Knowledge, customer-driven milestones
    - Set-based design
  - Push systems:
    - Activities performed according task-based planning
      - Built around *tasks*: begin and end at certain planned points

Set Based Design

- It is the concurrent approach used by Toyota for the product development process. It includes:
  - Identify and sequence key design decisions
  - For each decision, generate multiple design alternatives and the criteria for evaluating them
  - Determine the last responsible moment for decision making
  - Evaluate and choose from alternatives
  - Document each key design decision: alternatives, criteria, evaluation and selection
  - Produce 5 or more times the number of physical prototypes than their competitors
  - Reject changes that expand, rather than contract, the space of possible designs.
  - Put new products on the market faster than their competitors and at less cost.

Tools for Lean Design

- Pugh Method
- Waste Reduction
- Brainstorming
- Problem Solving Methods
- QFD
- Target Costing
- Design For Six Sigma
- Queuing Theory
- Project Management
- Design Tools
- Knowledge Management
- Value Engineering
- TRIZ
- Prioritization Methods

Target Costing

- Henry Ford used Target Costing around 1920's:
  - "We have never considered any costs as fixed. Therefore we first reduce the price to a point where we believe more sales will result. Then we go ahead and try to make the price. We do not bother about the costs. The new price forces the cost down." (Henry Ford, My Life and Work, 1922)

Designing to the Target Cost

- Steps to be performed:
  - Allocate the target cost to systems, subsystems, components, …
  - Form teams by 'systems' – each team has a cost target to meet with the design
  - Establish a personal relationship between designers and cost experts in each system team.
  - Ask cost experts to provide cost guidelines to designers before design begins.
  - Require designers to consult cost experts on the cost implications of design alternatives before they are developed.
  - Incorporate value engineering/value management tools and techniques into the design process.
  - Periodically bring all teams together, to make sure they are not sacrificing project-level value to local 'system' optimization.
    - It is also used to include suppliers in these discussions – suppliers are expected to meet cost goals, but are also expected to make a profit.
  - When meeting or beating the target cost, release funds for adding back lower ranking values or other scope additions valuable to the client.
  - Schedule cost reviews, but develop design and cost concurrently
    - Constant monitoring of product cost by Purchasing and Manufacturing
  - Use computer models to automate costing to the extent feasible.

Lean Indicators

- Time-to-market
- % NVA Activities
- Product Unit Errors
- % of Waiting Time in Progress
- Productivity
- Quality

Performance in Product Design

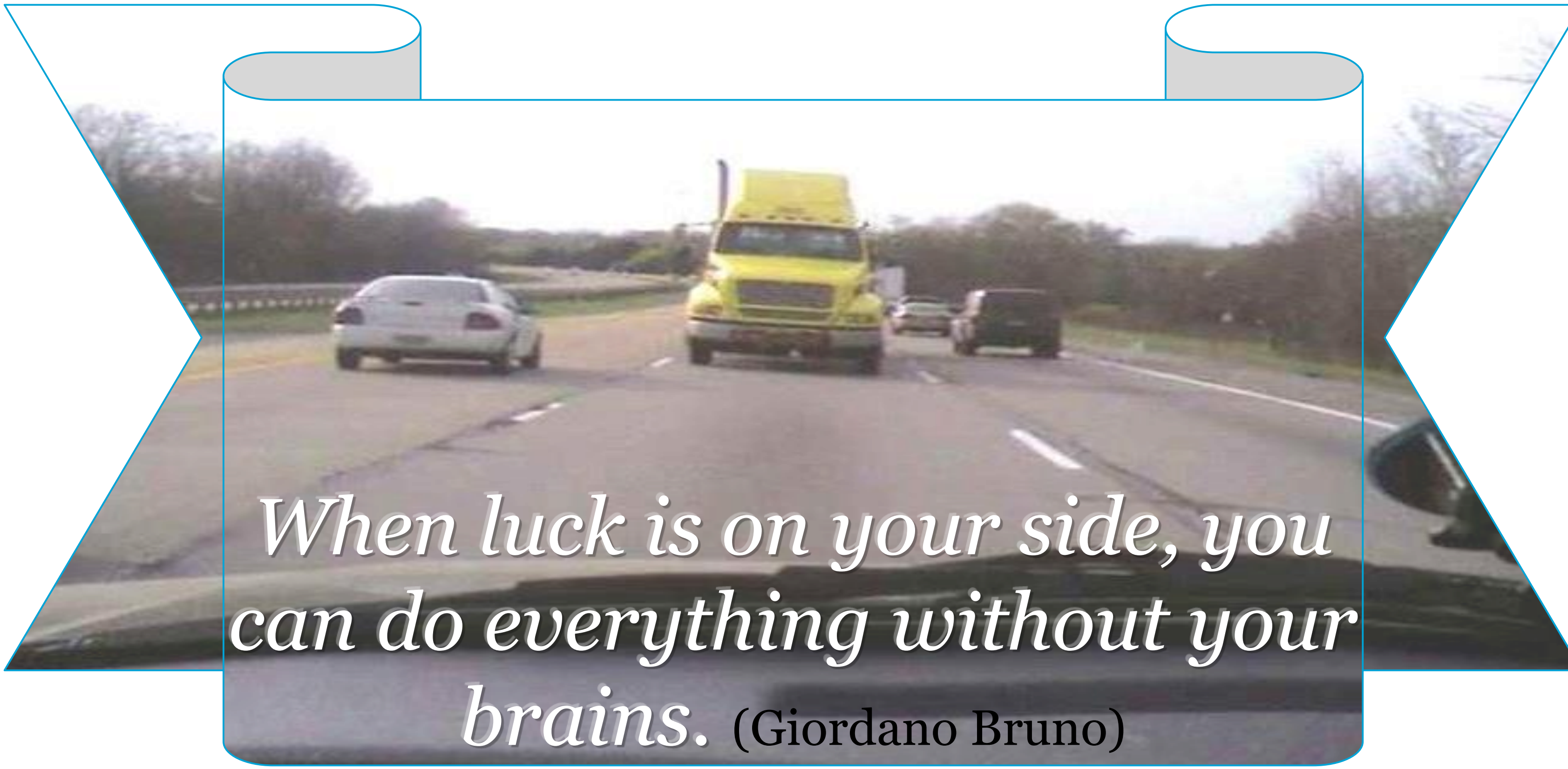
As the customer has required.

As Marketing understood it.

As the customer received it.

As it was designed.

Quote



When luck is on your side, you can do everything without your brains. (Giordano Bruno)

3. Quality Control

3.1. Quality at the Source

3.2. Quality Process Mapping

3.3. Quality Analysis Matrix

What is Quality Control (QC)?

- Control – the activity of ensuring conformance to requirements and taking corrective action when necessary to correct problems
- Quality Control:
  - A process to ensure a certain level of quality of the product or service completed during the production process.
  - It helps ensuring quality at the source
  - It involves a QC team to check the product / service / process / people.
    - Usually it is not the responsibility of QC team to correct problems observed.

Use of QC

- Quality Control means reducing dispersion; it has no adequate results unless the process is stable.
  - Any process has a large diversity of variation opportunities. It is obvious that excessive variation results in product failures, unhappy internal/external customers, and unnecessary costs.
  - Employing QC techniques requires a stable process:
    - A stable process is a process in which the key measures of the output from the process show no signs of special causes for variation - variation is a result of common causes only.
    - An unstable process is a process in which the key measures of the output from the process show signs of special causes in addition to common causes. Variation is a result of both common and special causes.

3.1. Quality at the Source

- The philosophy of making each worker responsible for the quality of his or her work.

3.1. Quality at the Source

- Quality products come from quality sources.
- **Quality at the source** is a philosophy whereby defects are caught and corrected as closest as possible of where they were created. Accordingly, quality at the source is the approach considering that it is better to uncover source of quality problems and correct it as soon as possible, before the product leaves downwardly on the process flow.
- Even if quality is built into the process, additional non-quality sources may appear during operations and additional contributing Techniques can be employed to have quality at the source :
  - Sequential Inspection
  - Stop the line / Fix the problem
  - Failsafe Devices
  - Standardized Parts and Processes
  - Design for Manufacturability
  - Operator Checklists
  - 5S
  - Vendor Base Reduction
  - Supplier Development

Sequential Inspection

- It is based on the ‘internal customer’ concept.
  - Each operator has to think of him/herself as a "customer“, receiving a product or a task from the preceding operation, which is considered the "supplier". Therefore, each internal ‘customer’ has the right to expect a quality product from the internal ‘supplier’.
- Sequential inspection identifies the key attributes that each operator should check prior to performing his/her own operation.
  - In this way, the nonconforming product stops at maximum at the next step on the process flow, immediate feedback is sent to the causing area. Consequently, the number of defects that can be produced before discovery is minimum.

Stop the Line / Fix the Problem

- Stop the Line / Fix the Problem (also known as Jidoka) - the name of the technique gives a clear indication on the activities needed to be performed to increase quality at the source:
  - The workers have the right to stop the production line whenever a non-conforming product occurs.
  - In this way, it is obvious that the quality at the source increases, as a spotlight is put on every defect, on its occurrence, source and causes.
  - Production resumes only after the problem has been solved and a correction action was put into practice.
  - Furthermore, after correcting the problem, a clear accountability has to be assigned, so as to “failsafe” the process against problem recurrence.

Failsafe

- Failsafe or Poka Yoke or ‘Zero Defects’ approach is the technique of making an operation "incapable of producing a defect".
  - Once the cause of a defect has been discovered, a failsafe device should be introduced to enhance the process robustness - either it can no longer be possible to produce that defect, or signalling immediately the defect occurrence, for human adjustment / correction. Consequently, a failsafe:
    - Eliminates the cause of an error at the source
    - Detects an error as it is being made
    - Detects an error soon after it has been made but before it reaches the next operation.
  - Common failsafe devices include *go/no-go gauges, limit switches, optical sensors, weight checkers, torque wrenches, on-machine gauging, lock-up devices, part re-design, one-way fixtures, parts standardization*, etc.

Standardized Parts and Processes

- The basic idea in using standardization is to minimize the "opportunity for error".
  - Standardization increases process efficiency, but has also several other benefits:
    - For example, the likelihood of installing a wrong part is reduced.
    - Learning process helps both quality and efficiency.
    - It reduces costs.

Design for Manufacturability

- It is a relevant approach to build in quality into the process, since the design phase, making processes more easy to be adequately controlled, hence enabling quality at the source.
- It implies:
  - Simplifying the design
  - Standardizing parts and processes
  - Reviewing production methods, equipment, and tooling capabilities.

Operator Checklists and 5S

- If each worker has 'Operation Checklists' for each planned activity and is working in a neat and clean environment provided by 5S, it is very likely to minimize the chance of an error or defect to appear, right at the source.
  - An 'Operation Checklist' is a listing of critical steps/checks to make, to help operators manage their processes.
  - A thorough workplace organization discipline (5S) keeps tools, parts, and fixtures in pre-determined locations, reducing the chances of using wrong items.

Vendor Base Reduction / Supplier Development

- Vendor Base Reduction implies selecting best quality suppliers to work with, so as to provide for improved parts and raw material consistency.
  - It includes:
    - Suppliers' evaluation based on quality problems recorded
    - Support offered to the suppliers, for quality improvement.

3.2. Quality Process Mapping

- The philosophy of making each worker responsible for the quality of his or her work.

Process Mapping

- Process Mapping is the most important and powerful tool used to control and to improve the effectiveness and efficiency of a process.
- Process Mapping, also called flowcharting, is a technique to visualize the stream of tasks, activities and steps that transforms a well defined input or set of inputs into a pre-defined set of outputs.
  - The preferred method for describing a process is to identify it with a generic name, show the workflow with a Process Map and describe its purpose with an operational description.
  - Process Mapping is based on identifying the inputs/outputs of each task, activity and step, and if it adds value, or not – as perceived by the customer, to the resulted product or service.

Process Mapping (2)

- The process map is a visual method used for displaying processes that illustrates the workflow either within a single process (Detailed Process Map) or the whole operation (High Level Process Map).
  - The Detailed Process Map is fit to identify potential causes and improve the process.
  - The High Level Process Map is utilized in understanding the links between the several process steps.
  - A good Process Map should:
    - Allow people unfamiliar with the process to understand the interaction of causes during the workflow.
    - Contain additional detailed information about input and output variables, time, costs.

Process Mapping (3)

- There are many reasons for creating a Process Map:
  - It integrates the whole process and allows all players to understand their part in the process and how their activity fits into the overall process.
  - it is a visual way to describe how activities are performed and how the work effort flows.
  - It can be used as an aid in training new people.
  - It will show you relevant points for taking measurements in view of process improvement.
  - It supports understanding of where problems occur and what the causes may be.
  - It leverages other analytical tools by providing a source of data and inputs into these tools.

Quality Mapping

- It is similar to Value Stream Mapping, because it defines in detail the processes to be analysed.
  - It starts with a walk along the process flow, gathering information about each operation performed.
  - A visual diagram joins up the information regarding each process step.
  - While mapping the process, hundreds of ideas appear, out of which some could be very useful for quality improvement.

Quality Mapping (2)

- Some basic steps:
  - List all quality specification or requirements that must be measured
  - For each feature, add:
    - The inspection method
    - The inspection frequency
    - The measurement method
  - List the defect potential of each measurement – what defects could be introduced or induced during the measurement process
  - List the potential causes for each defect listed
  - List the potential actions for improvement

Quality Mapping - Example

- It has the form of a matrix to be filled in:

	Product 1	Product 2	Product 3	Product 4
Feature				
Current Estimate of Rework				
Inspection Method				
Inspection Frequency				
Defect Potential				
Defect Cause				
Ideas for Improvement				

3.3. Quality Analysis Matrix

LLA

LEAN LEARNING ACADEMY

Education and Culture DG

Lifelong Learning Programme

Quality Matrix

No.	Greater Cost Efficiency	Increase value
1	**Cost:** •Cost reduction •Robust design of products •Embed quality in design (FMEA, Poka Yoke, Six Sigma)	**Knowledge management**: •Domain knowledge •Technology expertise •Share knowledge
2	**Productivity:** •Enhance productivity levels •Mature and robust processes – continuous improvement (Lean, VSM). •Reduce system inefficiencies •Process benchmarking	**Innovation:** •Structured innovation and Deployment. •Six Sigma initiatives
3	**Utilization:** •Improve utilization of resources - men, material and money •Improve employee performance and engagement.	**Value add:** •Go up the value chain •Create business impact to the customer •Increase customer engagement •Creation of intellectual property to the customer •Mitigate risks of Customers by addressing the requirement of their Customers •Partner with customer's for their success

4. Quality Improvement

- 4.1. Main Quality Tools
- 4.2. PDCA – Deming Circle

Quote

"You can't do today's job with yesterday's methods and be in business tomorrow." ***(Anonymous)***

Quality Improvement

- Quality comes not from inspection, but from improvement of the process.
  - The old way:
    - Inspect and sort bad quality out.
  - The new way:
    - Build good quality in and assure quality at the source.
- Quality Improvement
  - Develop processes able to produce the product and keep optimizing it.

Principles of Quality Improvement

- Philosophy of proactive culture of continually seeking ways to improve quality
- Top down and bottom up approach
- Responsibility for quality at every hierarchical level
  - Develop a sense of operator ownership in the process.
  - People have unexploited resources and only people who do the work are in the best position to improve quality – they have to work in teams and to be encouraged to involve themselves in improvement activities.
- Costs of quality
- Continuous and gradual improvement
  - Process view
  - Organization- wide involvement and commitment.
  - Problem-solving tools used by the work teams.

People Involvement in Quality Improvement

- Everyone and every department must devote themselves to constant improvement.
- Management must lead the way.

Management's Responsibility For Quality Cannot Be Delegated!

  - Decisions and actions of the Top Management
    - Make a quality statement
    - Serve on the quality council
    - Select quality policies, establish and deploy quality goals
    - Provide resources
    - Provide team oriented training
    - Review progress
    - Institutionalized recognition and reward system for involvement in quality improvement.
- The focus must be on improvement and not merely fire-fighting or on assigning blame on guilty persons.
  - Most people on the job do not know or are not told how to properly perform their duties (including managers) and are afraid to ask for fear of being viewed as incompetent, or of punitive measures being taken, or of dismissal.
  - For involvement in quality improvement, people must feel secure in their positions.

"Laws" of Quality Improvement

- Today's problems come from yesterday's solutions.
- The harder you push, the harder the system pushes back.
- Behaviour grows better before it grows worse.
- The easy way out usually leads back in.
- The cure can be worse than the disease.
- Faster is slower.
- Cause and Effect are not closely related in time and space.
- Small changes can produce big results, but the areas of highest leverage are the least obvious.
- You can have your cake and eat it too, but not at once.
- Dividing an elephant in half does not produce two small elephants.
- There is no blame.

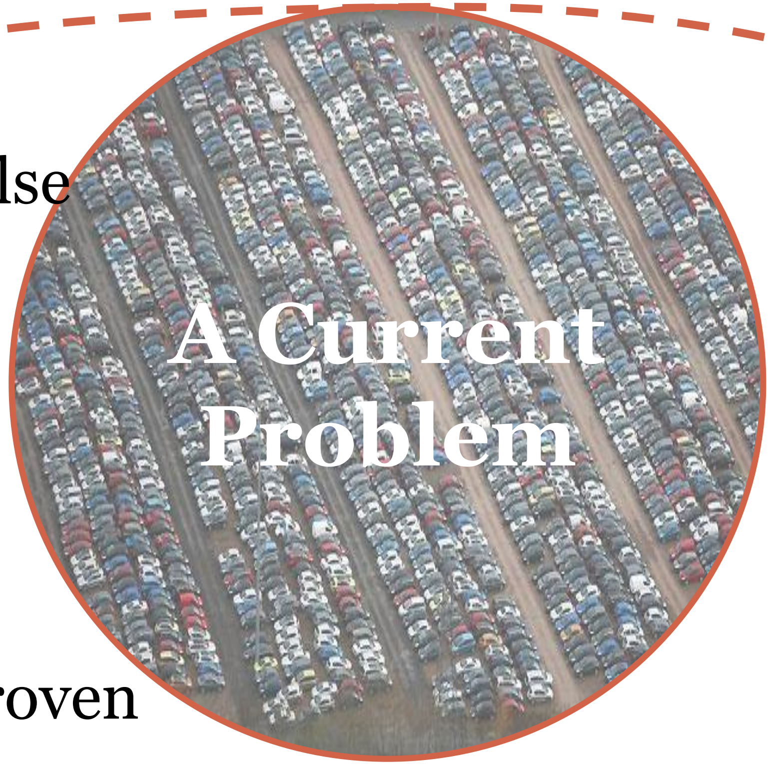
Sporadic vs. Chronic Quality Problems

- Sporadic problems are dramatic and require immediate attention.
  - Sporadic problems are solved by fixing the control process.
    - Solutions consist in sudden corrections.
- Chronic problems are not dramatic – being "accepted as inevitable" – they occur over a long period of time and are difficult to solve.
  - Chronic problems are solved using process improvement techniques.
    - Solutions consist in:
      - Corrective and preventive solutions
      - Actions for improvement.

See slide 27 – the Juran's Quality Trilogy

Usual Work Environment

Blame someone else for the problem



Make wild guess at what is wrong

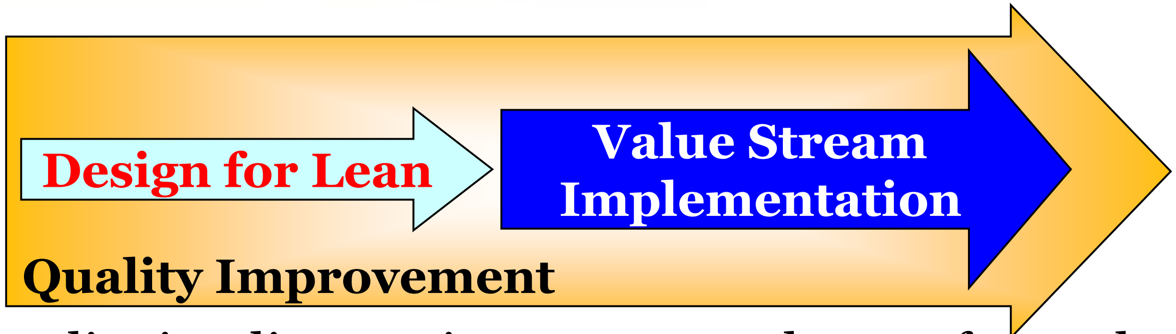
Adopt unproven solution

The Dilbert Cycle

Obstacles in Continuous Improvement

- Lack of top management commitment
- Setting mediocre expectations
- Poorly or inadequately monitoring and diagnosing the situation
- Failing to train personnel
- Making continuous improvement too complex
- Cause-Effect relationship not obvious
- Inadequate working environment
- Resistance to change
- Failing to recognize and celebrate successes.

Quality Improvement and the "Lean" Approach

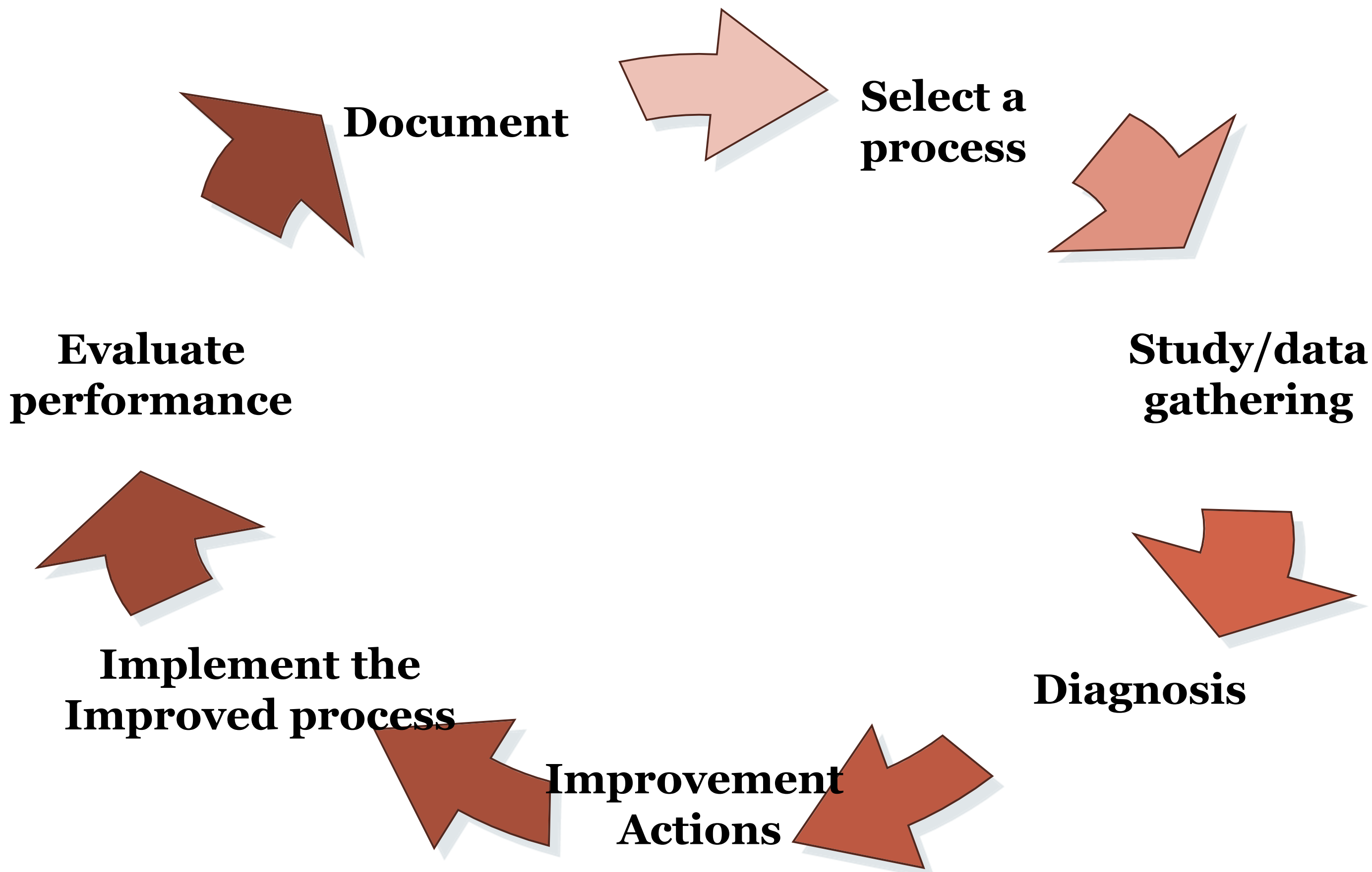


- Improving quality implies serving customers better, faster; lean implies providing the right results less expensively, by consuming fewer resources.
  - So, anything which does not contribute either directly or indirectly to customer satisfaction must be eliminated from the process flow, except for everything that is "just enough" in all sectors and at all levels of activity
  - Identify and eliminate with the goal of both Lean and continuous improvement:
    - Causes of rework
    - Poorly calculated workloads
    - Excessive inventory
    - Skills under-utilized or poorly utilized.
- This step will lead to a streamlining or an overhaul of all processes.

Process Quality Improvement

- A systematic approach to improving a process; the principle for process quality improvement is to “Challenge everything”:
  - Every activity has several steps and each step can always be done in a better way. The useful tools include:
    - Process mapping, process flowchart
    - Analyze the process
    - Improve the process
- Improvement can be:
  - Continuous, gradual, step-by-step improvement
    - Represents continual improvement of process and customer satisfaction
    - Involves all operations and employees
    - Other names and approaches of continuous improvement:
      - Kaizen (Japanese)
      - Zero-defects
      - Six sigma
  - Radical, revolutionary improvement
    - Reengineering, Kaikaku (Japanese)

The Quality Improvement Cycle



The Spiral of Quality Continuous Improvement

- The goal of quality improvement it to make progress - not to achieve perfection
  - This includes daily progress in routine matters as well as large-scale cross-functional improvements, without necessarily resorting to additional investment.
- There is no ideal quality level which, once reached, allows the company to quit its drive to improve quality, using one or more of the several ways of improving quality in different phases of the product life cycle:
  - Built in quality
    - Quality Function Deployment
      - Used to translate customer preferences to design
  - Quality at the source
  - The 7 Basic Quality Tools
    - There are a number of tools that can be used for problem solving and quality improvement
      - Quality tools aid in data collection and interpretation, and provide the basis for decision making
  - The 7 New Quality Tools
  - Problem solving methodologies
  - PDCA Cycle
    - Also called the Deming Wheel – it ensures that a certain degree of progress achieved
    - Recurrent problem solving process

4.1. Quality Tools

- The 7 Basic Quality Tools
- Other Quality Tools

The 7 Basic Quality Tools

- Kaoru Ishikawa selected 7 basic quality tools based on less complicated statistical analysis for the average person:
  - Check Sheet
  - Histogram
  - Run Charts
  - Pareto Analysis
  - Cause and Effect Diagram
  - Control Chart
  - Scatter Diagram

Check Sheet

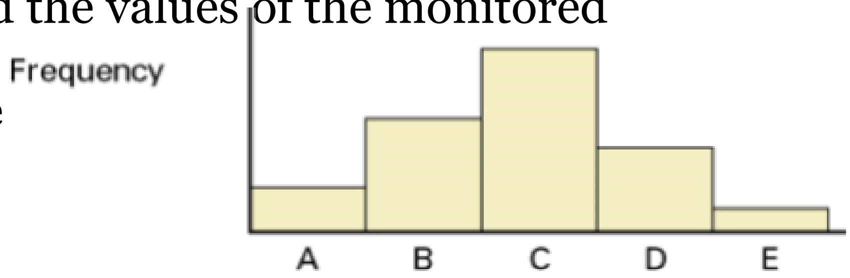
- Check sheet = a data collecting sheet
  - A tool for collecting and organising data
  - A tally of problems or other events grouped by category
  - A simple data check-off sheet designed to identify type of quality problems at each work station – per shift, per machine, per operator

- Objective:
  - To get the necessary information to answer to the following questions:
    - When it happens?
    - How many times it happens?

	Day				
Defect	1	2	3	4	TOTAL
A	///	~~////~~	////	/	13
B	//	/	//	///	8
C	/	////	//	////	11
TOTAL	6	10	8	8	32

Histogram

- A vertical bar chart showing an empirical frequency distribution of a set of observed values (quantities or characteristics) of a variable
  - It summarizes large data sets, communicating information graphically.
  - It enables comparison of recorded values with specification limits
  - It is a tool to assist in decision-making
    - By examining the shapes, sizes, and the spread of data of a histogram, it is possible to undertake decision-making process
    - It shows whether the distribution is symmetrical (normal) or skewed
  - Steps:
    1. Make the measurements or record the values of the monitored variable
    2. Count the frequency of each value
    3. Draw the histogram



Histogram - Example

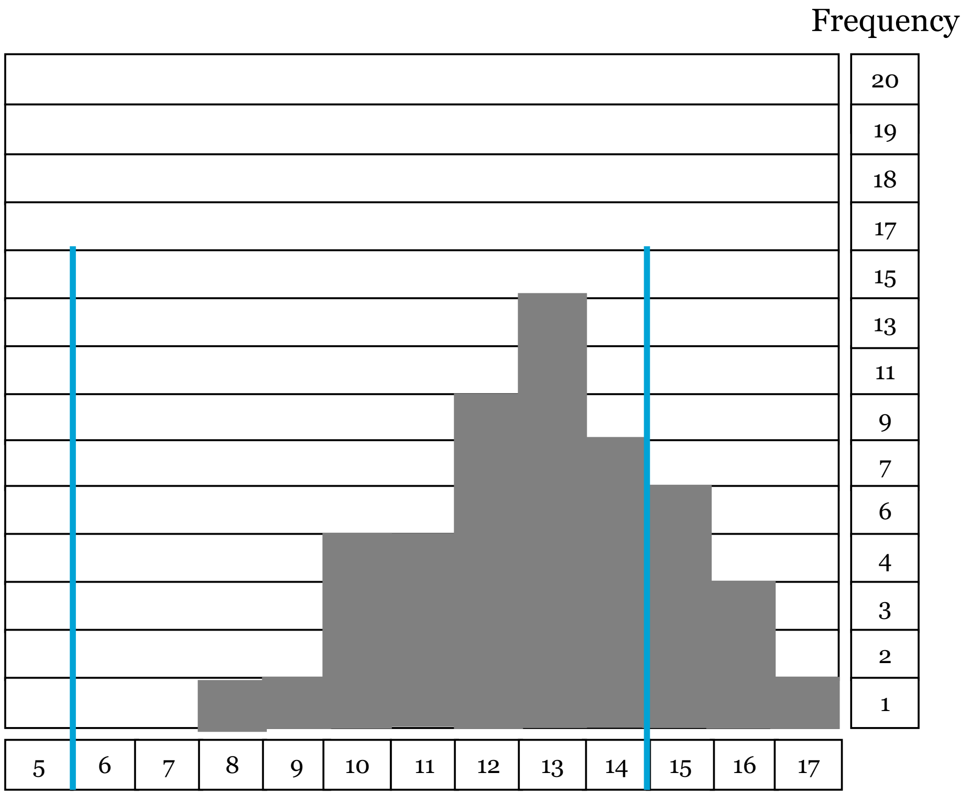
13	14	10	10	15	13	13	13	15	14
11	16	9	10	15	12	10	11	12	13
11	14	17	16	14	11	12	14	13	13
13	14	13	12	13	14	15	11	13	16
12	12	13	13	12	15	8	15	12	12

Data collected: 50 units
Specification: 5 < X < 15

Frequency Counting table

17	|	1
16	|||	3
15	||||||	6
14	|||||||	7
13	|||||||||||||	13
12	|||||||||	9
11	|||||	5
10	||||	4
9	|	1
8	|	1
7		
6		
5		

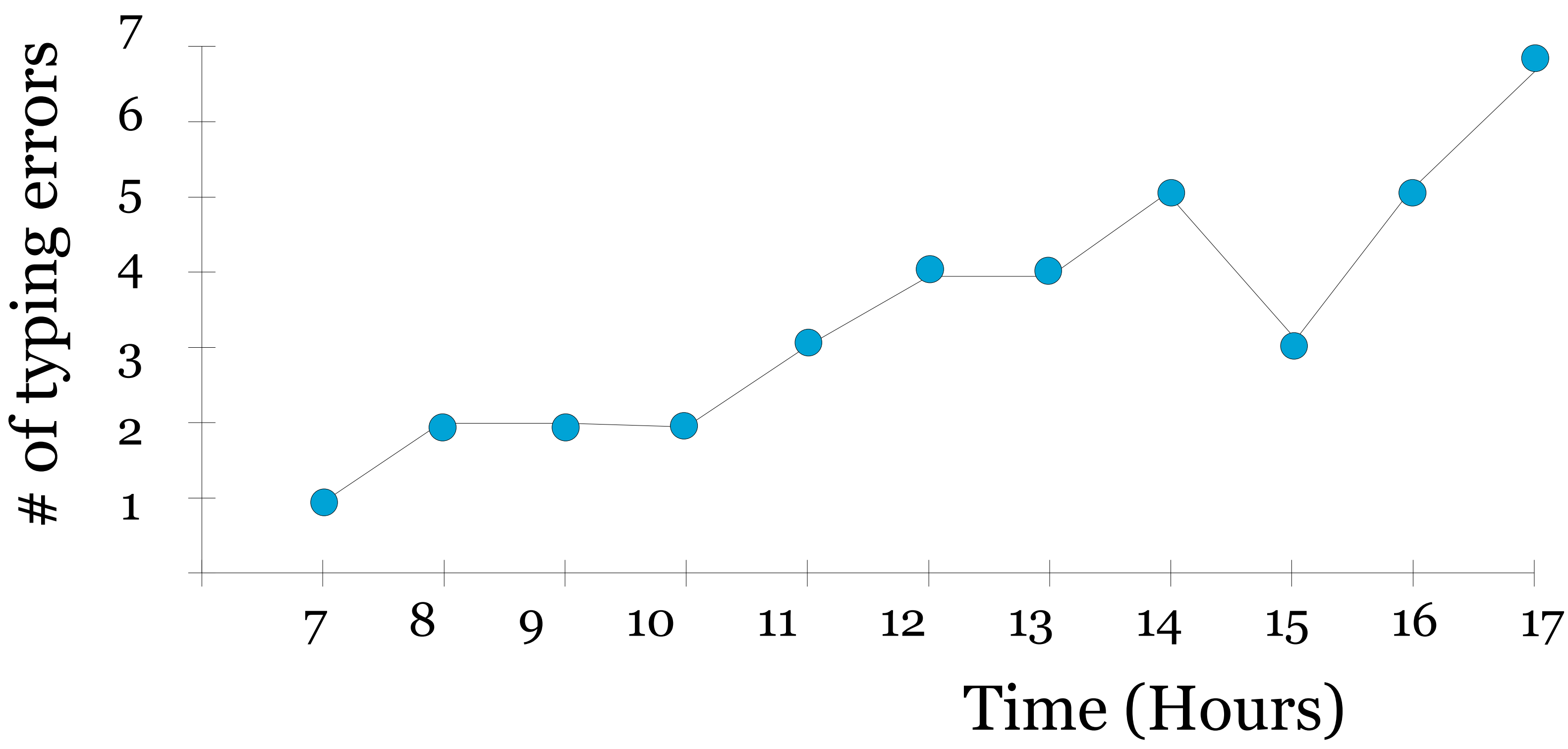
Histogram – Example (2)



Run Charts

- A chart showing the history of the process and pattern or variations in time sequence
  - It is plot of data points in time sequence, connected by a line.
  - It's very useful for identifying trends and cycles.
- This tool is used:
  - At the beginning of the change process – to see what the problems are
  - At the end of the change process – to see whether the change made has resulted in permanent process improvement
  - To identify when equipment or processes are not behaving according to specifications

Run Chart - Example



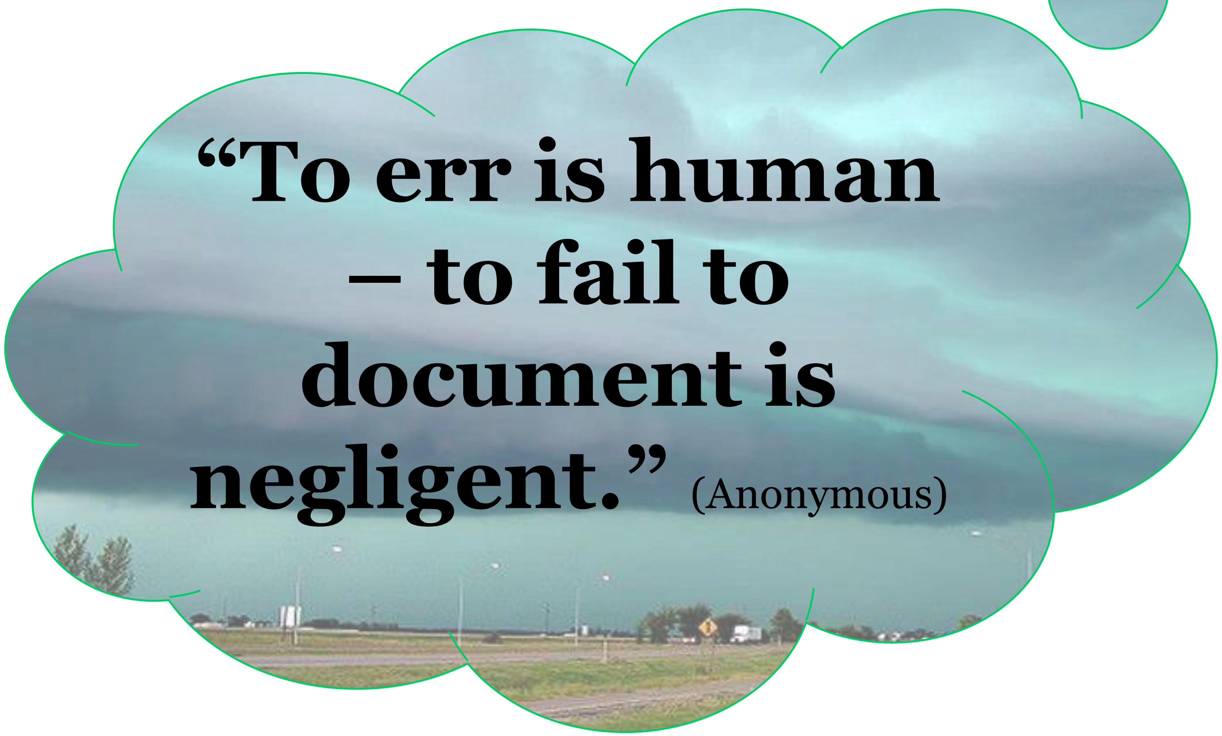
Steps to Build a Run Chart

- Step 1: Gather data
  - How many typing errors are registered every hour – see the previous example
- Step 2: Organise data
  - Determine the values for the x axis (minutes, hour, day of week, shift) and for the y axis (# of errors)
- Step 3: Plot the data on the chart
- Step 4 : Interpret data
  - # of errors increases after long working hours– see the previous example

Pareto Chart

- A Pareto chart is a graphic tool used to prioritize a list of variables or factors based on the distribution of effects produced by various causes, arranged from the most frequent to the least frequent.
- Objective:
  - Determine the relative importance of collected information to select priorities in problem solving.
- This chart is based on the Pareto principle, which states that typically 80% of the defects in a process or product are caused by only 20% of the possible causes
  - Often called the 80-20 Rule
  - The main idea is that quality problems are the result of only a few caused, e.g. 80% of the problems are triggered off by 20% of causes

Quote



“To err is human – to fail to document is negligent.” (Anonymous)

Pareto's Law

- Vilfredo Pareto (1848-1923) originated the 80/20 Rule, which states that 80% of the problems comes from only 20% of the causes.
- Pareto was an Italian economist and a political sociologist. He observed that 20% of the people in Italy owned 80% of the national wealth.
- Later on, Juran enlarged the use of the Pareto's Rule, and devised the law of the 'trivial many' and the 'critical few', starting from the 80:20 rule.
  - So, Juran proposed many adaptations of the Pareto's Law:
    - 80% of the potential value can be achieved from just 20% of the effort. The remaining 80% of effort shows relatively little return.
    - 80% of the sales income come from 20% of the customers
    - 80% of the defects are produced by 20% of the processes/workers
    - 80% of the non-quality costs are induced by 20% of the products, a.s.o.

Steps to Build a Pareto Chart

- Step 1: Gather data
  - Define the problem to be analysed
  - List the variables affecting the problem
  - Set a method and collect data
- Step 2: Prepare data
  - Fill in a table with variable category, values collected, relative and cumulative occurrence, totals
  - Sort the table in descending order to show max. to min. frequencies
- Step 3: Plot the data on the chart
  - Vertical bar chart for relative frequency occurrence of every variable
  - The x-axis shows the categories of variables, from the most frequent to the least frequent
  - The y-axis is for the relative frequency; it is recommended to show also the cumulative percentage on a second y-axis (to the right of the chart)
- Step 4 : Interpret data
  - This chart-type is used to identify if the Pareto principle is evident for the specific situation. If the Pareto principle is evident, about 20% of the categories on the far left of the x-axis will have about 80% of the impact on the problem and they'll be the priority to be approached for solving the analysed problem.

Pareto Chart - Example

- A printing company receives usually 100 complaints from customers per month.
- One of the managers decided to increase the customers' satisfaction and to decrease the monthly average # of complaints.
  - He started a Pareto analysis and discovered that the causes of the complaints refer to the fallowing situations:
    A. Off centred printing of the titles
    B. Misspellings
    C. Missing words
    D. Fading colours
    E. Others.
  - Afterwards he applied the others steps needed to build a Pareto chart

Pareto Chart - Example (2)

- Step 1: Gather data
  - He collected data from the complaints received during the last 6 months and obtained the following situation (a total of 600 complaints):
    - Off centred printing of the titles: 40 times mentioned in the last 6 months complaints
    - Misspellings: 460
    - Missing words: 179
    - Fading colours: 387
    - Others: 70

Pareto Chart - Example (2)

- Step 2: Prepare data

2.1. He filled in a table like the following:

Type of defect	#	Cumulative #
A	40	40
B	460	500
C	179	679
D	387	1066
E	70	1136
Total	1136	

2.2. The rows have to be sorted in a descending order

Type of defect	#	Cumulative #
B	460	460
D	387	847
C	179	1026
E	70	1096
A	40	1136
Total	1136	

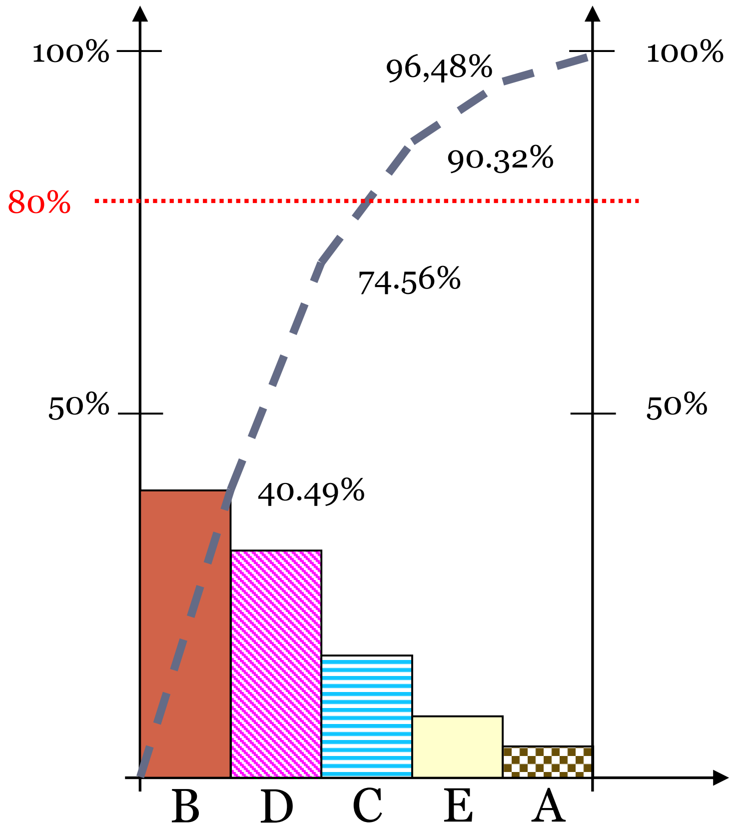
Pareto Chart - Example (3)

2.3. He calculated the relative and cumulative frequency for each type of defect:

Type of defect	#	Cumulative #	%	Cumulative %
B	460	460	40.49	40.49
D	387	460+387=847	34.07	40.49+34.07=74.56
C	179	847+179=1026	15.76	74.56+ 15.76 =90.32
E	70	1026+70=1096	6.16	90.32+6.16=96. 48
A	40	1096+40=1136	3.52	96.48+3.52=100
Total	1136		100	

Pareto Chart - Example (4)

- Step 3: Pareto Chart



- Step 4: Interpretation
  - To solve approx. 75% of the customer's complaints, it is necessary to eliminate 20% of the non-satisfaction causes (related to misspellings and fading colours)
    - The potential improvement actions are:
      - More efficient proof reading tools to correct spelling before printing
      - Better paint
  - Eliminating the 3rd cause as frequency (missing words) further reduces the complaints with approx. 16%, and fighting against all other remaining sources of complaint will improve the results with less than 10%.
  - It is recommended that the 'other" category to represent max. 10% of the causes. If more, the category should be split into several categories.

Pareto Chart - Conclusions

- The Pareto Chart has many advantages:
  - Easy to use and to interpret, even for beginners in statistics and complex data analysis techniques
  - The variable selected for analysis may be of different types:
    - Quality
      - Number of defects, % of defective products, quantity of defective products, # of customers' complaints, etc.
    - Costs
      - Value of sales income per product type, NVA costs, maintenance costs, etc.
    - Delivery
      - Time duration for certain activities, # of delayed deliveries, inventory quantity for product types
    - Employees' moral
      - Turnover, absenteeism, internal complaints
    - Safety at work
      - # of work accidents, gravity of the accidents, work incidents

Pareto Chart – Conclusions (2)

- Other advantages of the Pareto Chart:
  - It may be used as a recurrent tool – it can be built several times to go into details for better understanding the problem
    - For example, if we want to see what equipment, software or operator is responsible for misspelling errors, we have to gather data to analyse only the causes for misspelling.
    - Or if we want to know which shift is responsible for the majority of the misspelling errors, we make a Pareto analysis based on occurrence of these faults during a certain shift.
  - Pareto chart may be also used during Quality Planning or Quality Control phases:
    - For example, to stratify 'Voice of the Customer' data to indicate the most important requirements of the customer, or to stratify data collected on the run charts, for identifying the most important causes that contribute to a specific quality problem.

Cause and Effect Diagram

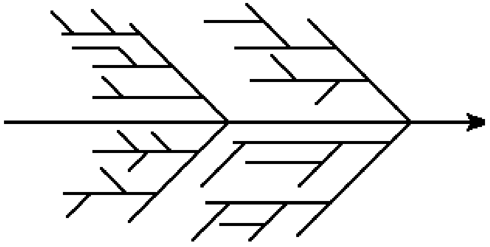
- A cause and effect diagram is a visual tool used to logically organize in a systematic way known or possible causes and sub-causes for a specific problem or effect by graphically displaying them in increasing levels of detail.
  - Objective: To find all the possible causes of a certain problem and/or to obtain the most probable causes of the same problem.
  - It helps to identify root causes and ensures common understanding of the causes
- Attributes of C&E Diagram:
  - No statistics involved
  - Uses an orderly, easy-to-read format
  - Sheds light on situations
  - Maps out a process/problem
  - Increases process knowledge
  - Indicates possible causes of variation
  - Helps determine root causes
  - Identifies areas for collecting data
  - Encourages group participation
  - Makes improvement easier

Cause and Effect Diagram

- Also known as:
  - Ishikawa Diagram
  - Fishbone Diagram, because it looks like a skeleton of a fish, with the main causal categories drawn as "bones" attached to the spine of the fish (the analysed effect)
- The cause and effect diagram can also be drawn as a tree diagram, resembling to a tree turned on its side.
  - From a single trunk, major categories of inputs or causes open out like branches, leading to smaller and smaller branches of causes all the way down to thinner twigs at the ends for the sub-causes.
  - The tree structure has an advantage over the fishbone-style diagram:
    - As a tree structure, all items on the same causal level are aligned vertically and are visible even for complex diagrams.

Steps to Build a Cause and Effect Diagram

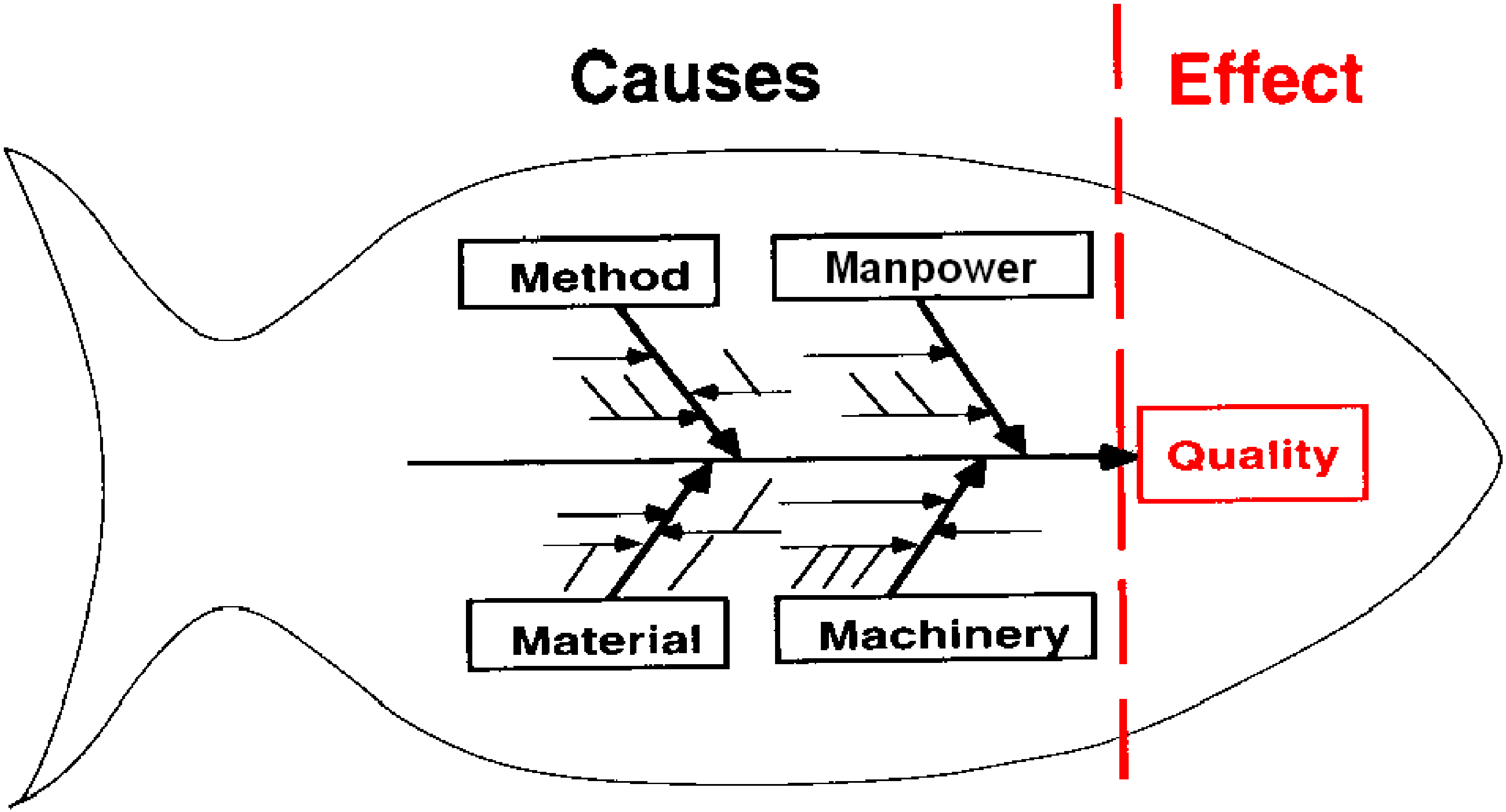
- Building a cause and effect diagram implies teamwork of people directly related to the problem, performing a specific methodology:
  - Step 1: Select the problem to be solved and write it in a rectangle, in the farthest right edge of a paper sheet.
  - Step 2: Draw the 'fish bones' and arrange the main causes according to their level of importance or detail, resulting in a depiction of relationships and hierarchy of events.
    - This can help search for root causes, identify areas where there may be problems, and compare the relative importance of different causes.
  - Step 3: Draw the thinner 'fish bones' by asking for each main cause: 'What could have caused problems in this area?' Repeat for each main cause and for each sub-cause/sub-area.



Recommendations for Building up a Cause and Effect Diagram

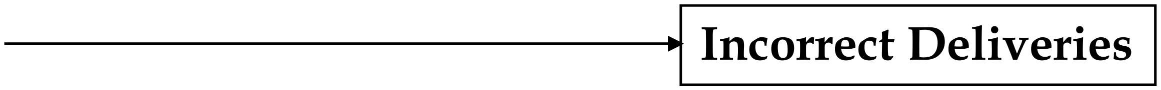
- Main causes in a cause and effect diagram are frequently arranged into four major categories, for example:
  - Manpower, Methods, Materials, and Machinery – recommended for manufacturing activities)
  - Equipment, Policies, Procedures, and People – recommended for service areas
- Sometimes it is required to use other quality tools as support :
  - Brainstorming, to identify real and potential causes and sub-causes
  - An affinity diagram, to identify other main branches of the cause and effect diagram
  - The '5 Whys' technique, to drill down to the root causes
  - Flow charts
- Some guidelines to draw the diagram:
  - Select a relevant effect or quality problem to analyse its causes
  - For each node, think what could be its causes and add them to the tree.
    - Pursue each line of causality back to its root cause.
    - Consider attaching relatively empty branches onto others.
    - Consider splitting up overcrowded branches.
  - Be concise and do not cover all causes in a comprehensive approach, but consider which root causes are most likely to merit further detailed investigation.

Cause and Effect Diagram – Example

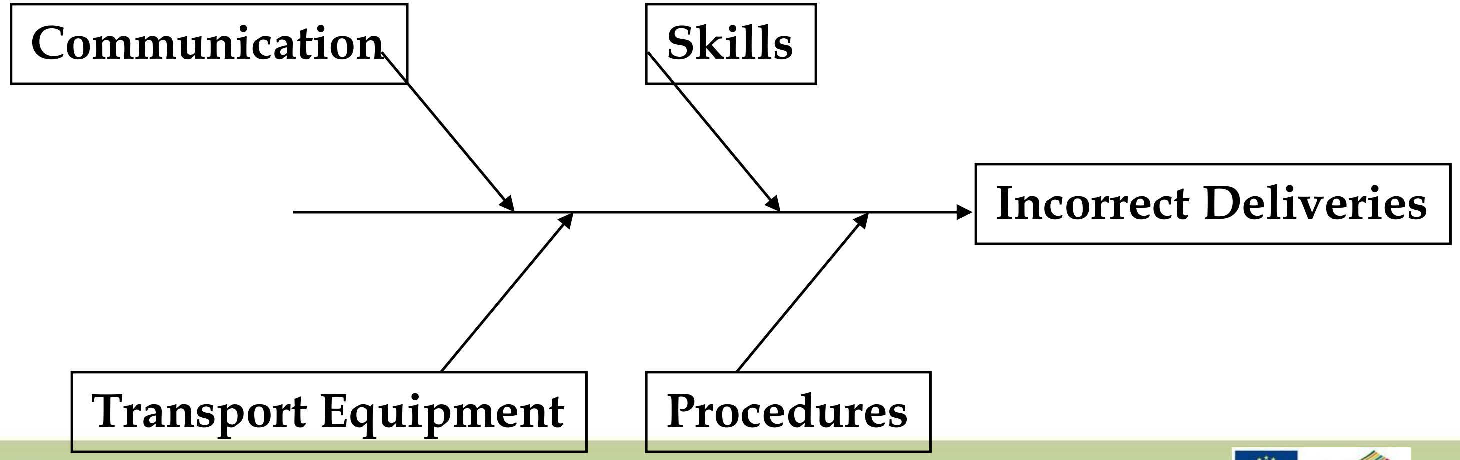


Cause and Effect Diagram – Example (2)

- A distribution company is confronted with a major quality problem: *many of the delivery addresses are incorrectly written on the delivery documents, therefore many of the orders are delivered late, with additional transport costs*. They decided to appoint a team for analysing the causes of such situation.
  - Step 1: Write down the effect to be investigated and draw the "backbone" arrow to it."



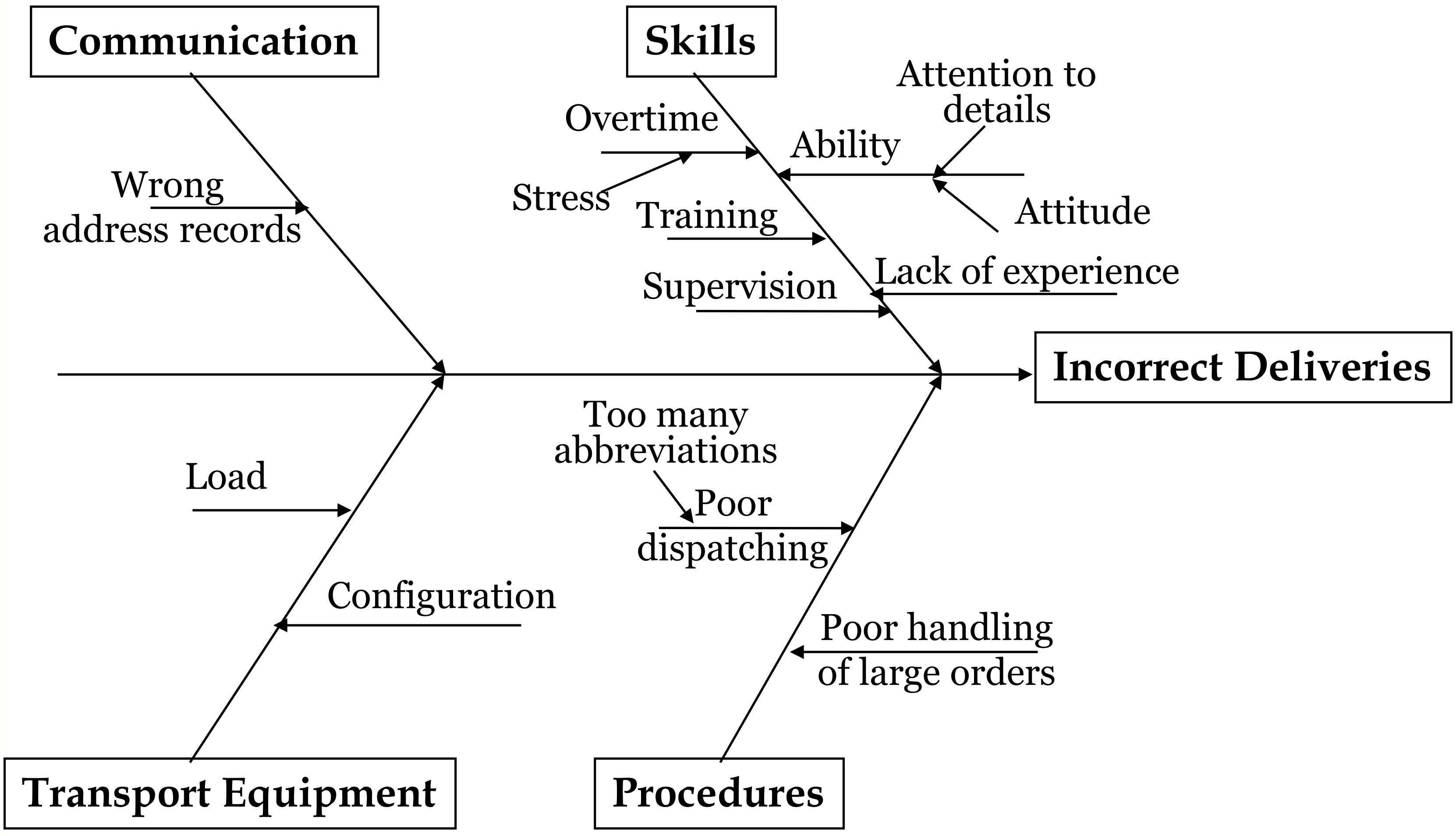
  - Step 2: Identify the broad areas of enquiry for the real or potential causes.



Cause and Effect Diagram – Example (3)

- Step 3: Complete the ‘fish skeleton’
  - Ask a team to be creative and write down all the detailed real or potential causes in each of the four broad areas of enquiry.
  - Each cause identified should be fully explored for further more specific sub-causes
  - Tips:
    - Keep team members’ attention focused on a specific problem and use brainstorming to generate ideas about causes
    - Take notice of all ideas, regardless their link to one of the four broad areas of enquiry – if needed, add an extra ‘bone’ to the diagram for a new category of causes to be investigated
    - Approach the broad areas of enquiry of the backbone from left to right, one by one
  - Main limitation of C&E Diagram
    - If the analyzed effect is caused by a combination of factors, the C&E Diagram is not a reliable tool to depict and solve the problem.

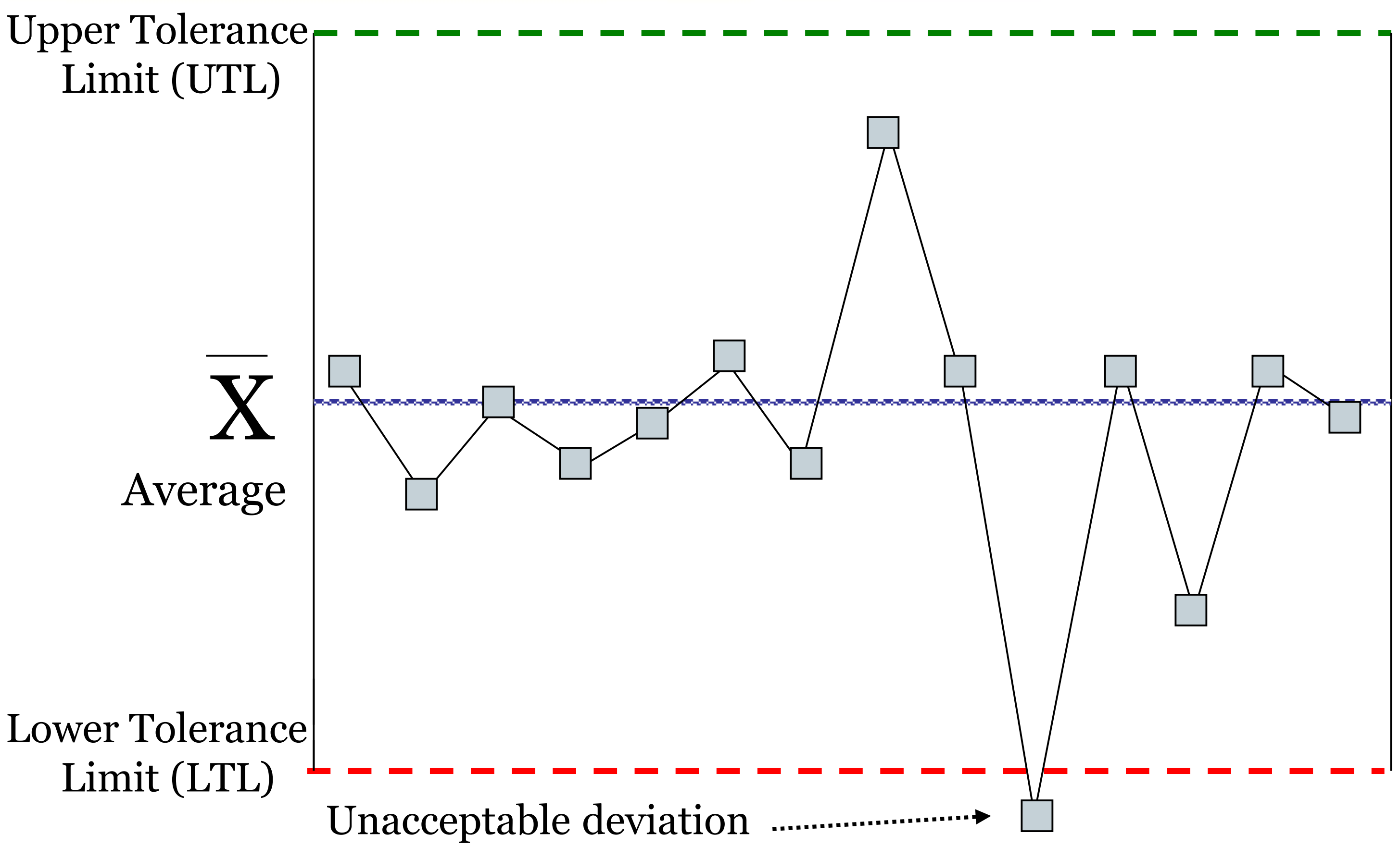
Cause and Effect Diagram – Example (4)



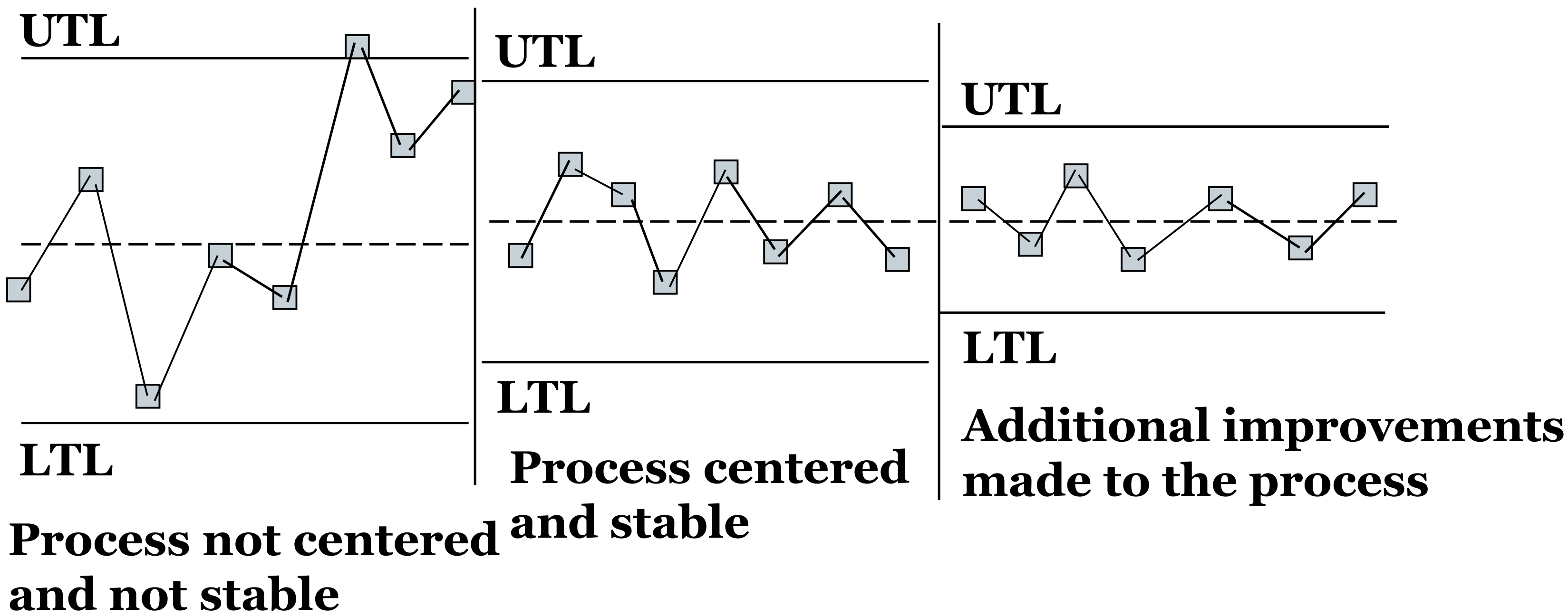
Control Chart

- A line chart showing the control limits and the average quality level
  - It is a run chart with specified UTL and LTL, for easier detection of trends and of correctable causes of variation
    - Developed by Shewhart in 1920's and used for SPC ever since
    - It provides information about process capability
    - It allows to identify the causes of non natural process variation
    - It provides diagnostic information.
- It can be used to:
  - Improve productivity by monitoring the ongoing production process quality and quality conformance to stated standards of quality
    - Defects prevention
      - Taking corrective action (if necessary)
    - Unnecessary process adjustments prevention
  - Tracking improvements

Control Chart



Tracking Improvements by using Control Charts



Types of Control Charts

Variables (Measurable characteristics; continuous variables)	**Attributes** (Discrete variables)
Average and Range *X* chart and *R* chart	Number of non conforms items *np chart*
Average and standard deviation *X* chart and *s* chart *(n>10)*	Proportions of non conform items *p chart*
Average and variance X chart and s^2 chart	Number of defects *c chart*
Individuals observations and moving ranges X chart and MR chart	Number of unit defects *u chart*

Interpretation of Control Charts

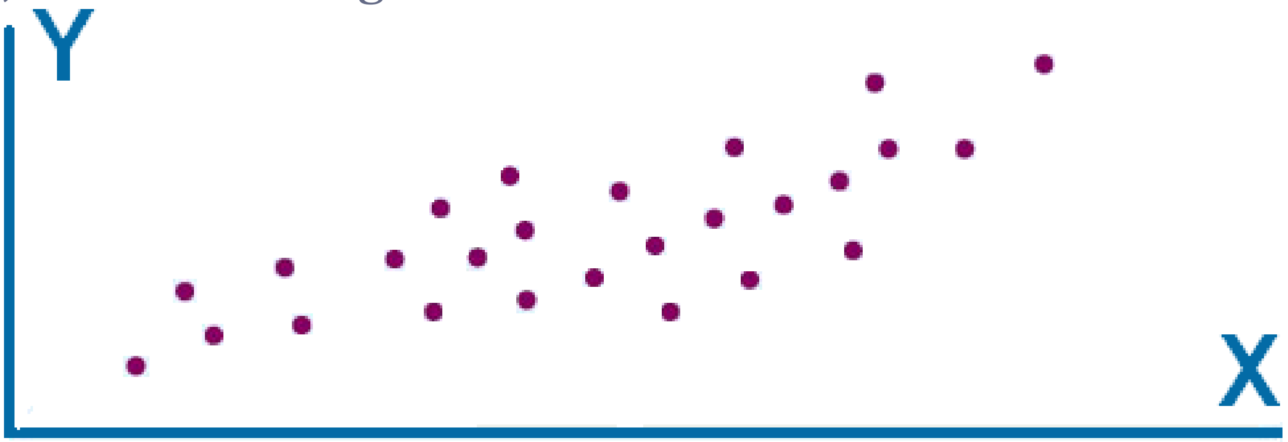
- Points out of control
  - Immediate analysis to find the possible causes
  - If the immediate causes could not be found, the points are registered and a corrective action should be taken
- The reasons for out of control points
  - The control limit or registered point are incorrectly marked
  - Variability has been changed
  - The measurement system was modified
- Out of control typical situations
  - Cyclic movements (up, down) show the existence of seasonal effects or workers rotation.
  - Tendencies (in one direction) may imply the existence of predictable causes (blunt of tools or a process improvement).
  - Isolated out of control points may mean defects in material, starting up or stop of machines.
  - Even if the points are within the acceptable limits, decisions should be taken when one of the following situation appears:
    - 7 successive points at the same side of the middle line
    - 10 in 11 points at the same side of the middle line
    - 12 in 14 points at the same side of the middle line
    - 16 in 20 points at the same side of the middle line

Benefits of the Control Charts

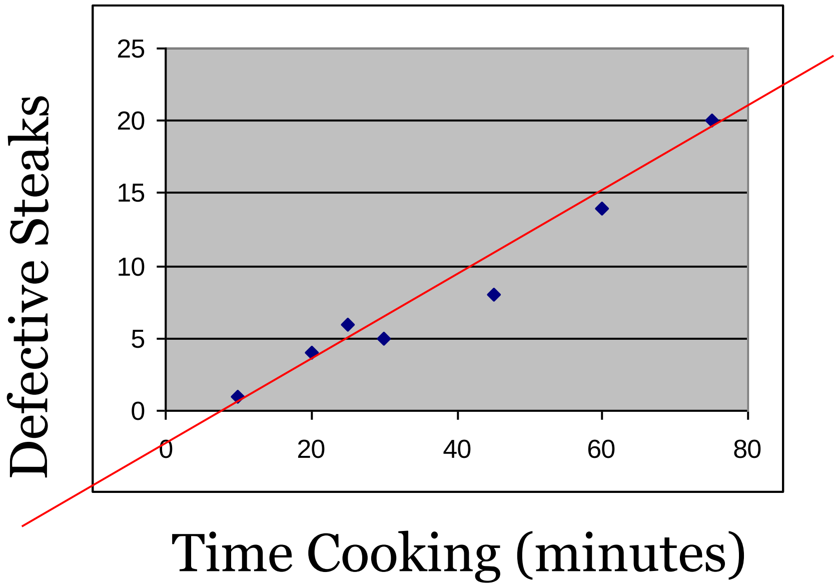
- Simple and easy tools to be applied by workers with the objective of getting a continuous process control and assure communication and visual management
- Since the process is under statistical control, control charts allow:
  - To identify trends of the process variation and to say when the process is stable and effective in terms of cost and quality
  - To improve the process performances, based on the information given by charts
- They allow the use of a common language:
  - When studying the improvements of process between workers and supervisors and the other activities related to production (methods, materials, etc.)
  - They establish a common language between the company and its customers
- When distinguish the common causes from special causes that affect processes, the control charts provide:
  - Precise indications about the opportunity and possibility of performing corrective actions:
    - By workers, directly in the job place, in certain limits, for normal variation causes
    - By process responsibles, according to the internal procedures, for special variation causes

Scatter Diagram

- A graph that shows how two variables are related to one another – the pattern that exists in the relationship between two variables ‘x’ and ‘y’.
  - Available data can be used in a regression analysis to establish the degree of correlation between variables
    - The degree of correlation shows if there is or not a significant relationship between the two variables
  - Intuitive and qualitative conclusions could be drawn about the two variables, about their degree and direction of correlation



Scatter Diagram (2)



- Scatter plots take place on an X and Y graph.
  - The variable on the x-axis should be the dependent variable and the variable on the Y-axis changes according to changes of X.
- Scatter diagrams may be used:
  - To develop informal models to predict the future based on past correlations.
  - To find direct or indirect relationships which can then be helpful to analyze/improve quality.

Other Tools for Quality Improvement

- There are many tools to be used for quality improvement, some very simple and familiar, others based on more advanced theories. Some examples:
  - Tools for problem solving
    - Process flow diagrams
    - Mistake proofing
  - Tools for process improvement / waste elimination
    - 6Sigma
    - Standard work
    - Total Productive Maintenance
    - Value Stream Mapping
    - Spaghetti diagram
  - Hoshin management and planning tools
    - Affinity diagrams
    - Relationship diagrams
    - Brainstorming and other creativity techniques
    - Matrix diagrams
    - Radar charts
    - Venn diagrams
    - Force field analysis
    - Prioritization matrices

4.2. PDCA – the Deming Circle

LLA

Lean Learning Academy

Plan – Do – Check – Act (PDCA)

- PDCA is a continuous quality improvement tool
- Also known as:
  - Shewhart Cycle
    - Walter Shewhart – Discussed the concept of the continuous improvement cycle PDCA in his book, "Statistical Method From the Viewpoint of Quality Control“, published in 1939
  - Deming Wheel
    - W. Edwards Deming – Modified and popularized the Shewart cycle (PDCA) to what is now referred to as the Deming Cycle, also known as PDSA (Plan, Do, Study, Act).

PDCA (2)

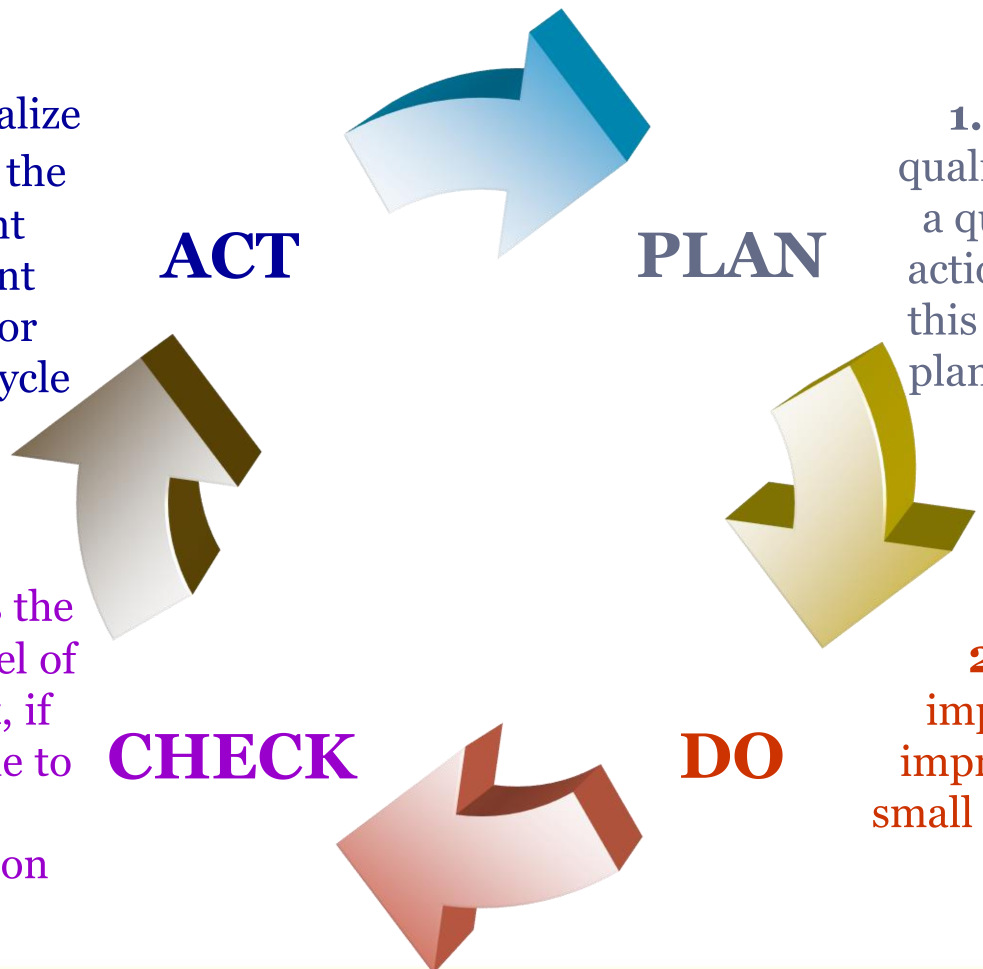
- PDCA says that processes should be addressed through four steps:
  - Plan
    - Establish a need for quality improvement
    - Conduct a root cause analysis
    - Generate potential solutions
    - Plan a test of the most likely solution
  - Do
    - Test the most likely solution on a small scale (i.e., conduct a pilot test)
  - Check
    - See if the pilot test works
  - Act
    - Implement the effective solution on general level to improve quality.

PDCA Model

- Deming used a circular model to show that the quality improvement never ends.
  - Once an improvement has been achieved, next the planning should begin for further improvement.
    - If during the 'Check' step it is obvious that the improvement solution doesn't work, Deming suggested to return to some prior step in the cycle to alter the plan so that another improvement action could be, in fact, successfully implemented.

PDCA Cycle

4. ACT – Institutionalize the change and adopt the quality improvement action as a permanent working procedure, or abandon it or do the cycle steps again.



1. Plan – Identify a quality problem and plan a quality improvement action. Predict the effect this action will have and plan how the effects will be measured.

2. DO – Test the implementation of the improvement action on a small scale and measure the effects attained.

3. CHECK – Assess the results to learn the level of quality improvement, if any, and if it is possible to implement the improvement action on larger scale.

PDCA Details – PLAN

- PLAN
  - Identify the quality problem
  - Describe the process flow
    - Question the capacity or capability of a process.
    - Is process in control (repeatable)?
  - Analyse the quality problem
    - Identify possible causes of the quality problem
  - Solve the quality problem
    - Establish theories on how to improve the process
    - Select the most probable solution and predict measurable outcomes.

- Tools to be used:
  - Problem solving techniques
  - Direct observation of the process
  - Data gathering techniques
  - Process mapping
  - Cause and effect diagram
  - Pareto analysis
  - Brainstorming

PDCA Details – DO

- Select and implement a quality improvement action as a pilot project
  - Establish success criteria
  - Design experiment to test the most probable solution
  - Obtain management support for implementing the chosen solution
  - Implement the solution on a trial or pilot basis
- Tools to be used:
  - Problem solving techniques
  - Design of Experiment (DoE)
  - On-the-job training

PDCA Details – CHECK

- Gather and analyze data regarding the outputs after the improvement solution testing
- Measure effects of change
- Determine whether improvement exists
- Measure outcomes compared to predicted outcomes
- Validate the solution
    - If YES, go to the next cycle step
    - If NOT, revise the plan.

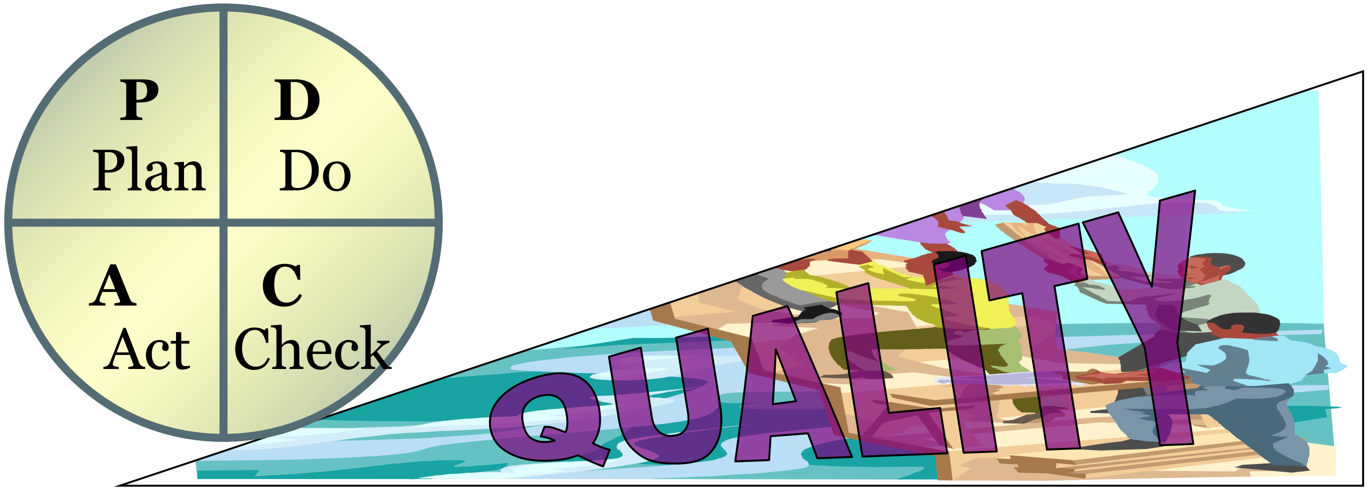
- Tools to be used:
    - Direct observation of the project
    - Charts, diagrams, graphical analysis
    - Key performance indicators

PDCA Details – ACT

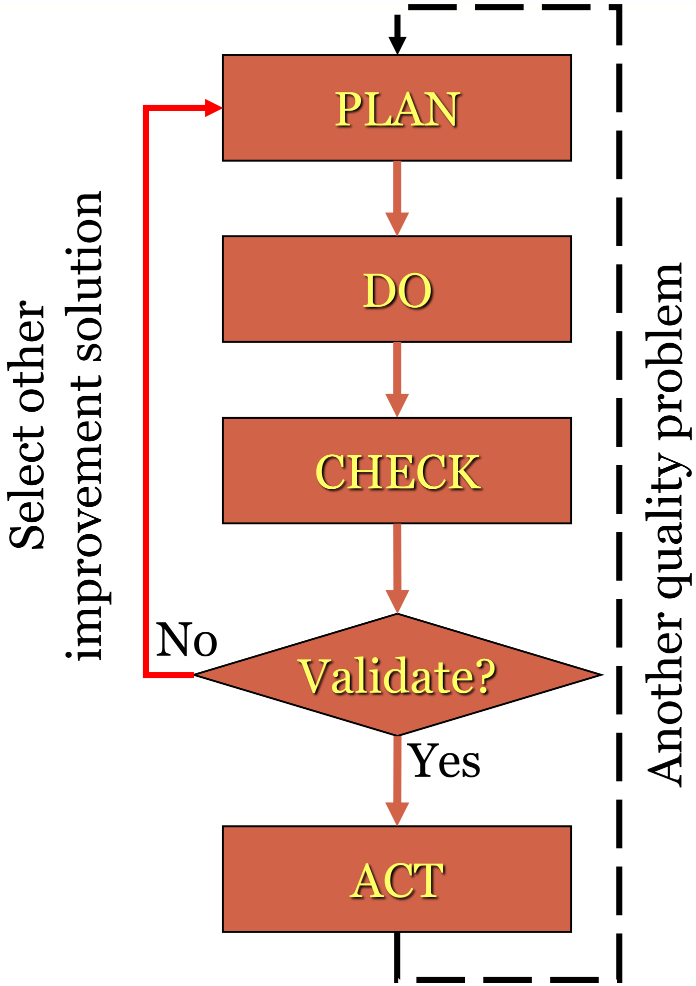
- If the ‘Check’ step proved that the improvement action is right, adopt it on a broad scale across organization
- Identify systemic changes and training needs to support general implementation of the improvement action
- Continue cycle by entering Plan
  - Monitoring the performance
  - Identify quality problems
  - Continuous improvement opportunities

- Tools to be used:
  - Process mapping
  - Work standards
  - Visual management
  - Error proofing
  - Training

Deming Quality Improvement Cycle



The PDCA Flow Chart



- The Six Stages of PDCA Cycle:
  - Determine goals and targets for the new improved level of quality
  - Determine methods of reaching the planned goals
  - Engage in education and training
  - Implement the improvement action
  - Check the effects of implementation
  - Take appropriate action
    - Standardize the new working procedure.
    - Hold the gain and the new level of quality performance

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PDCA – Group Activity

- Apply PDCA cycle for the weekly visit to a supermarket:
  1. PLAN
     - Make a plan
  2. DO
     - Do as planned
  3. CHECK
     - See if actual results are similar to the planned ones
  4. ACT
     - See in the procedure is right or it needs to be corrected

PLAN:
1. Make a list with items to be bought, including quantities and other relevant information
2. Plan the shortest route according to product locations
3. Add all price estimates to make a budget for the weekly visit to the supermarket
4. Set a budget limit for miscellanea.

DO:
1. Visit to the local supermarket
2. Do the buying

CHECK:
Check the list, the bags and the wallet – are they as expected/planned?

ACT:
If yes, keep the methodology in place. If not, improve the list, correct the prices, change the itinerary to find the planned items, add or exclude locations, etc.

Other PDCA-type Improvement Cycles

- PDSA
  - Deming preferred the term 'Study' later in his career, to replace the "Check" phase, as he considered that it takes more than merely checking to see if the pilot succeeded – it involves to study the results of the pilot test in order to better understand what happened.
- PDSA stands for:
  - Plan
    - Evaluate current process
    - Collect data, identify problems
    - Develop an improvement plan
  - Do
    - Implement the plan on a trial basis
  - Study
    - Collect data and evaluate performance against objectives
  - Act
    - Communicate the results from trial
    - If successful, implement new process
- Cycle is repeated
  - After the 'Act' phase, start planning and repeat process for another quality problem

Other PDCA-type Improvement Cycles (2)

- FAST-PDCA
  - This model adds a few preliminary steps aiming at speeding up the PDCA cycle:
    - **F** – Focus only on a specific goal for the process improvement effort, that is significantly beyond current expected performance
    - **A** – Analyze the data and do a cause-effect analysis.
    - **S** – Select potential improvement actions and the most likely to be effective
    - **T** – Test
      - **P**lan the test
      - **D**o the test
      - **C**heck if the test is validated
      - **A**ct on the knowledge gained
- The primary advantage of this approach over the traditional PDCA cycle is that the process improvement effort is more carefully defined and planned before initiating the PDCA steps.
  - FAST-PDCA is intended to be more of a quick fix tool.

Other PDCA-type Improvement Cycles (3)

- FOCUS-PDCA
  - In this model, there is significant preparation before initiating PDCA. FOCUS-PDCA is intended to be more methodical and thorough.
    - F – Find a process to improve
      - Carefully select which process will be the focus of the improvement effort.
    - O – Organize to improve the process
      - In this phase, all the resources needed to improve the process are gathered (a team, a facilitator, a team leader, preliminary project plans, estimated financial and equipment needs, ground rules, other resources needed)
    - C – Clarify current knowledge of the process
      - A flowchart is developed depicting how the process works and quick and easy improvements are spotted. Workers are trained on the best approach to the process as well as any necessary variations.
    - U – Understand types and sources of process variation
      - In this phase, measurement are made, the key quality indicators are studied
    - S – Select the solution that is most likely to improve the process
      - Using the quality tools previously discussed, the solution that is most likely to improve the process is selected and any necessary approvals to make the process changes are obtained.

PDCA – Concluding Comments

- The PDCA cycle is an effective and rapid method for continuous improvement.
- Each step (Plan, Do, Check, Act) is critical for consistent quality improvement and needs specific quality tools to be employed.

5. Conclusions

LLA

Lean Learning Academy

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Key Issues in Quality Management

- Customer focus
- A cultural change
- Committed leadership and company-wide definition of quality
- Real employee empowerment and strong motivation
- Step-by-step improvement strategy
  - Time to devote to quality initiatives
  - Any process can be improved
  - An systematic approach to improvement is necessary
- Good inter-organizational communication

Quality Costs

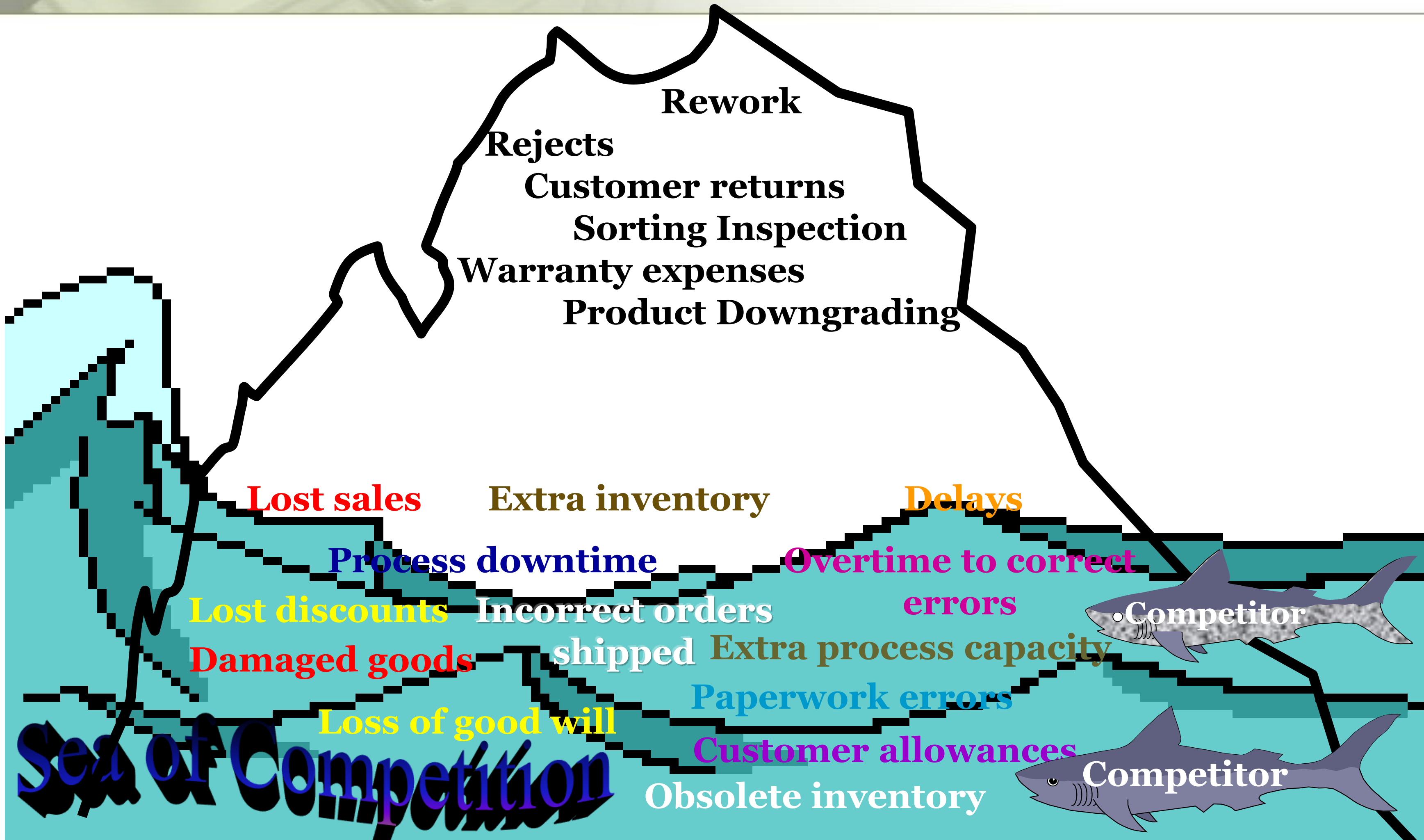
"We have never considered any costs as fixed. Therefore we first reduce the price to a point where we believe more sales will result. Then we go ahead and try to make the price. We do not bother about the costs. The new price forces the cost down."

- By Henry Ford, My Life and Work, 1922

Quality Costs

- Nothing is ever perfect. So quality affects all aspects of an organization and has dramatic cost implications on overall performance
- Crosby said that ‘Quality is free”, but the lack of quality is expensive, because the customers notice every non-conformity.
  - The law of the competition: ‘If we don’t do it better, someone else will.’
- Quality improve profit due to less costs of rework and scrap.

The Iceberg of the Hidden Costs of Poor Quality



Quality-Related Costs

- Quality-related costs are costs incurred by an organization to ensure that the provided products or services are in compliance with the customer requirements.
- Juran identified 2 types of quality-related costs :
  - Unavoidable Costs
    - Costs associated with defect prevention *(inspection, sampling, sorting, QC)*
  - Avoidable Costs
    - Costs associated with quality appraisal and product failures *(scrapped materials, labour for re-work, complaint processing, losses from unhappy customers)*

“Gold in the Mine”

Quality-Related Costs

Cost of good quality	*Cost of poor quality*
Prevention costs	**Internal failure costs**
Appraisal costs	**External failure costs**

"Costs of poor quality are huge, but the real amounts are not known with precision. In most companies, the accounting system provides only a minority of the information needed to quantify this cost of poor quality."

Juran on Quality by Design, The Free Press (1992)

Quality Costs

- There are four main categories of costs of quality, grouped into two major quality areas:
  - Quality Control Costs
    - Prevention Costs
      - Quality training, planning, customer assessment, process control, quality improvement, costs to prevent defects from occurring
    - Appraisal Costs
      - Costs of activities designed to ensure quality or uncover defects; inspection costs.
  - Quality Failure Costs - costs incurred by defective parts/products or faulty services.
    - Internal Failure Costs
      - Costs incurred to fix problems that are detected before the product/service is delivered to the customer.
    - External Failure Costs
      - All costs incurred to fix problems that are detected after the product/service is delivered to the customer.

Prevention Costs

- Costs associated with preventing poor quality products from reaching the customer:
  - Quality planning costs
    - Preventing defects before they happen
    - Quality improvement programmes and quality engineering
    - Supplier evaluations
  - Quality training costs
    - Training on quality, reliability, worker training and cross-training
  - Product design costs
    - Design reviews
    - Design, development and installation of quality measurement and test equipments
    - Product qualification
    - Reliability studies
  - Process design costs
    - Acquisition analysis and reporting of quality data
    - Preventive maintenance
    - Process capability studies

Appraisal Costs

- Costs incurred to identify defective products before they are shipped to customers or other tasks performed to ensure that the process is acceptable - costs of testing, evaluating and inspecting quality
  - Test and inspection of raw material, goods in process, finished goods
  - Maintenance and calibration
  - Line quality engineering
  - Vendor rejects
  - Process capability measurement control
  - Product acceptance
  - Prototype inspection and tests
  - Receiving inspection and tests
  - Product engineering review and shipping release
  - Supplier surveillance
  - Quality audits
  - Laboratory or other measurement service
  - Setup for test and inspection
  - Field testing

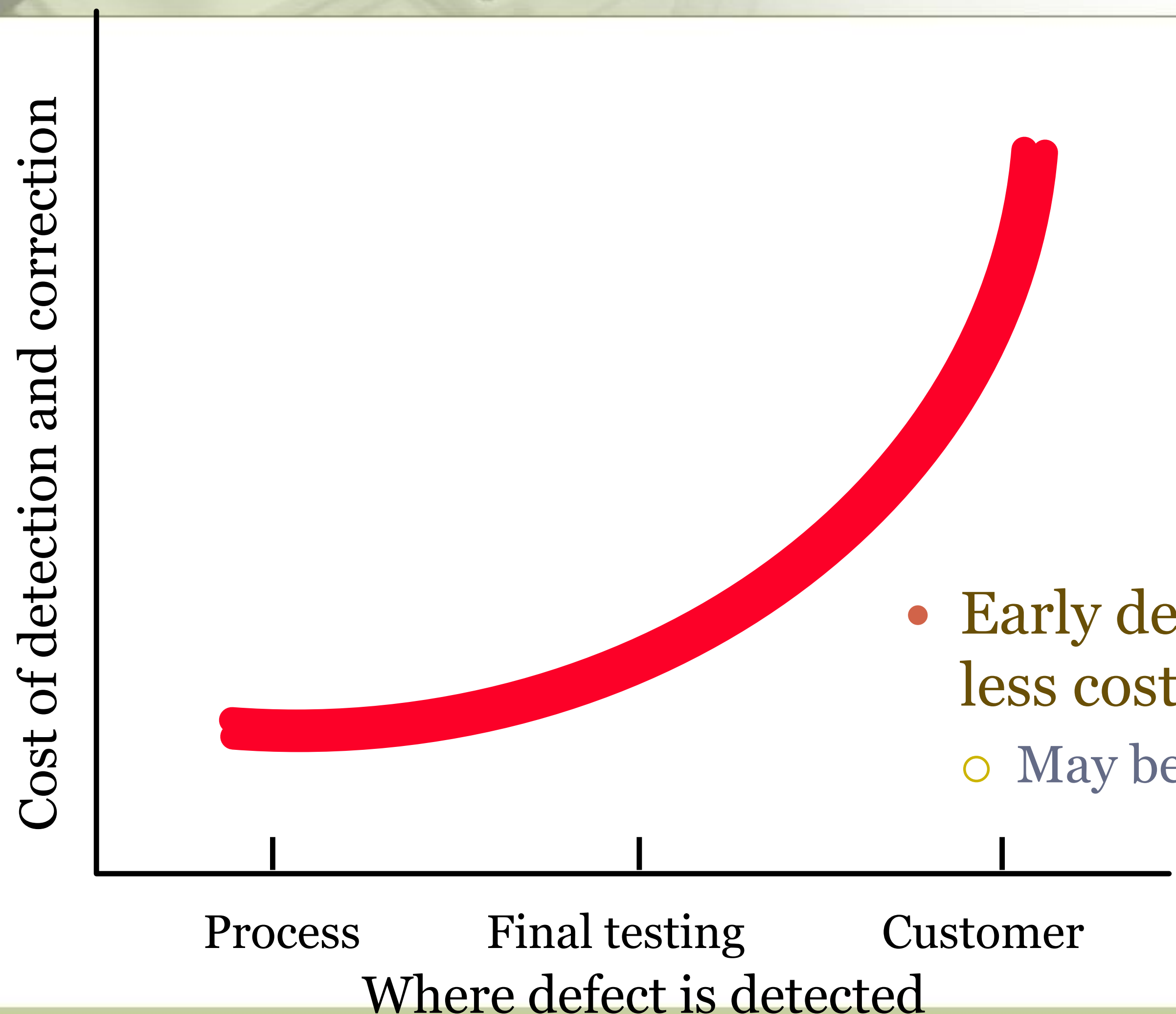
Internal Failure Costs

- Costs incurred when poor quality products are discovered during appraisal process – costs of scrap, rework, repair and material loss
  - Faulty goods or scraps/rejects.
  - Design changes
  - Trouble-shooting or defect failure analysis.
  - Re-inspection of reworked products
  - Downgrading
  - Downtime due to defects
  - Engineering change orders
  - Purchasing change orders
  - Re-testing
  - Material procurement
  - Material review activity
  - Rework costs

External Failure Costs

- Costs incurred when a defect is discovered after the customer receives the service or product, including returns, repairs, recalls
  - Complaints and loss of customer goodwill
  - Lost sales costs
  - Warranty claims
  - Product returns, recall, and corrective action costs
  - Product reliability compensation
  - Product liability (insurance and settlements)
  - Field maintenance and product service
  - Replacement inventories
  - Strained distributor relations

Costs of Detecting Defects



- Early detection/prevention is less costly
  - May be less by a factor of 10

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