Pearson BTEC Level 4 Higher Nationals in Engineering (RQF)

Unit 17: Quality and Process Improvement

Unit Workbook 1

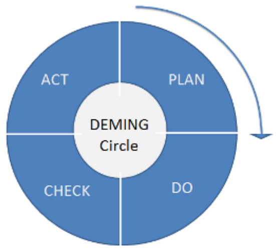
in a series of 2 for this unit

Learning Outcome 1 and 2

Quality Control Tools and Costing

- Institute a vigorous programme of education and retraining
- Create a structure in top management that will push on the above points every day

He believed that adoption of, and action on, the fourteen points was a signal that management intended to stay in business. Deming also encouraged a systematic approach to problem solving and promoted the widely known Plan, Do, Check, Act (PDCA) cycle.



The Deming Cycle

PLAN: identify an opportunity and plan for change

DO: implement the change on a small scale

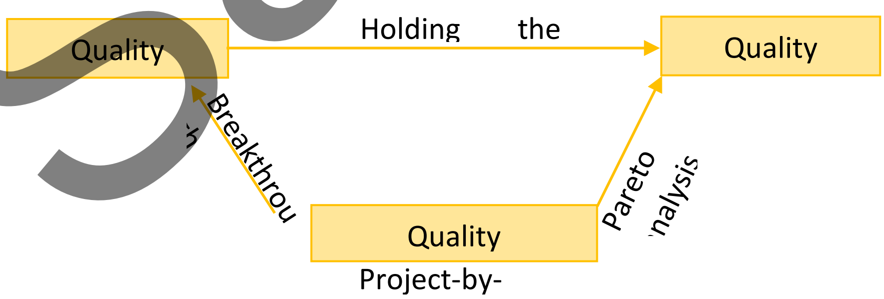
CHECK: use data to analyse the results of the change to determine whether it made a positive difference.

ACT: if the change was successful, implement it on a wider scale and continuously assess the outcome. If the change did not work, begin the cycle again.

The PDCA cycle is also known as the Deming cycle, although it was developed by a colleague of Deming, Dr Shewhart. It is a universal improvement methodology, the idea being to constantly improve, and thereby reduce the difference between the requirements of the customers and the performance of the process. The cycle is about learning and ongoing improvement, learning what works and what does not in a systematic way; and the cycle repeats; after one cycle is complete, another is started.

1.2 Dr Joseph M Juran

Juran developed the quality trilogy – quality planning, quality control and quality improvement. Good quality management requires quality actions to be planned out, improved and controlled. The process achieves control at one level of quality performance, then plans are made to improve the performance on a project by project basis, using tools and techniques such as Pareto analysis. This activity eventually achieves breakthrough to an improved level, which is again controlled, to prevent any deterioration



Juran believed quality is associated with customer satisfaction or dissatisfaction with the product, and emphasised the necessity for ongoing quality improvement through a succession of small improvement projects carried out throughout the organisation. His ten steps to quality improvement are:

- Build awareness of the need and opportunity for improvement
- Set goals for improvement

- Organise to reach the goals
- Provide training
- Carry out projects to solve problems
- Report progress
- Give recognition
- Communicate results
- Keep score of improvements achieved
- Maintain momentum

He concentrated not just on the end customer, but on other external and internal customers. Each person along the chain, from product designer to final user, is a supplier and a customer. In addition, the person will be a process, carrying out some transformation or activity.

1.3 Armand V Feigenbaum

Aramand Feignbaum was the originator of "total quality control", often referred to as total quality. He defined it as:

> "An effective system for integrating quality development, quality maintenance and quality improvement efforts of the various groups within an organisation, so as to enable production and service at the most economical levels that allow full customer satisfaction".

He saw it as a business method and proposed three steps to quality:
- Quality leadership
- Modern quality technology
- Organisational commitment

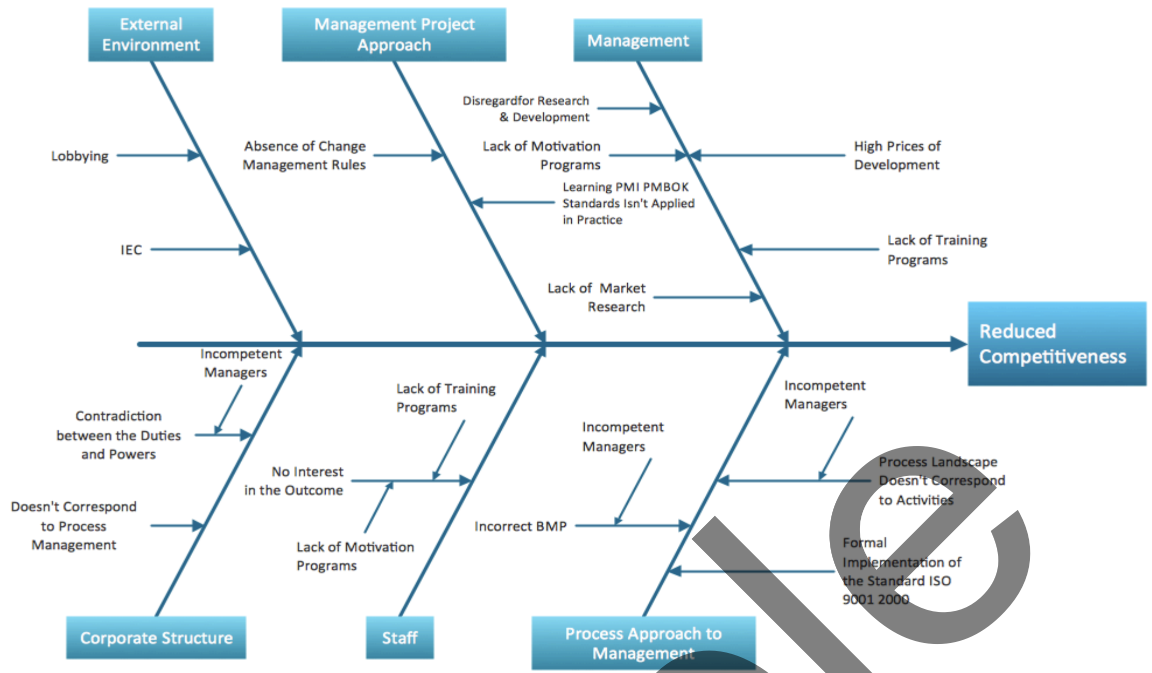
1.4 Dr Kaoru Ishikawa

Dr Ishikawa made many contributions to quality, the most noteworthy being his total quality viewpoint, company-wide quality control, his emphasis on the human side of quality, the Ishikawa diagram and the assembly and use of the "seven basic tools of quality":

- Pareto analysis: which are the big problems?
- Cause and effect diagrams: what causes the problems?
- Stratification: how is the data made up? (replaced by flow-charts in newer versions).
- Check sheets: how often it occurs or is done?
- Histograms: what do overall variations look like?
- Scatter charts: what are the relationships between factors?
- Process control: charts which variations to control and how?

He believed these seven tools should be known widely, if not by everyone, in an organisation and used to analyse problems and develop improvements. Used together they form a powerful kit.

One of the most widely known of these is the Ishikawa (or fishbone or cause and effect) diagram.

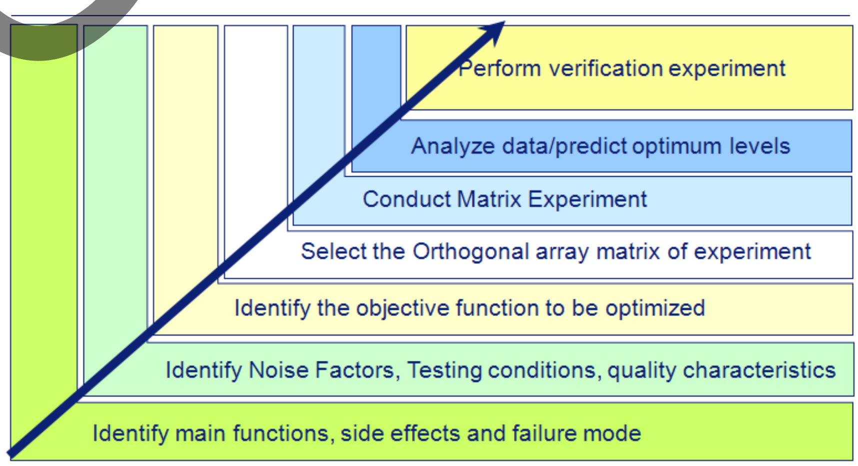


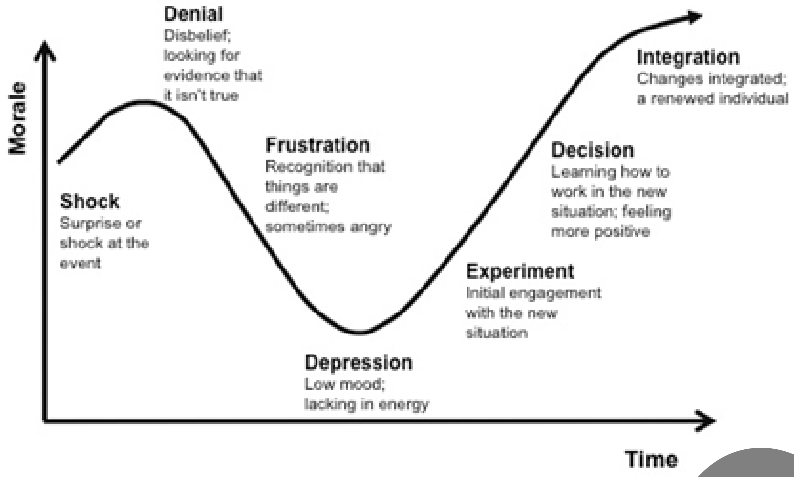
Like other tools, it assists groups in quality improvements. The diagram systematically represents and analyses the real causes behind a problem or effect. It organises the major and minor contributing causes leading to one effect (or problem), defines the problem, identifies possible and probable causes by narrowing down the possible ones. It also helps groups to be systematic in the generation of ideas and to check that it has stated the direction of causation correctly. The diagrammatic format helps when presenting results to others.

1.5 Dr Genichi Taguchi

Taguchi believed it is preferable to design product that is robust or insensitive to variation in the manufacturing process, rather than attempt to control all the many variations during actual manufacture. To put this idea into practice, he took the already established knowledge on experimental design and made it more usable and practical for quality professionals. His message was concerned with the routine optimisation of product and process prior to manufacture rather than quality through inspection. Quality and reliability are pushed back to the design stage where they really belong, and he broke down off-line quality into three stages:

- System design
- Parameter design
- Tolerance design





The original five stages of grief – denial, anger, bargaining, depression and acceptance – have been adapted over the years. There are numerous versions of the curve in existence; however, the majority of them are consistent in their use of the following basic emotions, which are often grouped into three distinct transitional stages:

Stage 1 Shock and Denial

Stage 2 Anger and Depression

Stage 3 Acceptance and Integration

Each person reacts individually to change, and not all will experience every phase. Some people may spend a lot of time in stages 1 and 2, whilst others who are more accustomed to change may move fairly swiftly into stage 3. Although it is generally acknowledged that moving from stage 1 through stage 2 and finally to stage 3 is most common, there is no right or wrong sequence. Several people going through the same change at the same time are likely to travel at their own speed, and will reach each stage at different times.

2.5 Focus i.e. internal and external customers

The term customer is most commonly associated with someone who purchases goods or services. However, Joseph Juran (see 1.2 above) expressed the view that organisations have both internal and external customers, and, internal customers have a direct link to a positive external customer experience. The external customer is the person who purchases the goods or services, while the internal customer is anyone within an organisation who at any time is dependent on anyone else within the organisation. So, an internal customer can be a co-worker, another department, or a distributor who depends upon an organisation to provide products or services which in turn are utilised to create a deliverable for the external customer. In the diagram below, the 'Customer' in the centre is the focus for the departments and functions surrounding it: these are the 'internal customers'.

In recent years, there has been a move toward gauging internal customer satisfaction in much the same way as organisations have been polling external customers' views for many years i.e. the satisfaction survey. One model comprises five steps:

1. Have each department identify who is/are their internal customer/s and who is/are their internal supplier/s.
2. Request each department to talk to their internal customer/s and ask them specifically what is needed for them to do their jobs that they provide.
3. Have them ask these internal customers what they currently do that disappoints them in delivering what they provide.
4. Request they ask these internal customers what they could do that would delight them and make their jobs easier.
5. Document all of the above.

When employees (internal customers) are satisfied with their treatment and given the correct tools to do their jobs, external customers are more likely continue to do business with the company.

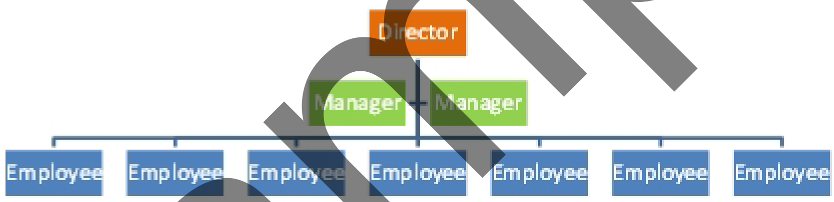
2.6 Quality management: the application of supporting theories

Quality management has four components; quality planning, quality assurance, quality control and continual improvement. These include procedures, tools and techniques that are used to ensure that the outputs and benefits meet customer requirements.

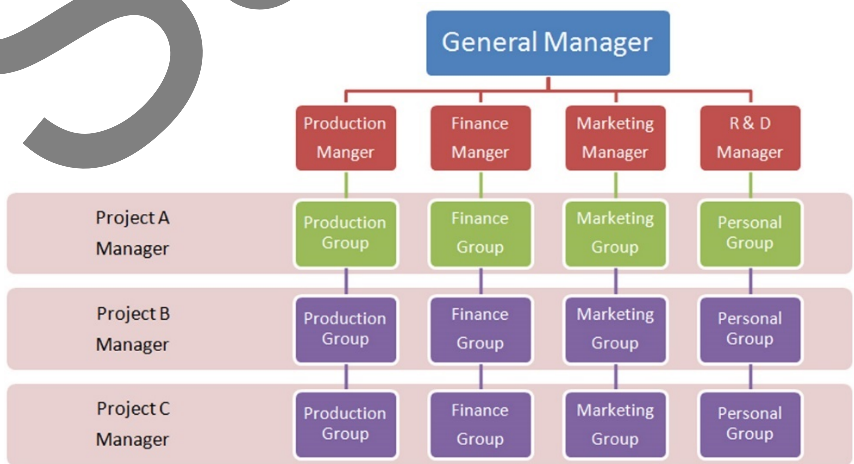
The first component, quality planning, involves the preparation of a quality management plan that describes the processes and metrics that will be used. The quality management plan needs to be agreed with relevant stakeholders to ensure that their expectations for quality are correctly identified. The processes described in the quality management plan should conform to the processes, culture and values of the host organisation.

Quality assurance provides confidence to the host organisation that its projects, programmes and portfolios are being well managed. It validates the consistent use of procedures and standards, and ensures that staff have the correct knowledge, skills and attitudes to fulfil their project roles and responsibilities in a competent manner. Quality

- Horizontal or flat structures. Here there are fewer layers and more people in each layer. Decision making may need to take account of several groups within a layer. However, communication is usually more effective. Flat structures often work well with skilled and motivated workers.



- Matrix structures**.** Sometimes the business needs to use people with a variety of skills who are drawn from many parts or functional areas of the business such as marketing, operations, finance and human resources. These can be organised into teams to complete projects.



Research presented at 11th International Conference on Manufacturing Research (ICMR2013), Cranfield University, UK, in Sept 2013 identified 20 frequently quoted barriers to the implementation of a Total Quality Management strategy. These are given below (in no particular order):

- Employees are not trained in problem identification and problems solving techniques.
- Employees are not trained in quality improvement skills.
- Employees are not empowered to implement quality improvement efforts.
- Teams involving all departments are not employed.
- There is frequent turnover of employees.
- Quality is not everyone's responsibility.
- Top management is not committed to quality.
- Quality is treated as a separate initiative.
- There are excess layers of management.
- The best practices and/or products of other companies are not benchmarked.
- Strategic plans do not include quality goals.
- There is no joint planning with suppliers.
- The strategic plan is not customer driven.
- Quality action plans are often vague.
- Quality is not effectively measured.
- Management's compensation is not linked to achieving quality goals
- Time constraints prohibit effective TQM implementation.
- There are inadequate resources to employ TQM.
- Employees are resistant to change.
- The high costs of implementing TQM outweigh the benefits.

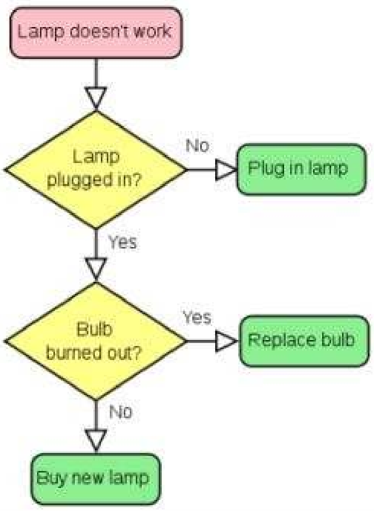
4. TQM Techniques

When planning and implementing a total quality management system or quality management strategy, there is no one solution for every situation. Each organisation is unique in terms of the culture, management practices, and the processes used to create and deliver its products and services. The quality management strategy will then vary from organization to organization; however, a set of primary elements or tools should be present in some format or other.

4.1 The seven basic tools of quality control

1) Flow chart

This is one of the basic quality tools that can be used for analysing a sequence of events. The tool maps out a sequence of events that take place sequentially or in parallel. The flow chart can be used to understand a complex process in order to find the relationships and dependencies between events. You can also get a brief idea about the critical path of the process and the events involved in the critical path.
Flow charts can be used for any field to illustrate complex processes in a simple way. There are specific software tools developed for drawing flow charts, such as MS Visio.



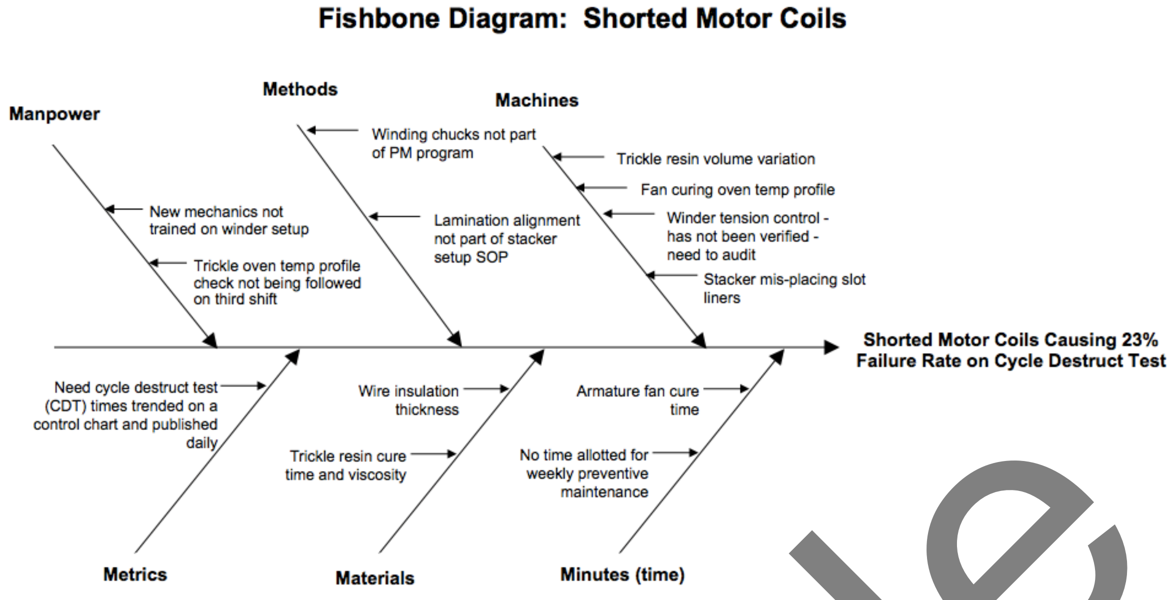
2) Check list

A check list (also referred to as a check sheet, tally list, tally sheet or one of numerous other names) is probably the most basic tool for quality. A check sheet is basically used for gathering and organising data. When this is done with the help of software packages such as Microsoft Excel, you can derive further analysis e.g. graphs, and automate through macros. Therefore, it is always a good idea to use a software check sheet for information gathering and organising needs. You can always use a paper-based check sheet when the information gathered is only used for backup or purposes other than further processing.

Defect Types ? (Major/ Minor)	Defects in Supplied Items							Total Count
	Sun	Mon	Tue	Wed	Thu	Fri	Sat	
Rusted Items		▯▯▯▯	▯▯		▯▯	▯		9
Items with Scratch	▯							1
Dirty		▯		▯▯▯		▯▯		6
Broken/ Cracks			▯▯				▯	3
Main Body Dent					▯▯▯			3
Missing Components		▯▯		▯▯			▯	5
Labelling Error					▯	▯▯▯		4
Damage in Packaging			▯▯					2
Wrong Item Issued					▯▯		▯	3
Film on Parts			▯▯▯▯					4
Voids in Casting	▯					▯	▯▯	4
Incorrect Dimensions			▯▯	▯	▯▯			5
Failed to pass the quality test		▯▯				▯		3
Total Count	2	9	12	6	10	8	5	52

3) Fishbone diagram

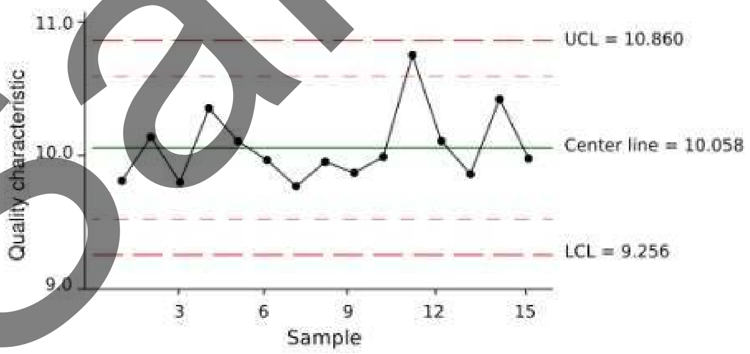
Cause and effect diagrams (Ishikawa Diagram) are used for understanding organisational or business problem causes. Organisations face problems every day, and it is required to understand the causes of these problems in order to solve them effectively. A cause and effect diagrams exercise is usually a teamwork exercise: a brainstorming session is required in order to come up with an effective cause and effect diagram. All the main components of a problem area are listed and possible causes from each area is listed. Then, most likely causes of the problems are identified to carry out further analysis.



4) Control chart

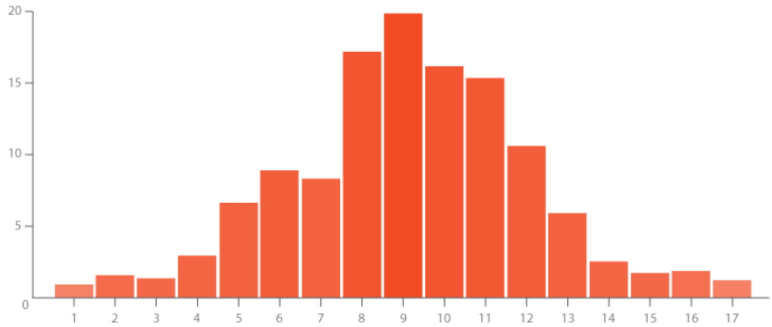
A control chart is the best tool for monitoring the performance of a process. These types of charts can be used for monitoring any processes related to function of the organisation. These charts allow you to identify the following conditions related to the process that has been monitored.

- Stability of the process
- Predictability of the process
- Identification of common cause of variation
- Special conditions where the monitoring party needs to react



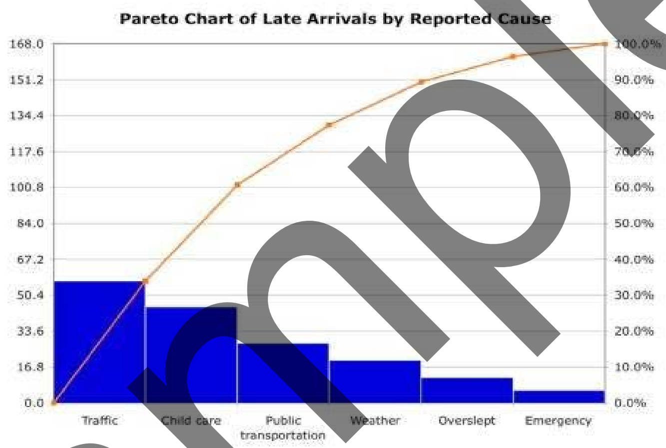
5) Histogram

A histogram is a chart with columns, and is used for illustrating the frequency and magnitude in the context of two variables. This represents the distribution by mean. If the histogram has a normal distribution, the graph takes the shape of a bell curve. If it is not normal, it may take different shapes based on the condition of the distribution. Histograms can be used to measure and compare one thing against another thing.



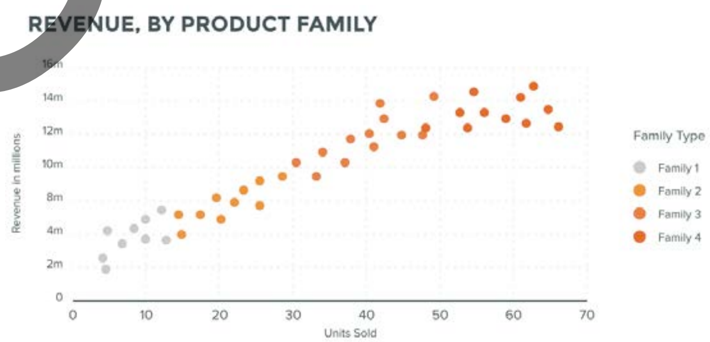
6) Pareto chart

Pareto charts are used for identifying a set of priorities. You can chart any number of issues/variables related to a specific concern and record the number of occurrences. In this way you can identify the parameters that have the highest impact on the specific concern. This helps you to work on the most important issues in order to get the condition under control.



7) Scatter diagram

When it comes to the values of two variables, scatter diagrams are the best way to present data. Scatter diagrams present the relationship between two variables and illustrate the results on a Cartesian plane.
Further analysis, such as trend analysis can then be performed on the values. In these diagrams, one variable denotes one axis and another variable denotes the other axis.



The seven basic quality tools help to address different quality concerns in an organisation, therefore, use of such tools should be a basic practice in the organisation in order to enhance the efficiency and effectiveness of operations. Trainings on these tools should be included in the organisational orientation program, so all the staff members get to learn these basic tools.

4.2 Hazard Analysis Critical Control Point (HACCP)

HACCP is an approach to food safety that is systematic and preventive. It is recommended by the *Codex Alimentarius Commission*, the United Nations international standards organization for food safety. HACCP is used by most countries around the world, and has been in use since the 1960s. Under Article 5 of Regulation (EC) 852/2004, food businesses must put in place, implement and maintain a food safety management system based on Hazard Analysis Critical Control Points (HACCP) principles to ensure the food produced from their premises is safe to eat.

There are seven universally-accepted HACCP principles: every country that uses HACCP follows these principles.

Principle 1: The first principle is hazard analysis. At this stage, a plan is laid out to identify all possible food safety hazards that could cause a product to be unsafe for consumption, and the measures that can be taken to control those hazards.
For example: at the cooking step of the production process, one of the identified hazards is the survival of pathogens due to inadequate cooking time or temperature.

Principle 2: The second principle is identifying critical control points. These are the points in the production process where an action can be taken to prevent, eliminate, or reduce a food safety hazard to an acceptable level.
For example: the cooking step is considered a "critical control point" because control measures are necessary to deal with the hazard of pathogens surviving the cooking process.

Principle 3: The third principle is establishing critical limits for each critical control point. A critical limit is the limit at which a hazard is acceptable without compromising food safety.
For example: critical limits" at the cooking stage include specific time and temperature for cooking the product.

Principle 4: The fourth principle is establishing monitoring procedures for critical control points. Highly detailed monitoring activities are essential to make sure the process continues to operate safely and within the critical limits at each critical control point.
For example: monitoring procedures at a cooking critical control point could include taking the internal temperature of the product with a specialized thermometer.

Principle 5: The fifth principle is crucial: establishing corrective actions. These actions must be taken to bring the production process back on track if monitoring indicates that deviation from critical limits has occurred. In food production, correcting problems before end-stage production is far more effective than waiting until a product is finished to test it.
For example: if the required internal temperature has not been reached, a corrective action would require that the product be cooked further. If the cooking temperature cannot be reached, another corrective action would call for the product to be held and destroyed.

Principle 6: The sixth principle is establishing verification procedures. Verification means applying methods, procedures, tests, sampling and other evaluations (in addition to monitoring) to determine whether a control measure at a critical control point is or has been operating as intended. Verification activities also ensure that the monitoring and the corrective actions are done according to a company's written HACCP program.

Principle 7: The seventh principle is record keeping. Records must be kept by the company to demonstrate the effective application of the critical control points, and assist with official verification. Records must be established to document the monitoring and verification results, and all information and actions taken in response to any deviations found through monitoring and verification.

For example: the plant employee responsible for monitoring a cooking critical control point completes a cooking log sheet. This sheet includes the date, the start and finish time, the temperature and the employee's signature. If a deviation has occurred in the production process, the responsible plant employee records the details in a deviation log book.

4.3 Statistical Process Control (SPC)

(SPC will be covered in detail in Workbook 3 – for the moment, just try to understand the concepts)

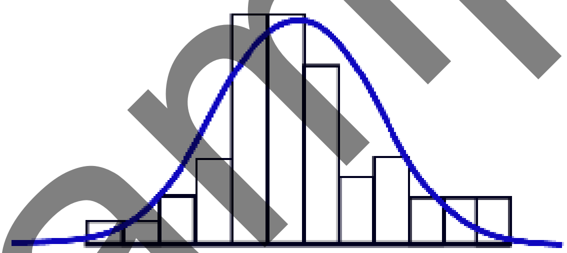
The concepts of Statistical Process Control (SPC) were initially developed by Dr. Walter Shewhart of Bell Laboratories in the 1920's, and were expanded upon by Dr. W. Edwards Deming, who introduced SPC to Japanese industry after WWII. After early successful adoption by Japanese firms, SPC has now been incorporated by organisations around the world as a primary tool to improve product quality by reducing process variation.

Shewhart identified two sources of process variation:

- *Chance* variation that is inherent in process, and stable over time, and
- *Assignable*, or *Uncontrolled* variation, which is unstable over time - the result of specific events outside the system. (Deming relabelled chance variation as *Common Cause* variation, and assignable variation as *Special Cause* variation).

4.3.1 Process Variability

Many histograms of process data approximate a Normal Distribution, as shown below:



NB: **control charts do not require normally distributed data in order to work** - they will work with any process distribution

In order to evaluate any distribution, it is important to have a measure of the data dispersion, or spread. This can be expressed by the range, R (highest value - lowest value), but is better captured by the standard deviation σ (sigma). The standard deviation can be easily calculated from a group of numbers using a scientific calculator, a spreadsheet or statistics software program.

Often we focus on average values, but understanding dispersion is critical to the management of industrial processes. Consider two examples:

- If you put one foot in a bucket of ice water (2°C) and one foot in a bucket of scalding water (82 °C), on average you'll feel fine 48°C), but you won't actually be very comfortable!

- If you are asked to walk through a river and are told that the average water depth is 3 feet, you might want more information. If you are then told that the range is from zero to 15 feet, you might want to re-evaluate the trip.

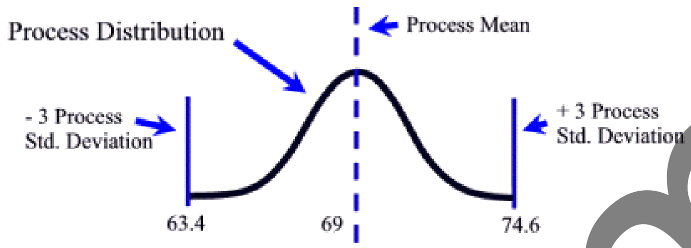
4.2.1 Control Limits

Statistical tables have been developed for various types of distributions that quantify the area under the curve for a given number of standard deviations from the mean. These can be used as probability tables to calculate the odds that a given value (measurement) is part of the same group of data used to construct the histogram.

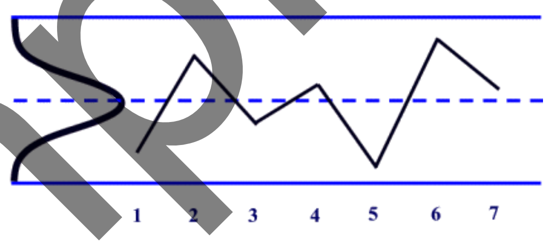
Shewhart found that control limits placed at three standard deviations from the mean in either direction provide an economical trade-off between the risk of reacting to a false signal and the risk of not reacting to a true signal - regardless of the shape of the underlying process distribution.

If the process has a normal distribution, 99.7% of the population is captured by the curve at three standard deviations from the mean (±3σ). Stated another way, there is only a 1-99.7%, or 0.3% chance of finding a value beyond 3 standard deviations. Therefore, a measurement value beyond 3 standard deviations indicates that the process has either shifted or become unstable (more variability).

The illustration a) below shows a normal curve for a distribution with a mean (‘average’ value $\bar{X}$ referred to as x- bar) of 69 and a standard deviation of 1.87 giving a mean less 3 standard deviations a value of 63.4, and a mean plus 3 standard deviations of 74.6 ($\bar{X} \pm 3\sigma$). Values, or measurements, less than 63.4 or greater than 74.6 are extremely unlikely. These laws of probability are the foundation of the control chart.



a) Normal distribution



b) normal distribution turned on its side

Now, consider that the distribution is turned sideways as shown in b) above, and the lines denoting the mean and ± 3σ are extended. This construction forms the basis of the Control Chart. Time series data plotted on this chart can be compared to the lines, which now become **control limits** for the process. Comparing the plot points to the control limits allows a simple probability assessment.

We know from our previous discussion that a point plotted above the upper control limit (or lower control limit) has a very low probability (0.3%) of coming from the same population that was used to construct the chart - this indicates that there is a Special Cause - a source of variation beyond the normal chance variation of the process.

4.4 Benchmarking

Benchmarking is a way of discovering what is the best performance being achieved – whether in a particular company, by a competitor or by an entirely different industry. This information can then be used to identify gaps in an organization’s processes in order to achieve a competitive advantage. Although there are many forms of benchmarking, they can be classified into three categories – internal, competitive and strategic:

- *Internal benchmarking:*
  is used when a company already has established and proven best practices and they simply need to share them. Depending on the size of the company, it may be large enough to represent a broad range of performance (i.e.,

cycle time for opening new accounts in branches coast to coast). Internal benchmarking also may be necessary if comparable industries are not readily available.

- *Competitive benchmarking*:
  is used when a company wants to evaluate its position within its industry. In addition, competitive benchmarking is used when a company needs to identify industry leadership performance targets.

- *Strategic benchmarking:*
  is used when identifying and analysing world-class performance. This form of benchmarking is used most when a company needs to go outside of its own industry. Often, these benchmarks are obtained from outside sources.

4.4.1 Steps Involved in Benchmarking

The following is a list of the vital steps involved in benchmarking. These steps should be tailored, based on company policies, resource availability and the project or process one is dealing with:

1. Understand the company's current process performance gaps. This will help decide what needs benchmarking.

2. Obtain support and approval from the executive leadership team. That approval and support will assist with eliminating roadblocks, providing adequate resources and expediting the benchmark-gathering process.

3. Document benchmarking objectives and scope. This is a necessity for any project.

4. Document the current process. Without up-to-date knowledge of the current process:
a. Time and resources can be wasted collecting process documentation and data that already exists.
b. The project may lack focus, purpose and/or depth.
c. Benchmarking visits may appear to be random exercises in information-gathering.
d. The team could select a partner whose performance is actually worse than that of its own organization.
e. Collected benchmarking data will be difficult to compare "apples to apples" in terms of process requirements.

5. Agree on the primary metrics. Benchmarking measurements are used as the basis of many comparisons:
a. To determine the gap between current performance and that of partner organizations.
b. To track progress from the present (with the current process) into the future.
c. To track partners' progress toward their goals.
d. To determine superior performance with process improvements.
e. To use a measurement systems analysis (MSA):
f. These comparisons will be valid only if everyone participating in the study measures performance in exactly the same way – every time.
g. It is important to make sure metrics are being established that potential benchmarking partners are probably already tracking or that can be easily derived from existing measurements.

6. The metrics should be put in writing. In particular:
a. What is being measured
b. How the units of measure will be classified.
c. What should be included in the measurement.
d. What should not be included.
e. How to make any necessary calculations.
f. Examples of typical measurements.

7. Agree on what to benchmark. Everyone must be in agreement on what to benchmark prior to any benchmark gathering initiative in order to:
a. Understand gaps of low performers.
b. Understand impact to customers, associates and shareholders.
c. Prioritize and select one to three metrics to benchmark.

8. Develop a data collection plan.

9. Identify research sources and initiate data gathering.

10. Design a screening survey to assist with partner selection. Characteristics of the survey are important:
a. Crisp focus on indicators of excellence
b. Two pages maximum
c. 30 minutes maximum to complete
d. Objective, multiple-choice questions
e. Communicates the plans, objectives and resource requirements for the study
f. Reflects focus areas for subsequent in-depth questionnaires

11. Determine how to contact and screen companies.

12. Design a detailed survey to gather information.

13. Decide if gathered information meets original objectives.

14. Conduct a site visit.

15. Apply the learnings to performance gaps.

16. Communicate to the executive leadership to ensure continued support.

17. Develop a recommended implementation plan with process owner.

18. Know when to update and recalibrate.

5 Compliance to Standards

There are a significant number of 'standards' that an organisation is required to adhere to: these range from internal company standards, industry standards and international standards, most notably those set by the International Organisation for Standardisation (ISO).

Internal standards are those that are set by the organisation e.g. quality standards, which may include specifications, processes and procedures.

Industry standards are a set of criteria within an industry relating to the standard functioning and carrying out of operations in their respective fields of production. In other words, it is the generally accepted requirements followed by the members of an industry.

Examples:

SO/TS 16949 was jointly developed by The International Automotive Task Force (IATF) members and submitted to the International Organization for Standardization (ISO) for approval and publication. The document is a common automotive quality system requirement based on ISO 9001, and customer specific requirements from the automotive sector. ISO/TS 16949 emphasizes the development of a process oriented quality management system that provides for:

- continual improvement
- defect prevention
- reduction of variation and waste in the supply chain

The goal is to meet customer requirements efficiently and effectively.

The Electronic Industries Alliance (EIA) standards direct component marking, data modelling, colour coding and packaging materials. Products and services covered under this collection range from the smallest electronic component to the most complex systems used by the defence, space and consumer product industry. The American National Standards Institute (ANSI) accredits EIA standards, which help you:

- Increase market share
- Boost quality levels
- Elevate customer satisfaction

Good manufacturing practice (GMP) is the minimum standard that a medicines manufacturer must meet in their production processes. Products must:

- be of consistent high quality
- be appropriate to their intended use
- meet the requirements of the marketing authorisation (MA) or product specification

Good distribution practice (GDP) requires that medicines are obtained from the licensed supply chain and are consistently stored, transported and handled under suitable conditions, as required by the product specification. Organisations that may have to comply with good manufacturing practice (GMP) and/or good distribution practice (GDP) include:

- manufacturer licence holders
- wholesale dealer licence holders
- blood establishment authorisation holders
- non-UK sites employed by UK MA holders

British Standards are an agreed way of doing things. They could be about manufacturing products, managing processes, delivering services or materials, and can cover a huge range of activities. BSI Standards represent the condensed knowledge of a group of people who have a huge amount of experience or expertise regarding a given subject, for example, sellers, buyers, users or regulators. There are in excess of 50,000 current British and ISO Standards, all of which are voluntarily written to help businesses work more efficiently and to higher standards. The BSI Kitemark™ is a quality mark owned and operated by BSI. It is one of the most recognised symbols of quality and safety and confirms conformity certification to consumers, businesses and procurement practices.

Investors in People is the standard for people management. The Standard defines what it takes to lead, support and manage people well for sustainable results. The Investors in People Standard is underpinned by a rigorous assessment methodology and a framework which reflects the latest workplace trends, essential skills and effective structures required to outperform in any industry.

International Standards reflect agreements on the technical description of the characteristics to be fulfilled by the product, system, service or object in question. They are widely adopted at the regional or national level and are applied by manufacturers, trade organizations, purchasers, consumers, testing laboratories, governments, regulators and other interested parties. Some of the more common standards are:

ISO 14001: 2015 Environmental Management
ISO 14001 is an internationally accepted standard that sets out how an organisation can go about putting in place an effective Environmental Management System (EMS). The standard is designed to address the delicate balance between maintaining profitability and reducing environmental impact; with the commitment of your entire organisation, it can enable you to achieve both objectives.

BS OHSAS 18001: 2007 Health & Safety Management
BS OHSAS 18001 is the internationally recognised assessment specification for occupational health and safety management systems. It was developed by a selection of leading trade bodies, international standards and certification bodies to address a gap where no third-party certifiable international standard exists. BS OHSAS 18001 has been designed to be compatible with ISO 9001 and ISO 14001, to help organisations meet their health and safety obligations in an efficient manner.

ISO/IEC 27001: 2013 Information & Data Security
ISO 27001 is the only auditable international standard which defines the requirements for an Information Security Management System (ISMS). The standard is designed to ensure the selection of adequate and proportionate security controls. This helps you to protect your information assets and give confidence to any interested parties, especially your customers. The standard adopts a process approach for establishing, implementing, operating, monitoring, reviewing, maintaining, and improving your ISMS.

5.1 ISO 9001: 2015 Quality Management
ISO 9001 is the world's most established quality framework, currently being used by over 1 million organisations in 178 countries worldwide, and sets the standard not only for quality management systems, but management systems in general. It helps all kinds of organisations to succeed through improved customer satisfaction, staff motivation and continual improvement. We will consider this standard in more detail.

The International Standard for Quality Management (ISO 9001:2015) adopts a number of management principles, that can be used by top management to guide their organisations towards improved performance. These are:

I. Customer focus
   The primary focus of quality management is to meet customer requirements and to strive to exceed customer expectations.
   Rationale
   Sustained success is achieved when an organisation attracts and retains the confidence of customers and other interested parties on whom it depends. Every aspect of customer interaction provides an opportunity to create more value for the customer. Understanding current and future needs of customers and other interested parties contributes to sustained success of an organisation

II. Leadership
   Leaders at all levels establish unity of purpose and direction and create conditions in which people are engaged in achieving the organisation's quality objectives.
   Rationale
   Creation of unity of purpose and direction and engagement of people enable an organisation to align its strategies, policies, processes and resources to achieve its objectives.

III. Engagement of people
   Competent, empowered and engaged people at all levels throughout the organisation are essential to enhance its capability to create and deliver value.

The best way to make sure your products are up to quality is to undergo quality control (QC). It is vital that any business is giving the customer high quality products that are excellent value for money. Customer satisfaction should be the priority for a business, a satisfied customer is one that will come back and spend more money.

1.1 Six Sigma Quality Control Techniques

Six Sigma are a well-recognised institution for business education, they believe that QC can be measured using seven tools, which are:

- cause and effect diagrams,
- check sheets,
- control charts
- histograms
- pareto charts
- scatter diagrams
- stratification

By implementing these techniques, it is possible to notice trends that must be avoided if a company is to produce high quality products.

1.1.1 Cause and Effect Diagrams

Theory

Cause and Effect, or Fishbone or Ishikawa diagrams are used as a brainstorming technique, and a way to sort useful ideas into appropriate categories. The team agrees on the problem statement and writes it on the right-hand side of the board, an arrow pointing to the statement, which will diverge into major categories of possible causes. The typical categories are:

- methods,
- materials,
- equipment,
- measurement,
- worker's skills or availability,
- environment.

The team then starts to brainstorm the potential causes of the problem and writes it as a branch from the appropriate category. The team will drop one level deeper and ask, "why do these causes happen?" and we can delve deeper and deeper into the fundamental flaws that can build to the problem, and the team can look for solutions to mitigate this. Fig.1.1 shows a fishbone diagram template.

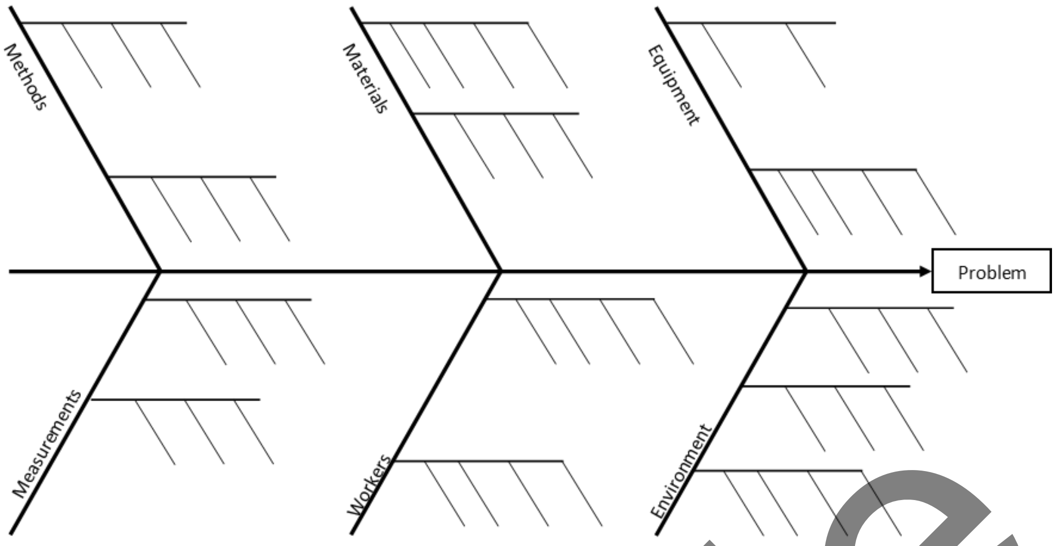


Fig.1.1: A cause and effect diagram template

1.1.2 Check Sheet

A check sheet is a very basic method of actively collecting data and can be used to collect quantitative data or qualitive. In the case of quantitative data, it becomes a tally sheet. They are kept in very basic formats to keep check sheets quick to complete and can be used to quantify any defects.

1.1.3 Control Chart

Control charts are used to reduce variation in the production line, the charts will have a control limits, and if the products go beyond these limits, then it is clear there is a large variation, and is used to try and trace the source of the variation.

1.1.4 Histograms

Histograms are similar to bar charts, but are used to cover a range of values, instead of a singular value and can be used to show a probability distribution graphically, Fig.1.2 shows a histogram for the production rate per hour over a 24-hour period, the data is shown in Table 1.1. It is possible that the histogram can create a normally distributed graph, recalling from Unit 2: Engineering Maths, it produces the bell curve that is used to calculate the probability using "Z values".

Table 1.1: Frequency of achieved production rates over a 24-hour period.

Production rate (products/hour)	Frequency
0-5	1
6-10	3
11-15	4
16-20	7
21-25	6
26-30	2
31-35	1
Total	24

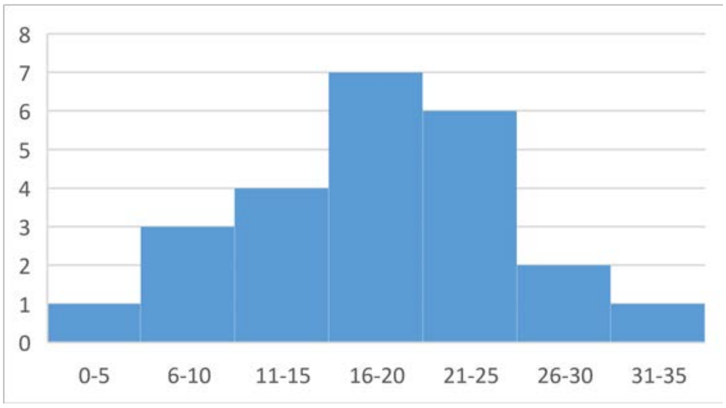


Fig.1.2: Histogram example

1.1.5 Pareto graph

Pareto graphs are used to quantify the amount of a certain problem and compare them as a percentage of the total problems caused. With this information, we can quickly see what the largest problems are, and which need to be addressed first, the pareto graph is used to visualise the priorities by looking at the "significant many" that accounts for 80% of the problems the company may have.

Example 1

Our company has been failing to meet production targets recently, and so we have started to analyse why the problems have been occurring, Table 1.2 shows the data that has been collected, showing delays that have occurred and any reduction in manpower.

Table 1.2: Problems that have caused a failure to reach production targets

Problem	Description	Frequency	% of total	Cumulative %
1	Delay from supplier	35	47.3	47.3
2	Machine failure	28	37.8	85.1
3	Staff Sickness	2	2.7	87.8
4	Defective Materials	6	8.1	95.9
5	Outside control limits	3	4.1	100.0
	Total	74	100	

This is a very basic table, and it's clear what the main problem is here. Sometimes there are a vast range of errors, or service managers use this to analyse customer complaints and what needs to be fixed to improve the restaurant. The table is then converted to a pareto graph in Fig.1.3 below.

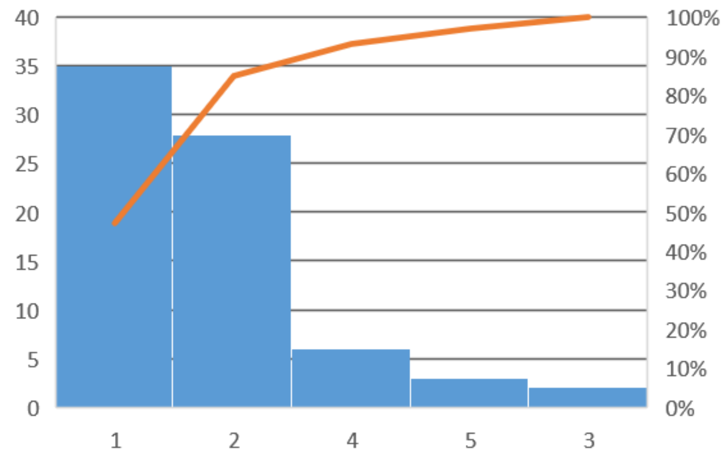


Fig.1.3: Example 1 pareto graph

So, in order to reduce or eliminate the top 80% of problems faced by the company, we need to replace our supplier and improve our machine reliability.

1.1.6 Scatter Graphs

Scatter graphs are used to show check for any linear correlation, and with the correlation try to confirm a causation. It's always important to see if there are relationships and trends between two quantitative pieces of data. The correlation is the apparent relationship between the two variables, a strong correlation between two variables does not mean there is a causation.

Let's say we run an ice cream van, we record the average temperature over the hour, and record how many sales we make for that hour. Fig.1.4 shows the scatter graph for the data collected over 14 days.

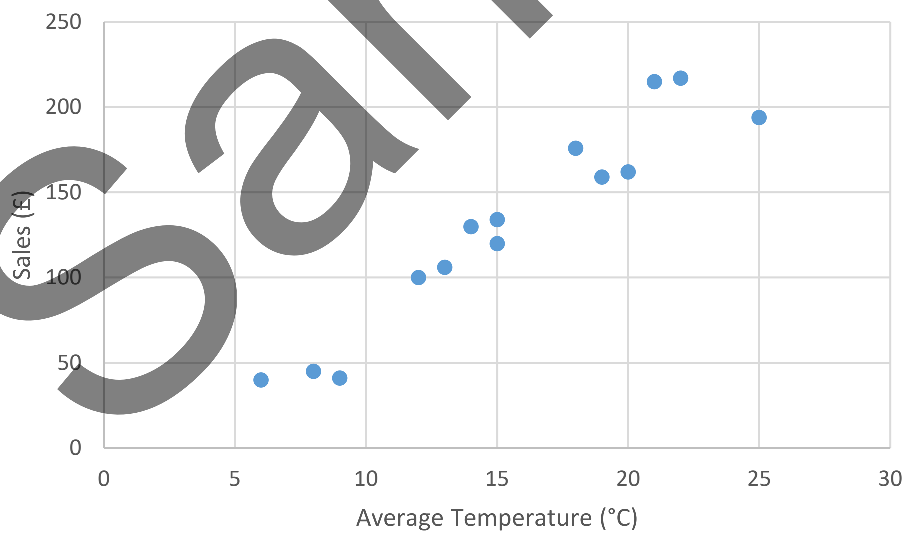


Fig.1.4: Average temperature compared to ice cream sales

We can see there is a strong positive correlation between the temperature outside, and the number of ice creams sold, and in this case, we know the causation (everyone wants an ice cream when its hot outside). This would be defined as a strong positive correlation, Fig.1.5 shows different correlations that a graph can show.

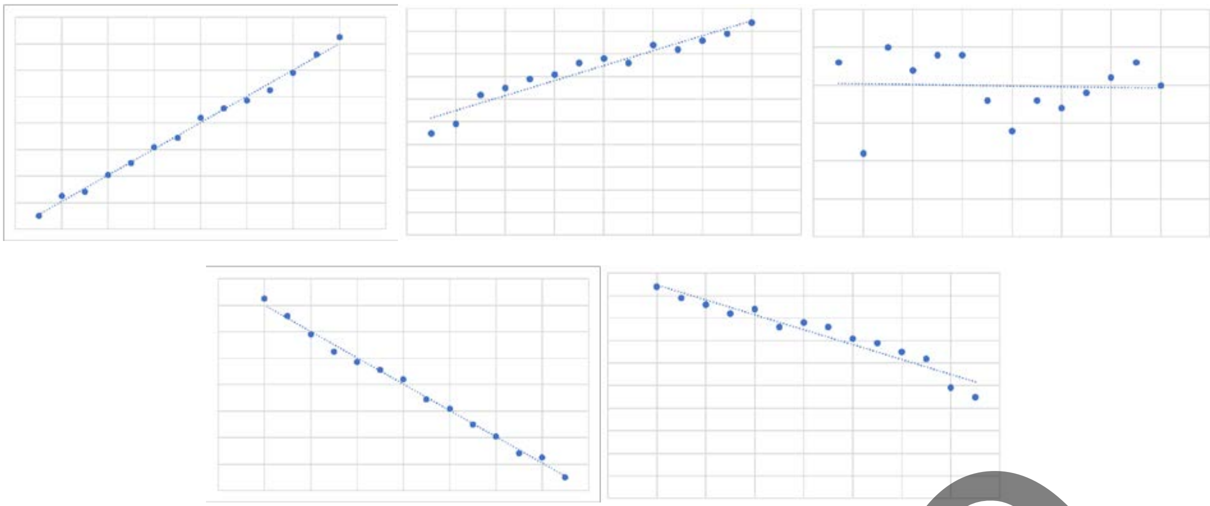


Fig.1.5: Possible correlations (clockwise from top left): Strong positive, weak positive, no correlation, weak negative, and strong negative

Sometimes there can be too much data to realise there is a correlation, so it can be important to use the equations discussed in Unit 2: Engineering Maths.

Example 2

Consider the following 15-point data set:

Table 1.3: Resistance of a component compared with current drawn

Resistance (Ω)	Current Drawn (A)
1	4
5	2
1	8
6	2
8	4
4	3
3	6
5	5
8	4
7	2
9	1
4	3
3	5
2	8
1	7

Recalling the general equation for a straight-line graph, shown with Eq.1.1.

$$y = mx + c \qquad \text{(Eq.1.1)}$$

Eq.1.2 shows the equation with linear regression analysis variables:

$$y = a_1 x + a_0 \qquad \text{(Eq.1.2)}$$

Use Eq.1.3 and 1.4 to calculate a_0 and a_1, where N is the number of points.

$$\sum y_i = a_0 N + a_1 \sum x_i \qquad \text{(Eq.1.3)}$$

$$\sum x_i y_i = a_0 \sum x_i + a_1 \sum x_i^2 \qquad \text{(Eq.1.4)}$$

Table 1.4 gives more information needed to calculate a_0 and a_1.

Table 1.4: $x_i, y_i, x_i y_i, x_i^2$ and their respective totals

x_i	y_i	$x_i y_i$	x_i^2
1	4	4	1
5	2	10	25
1	8	8	1
6	2	12	36
8	4	32	64
4	3	12	16
3	6	18	9
5	5	25	25
8	4	32	64
7	2	14	49
9	1	9	81
4	3	12	16
3	5	15	9
2	8	16	4
1	7	7	1
67	64	226	401

With the following information we can put the appropriate values into Eq.1.3 and 1.4 to create two simultaneous equations.

$$64 = a_0(15) + a_1(67) \qquad [1]$$

$$226 = a_0(67) + a_1(401) \qquad [2]$$

Multiply [1] by 67 and [2] by 15 to get [3] and [4]

$$4288 = 1005a_0 + 4489a_1 \qquad [3]$$

$$3390 = 1005a_0 + 6015a_1 \qquad [4]$$

Subtract [3] from [4]

$$-898 = 1526a_1 \therefore a_1 = \frac{-898}{1526} = -0.588$$

$$\therefore a_0 = \frac{64 - 67(-0.588)}{15} = 6.89$$

The equation for linear regression is therefore:

$$y = -0.588x + 6.89$$

The scatter graph with the line of regression is shown by Fig.1.6.

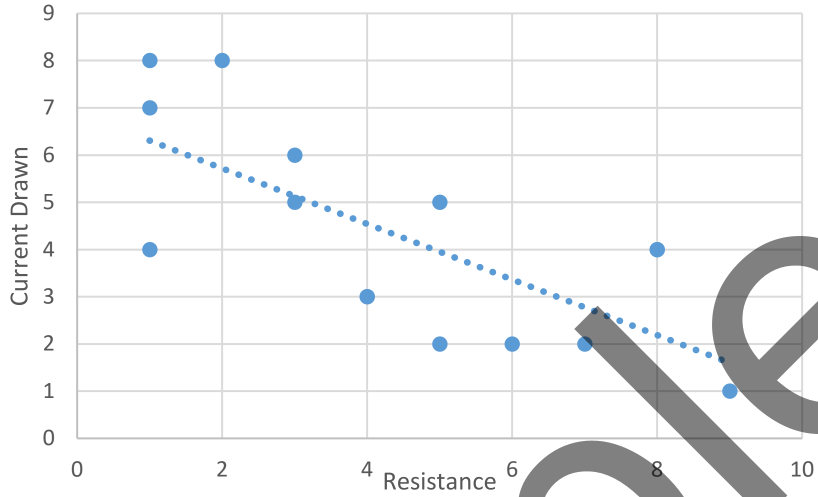


Fig.1.6: Scatter graph and linear regression line for Example 2

However, just because there is a correlation, does not mean there is a causation. In Example 2 we know that on a hot day everyone loves an ice cream, so we can link that causation. If I were to say, “let’s compare the height of a person and the number of times they have been skydiving” and the data I have obtained just happens to look like Fig.1.6 below. You could say, “from the data obtained, more people who have skydived were tall” but you can’t say “people skydive because they’re tall”.

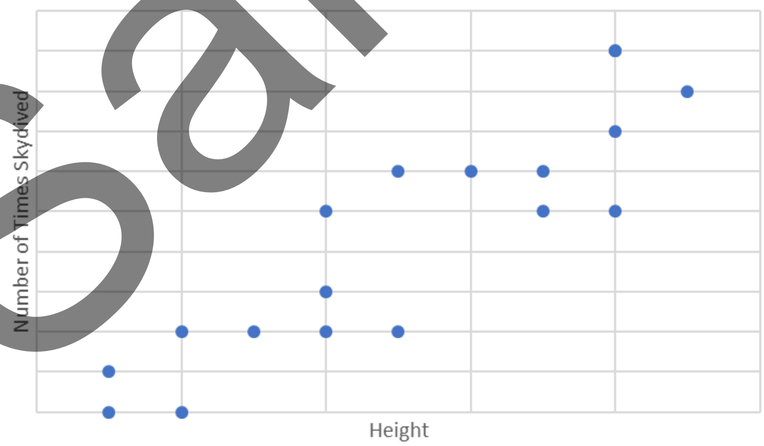


Fig.1.6: Height compared to number of times skydived

1.1.7 Stratification

We’ve collected a lot of data at this point, and stratification is used to organise into different groups and sub-groups. You’ve probably seen stratification before with the food pyramid, you have the 5 main groups (fats, dairy, meats, fruit and veg, carbohydrates) which themselves can be broken down into smaller groups

1.2 Attributes and Variables

Data can be classified into two types, attributes or variables. Both have their advantages and disadvantages.

1.2.1 Variable Data

Variable data is numerical information about the product (height, weight, brightness etc.) it is something that can be quantified. If we look at the height of five people who are: 6”3’, 5”4, 6”0’, 5”11’, and 5”1’. We can use this variable data to answer, “who’s the tallest?” or “what’s the average height?”. Variable data gives precise information about the product.

1.2.2 Attribute Data

Attributes consider the quality of a product rather than a quantifiable measurement. Attribute data is more to do with looking at whether the product is “this attribute” or not. If we were to look at the heights of 5 people, we look at whether or not they are “tall” or “short”. We aren’t concerned with their actual height value, but we can count that there are 3 tall people, and two short. Attributes are more about counting the number of products that fall into specific classifications. We cannot use attributes to calculate averages or rankings, as it is more obscure than variable data, and they are better suited towards calculating ratios, percentages or generating charts.

1.3 Testing Processes

The easiest way to make sure the quality is in your product is to test it, there’s different ways to test whether or not the product meets the quality standards. But they can be split into destructive and non-destructive testing

1.3.1 Destructive Testing

Destructive testing is used to test the durability for any misuse or its safety. For example, to test if a car is safe, its crashed into walls at varying speeds, with the crash test dummy being used to simulate the potential damage that would be done to a human in real life circumstances. Or the reason we know a standard Lithium-Ion battery can be recharged for around 500-1000 cycles, all depending on the chemistry, temperature, charging currents and voltages. But we know they last this long due to factory testing to completely draining the battery from constant charging and discharging. It cannot give a precise measurement, because real world conditions won’t match that of a laboratory, nor will every battery be perfectly identical.

Destructive tests are carried out to the point of failure for a test specimen. This helps us to understand a specimen's performance and/or its material behaviour under various loads. These tests are generally simple to undertake/analyse and yield more information than non-destructive testing.

Destructive testing is best suited to mass-produced objects, as the cost of destroying a small number of objects is small. It is not economical to perform destructive testing where only a few items exist (e.g. a spacecraft).

Analysing and recording the destructive failure mode is often achieved using a high-speed camera which records continuously until the failure appears. Detecting the failure can be achieved using a sound detector or stress gauge which will produce a signal to start the high-speed camera, which will have various recording modes to evidence virtually any type of destructive failure. Once the failure has occurred the high-speed that more satisfactory products are made in the same amount of time, so a boost in productivity is shown. Less waste also means less costs, and production errors can be found and fixed almost immediately.

1.5 Quality Function Deployment

1.5.1 What is Quality Function Deployment?

Quality Function Deployment (QFD) is a tool that companies use to ensure that what the final product that you are working towards is what is required to satisfy the customer. There several names for it such as matrix product planning, decision matrices and customer-driven engineering.

1.5.2 QFD Methodology

We typically begin with the "house of quality" shown in Fig.1.8 to focus on what the customer needs and wants, and we can also include features that would "wow" them. Once we have prioritised these qualities, we use QFD to work back and deploy them at the specific points.

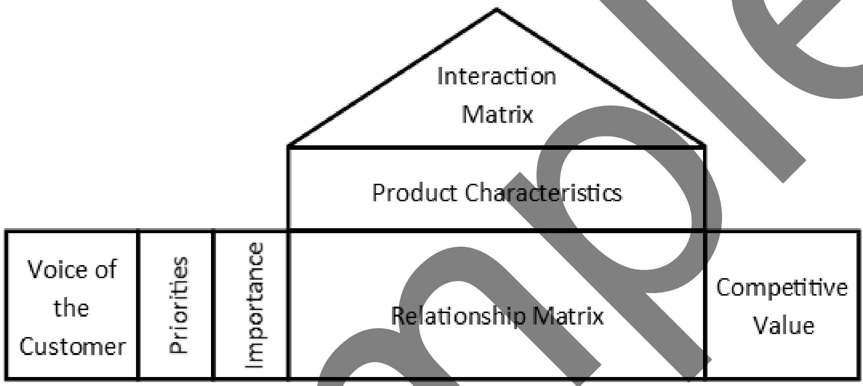


Fig.1.8: QFD "house of quality"

The house of quality is a useful graphical tool to incorporate an integrated style of thinking. It also provides a capability to plan tackling requirements. QFD teams use it as a useful method of communications to newer members of the team, or to mangers with regards to any inconsistencies between the needs of the customer, the requirements of the products and the risks at hand.

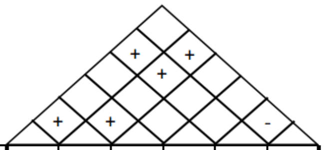
Let's say we are part of the QFD team for a company that makes bicycles, we are Company O. We are building the house of quality because we need feedback to keep up with competing companies in the market. The voice of the customer has been interpreted into the priorities, which have been ranked by importance through customer interpretation. The competitive benchmarking is Company O, against Company A, Company B and Company C.

The voice of the customer has been broken down into five priorities, with the weightings of the importance also included. The company has looked into six different product characteristics of the bike that could affect each of the priorities (**Realistically, there could be an unlimited number of product characteristics, but for the purpose of this example, it is just kept to six**). The competitive benchmarking has shown that Company O is a strong competitor in terms of style, price and safety however, Company O is struggling in terms of comfort and weight.

The relationship matrix is used to compare the product characteristics and their effect on the priorities. Which can be broken down as:

- ++: Strong positive effect
- +: Positive effect
- No sign: No effect
- -: Negative effect
- --: Strong negative effect

For example, if the frame of the bicycle was made with different materials (e.g., from steel to Carbon Fibre) the frame would be a lighter weight, Carbon Fibre is a stronger than steel and will make the bike safer from dangers such as buckling, as well as improve the balance. Carbon fibre is much more expensive than steel, and hence the negative effect with regards to the price.



Characteristics / Priorities		Frame material	Suspension	Seat Padding	Range of colours	Brakes	Gears	Competitive Benchmarking			
Lightweight	23	+	-			-	-	A	B	O	C
Comfortable	20		++	++			+	C	B	A	O
Safe	30	+	++			++		B	O	C	A
Cheap	10	-	-	-	-	-	--	B	O	C	A
Stylish	15				++			O	A	C	B
	Importance										

Fig.1.9: House of Quality for Company O

The interaction matrix at the top shows how the product characteristics interact with each other. It is a way of comparing how the two characteristics complement each other when they are adjusted, when one is detrimental to the other it is noted with a −ve (in this case, gears add mass to the system, which will have a detrimental effect on the brakes).

With this system in place, it is used to prioritise what will need to be done first. It is clear that the bikes are not comfortable, we can see that the best method of quickly improving the comfort is to improve the seat padding, as well change the frame material to something more lightweight. The seat padding will improve the comfort but will not be detrimental to the weight of the bike, unlike the gears and suspension.