Tomi Salminen

DEVELOPMENT OF LEARNING MATERIAL

Tietotekniikan koulutusohjelma

TQM suuntautumisvaihtoehto

2011

Satakunnan ammattikorkeakoulu
Satakunta University of Applied Sciences

OPETUSMATERIAALIN KEHITTÄMINEN

Salminen, Tomi
Satakunnan ammattikorkeakoulu
Tietotekniikan koulutusohjelma
Toukokuu 2011
Ohjaaja: Valtanen, Pasi-Waltteri
Sivumäärä: 25
Liitteitä: 5

Asiasanat: laatu, laadun valvonta, laatu johtaminen, opetusmateriaali

---

Tämän opinnäytetyön tavoitteena oli luoda itseopiskelumateriaalia tukemaan tuntiopetusta.

Opinnäytetyön aiheen kehitti Pasi-Waltteri Valtanen, hän tarvitsi materiaalia joka tukee Quality tools opintojakson tuntiopetusta.

Aiheet joista itseopiskelumateriaali paketit kehitettiin ovat Quality Function Deployment (QFD), Design of Experiments (DOE), Failure Mode and Effect Analysis (FMEA), Statistical Process Control (SPC) ja Taguchi metodi.

Nämä aiheet valittiin koska ne kuuluvat olennaisesti Total Quality Managemet (TQM) opetukseen.

Nämä materiaali paketit luotiin Power Point ohjelmalla.

DEVELOPMENT OF LEAFNING MATERIAL

Salminen, Tomi
Satakunta University of Applied Sciences
Degree Programme in Information technology
May 2011
Supervisor: Valtanen, Pasi-Waltteri
Number of pages: 25
Appendices: 5

Keywords: quality, quality control, quality management, learning material

---

The purpose of this thesis was to develop learning material to support the Quality tools lectures.

The topic of this thesis was generated by Pasi-Waltteri Valtanen, out of need for learning material that supports the Quality tools lectures.

Topics which the learning material was creates were Quality Function Deployment (QFD), Design of Experiments (DOE), Failure Mode and Effect Analysis (FMEA), Statistical Process Control (SPC) and the Taguchi method

These topics were chosen because they firmly belong to Total Quality Management (TQM) education.

Implementation of these material packages was done with Power Point.

TABLE OF CONTENS

1 INTRODUCTION

The subject of this thesis is generated by Valtanen Pasi-Waltteri. These material packages are needed to support the Quality tools lectures. Goal is to give the students additional material to learn the basic quality tools and procedures. Also give them readiness to independent information search concerning following topics.

Topics Quality Function Deployment (QFD), Design of Experiments (DOE), Failure Mode and Effect Analysis (FMEA), Statistical Process Control (SPC) and the Taguchi method are chosen because they are closely related to Total Quality Management (TQM) education.

Development process started with acquiring material from library of SAMK and from the supervisor Valtanen Pasi-Waltteri. First task was to familiarize with all the topics (QFD, DOE, FMEA, SPC and Taguchi method) and then study one topic at a time. After topic was studied thoroughly the material package was created.

All material used in this thesis and produced during the thesis was approved by supervisor. These material packages were implemented with Power Point presentation because with power point the structurization of material is easy and logical.

The final product is five separate material packages which include basic principles of each topic. Familiarization of basic tools for quality control and the way they are used.

2 THEORY

2.1 Learning process

In 1960s and 1970s learning was defined as change in behavior, it was approached as an outcome. After that learning process has been studied and different theories developed, of what is learning and how it actually happens.

Roger Säljö asked a number of adult students what they understood by learning. Their responses fell into five main categories

1. Learning is acquiring information
2. Learning is memorizing
3. Learning is acquiring facts, skills and methods
4. Learning is making sense
5. Learning is interpreting and understanding reality in a different way

These five categories Säljö recognized. Learning can be seen as a process by which behavior changes as a result of experience and there are four different theories about learning, ideas how or why change occurs.

1. Behaviorist orientation
2. Cognitive orientation
3. Humanistic orientation
4. Social/situational orientation /10/

2.1.1 Behaviorist orientation to learning

Learning is seen as change in behavior rather than internal thought process. Environment affects learning, what you learn is defined by the elements in environment. Activity and repetition is important to the learning process, learner must be active and repeat frequently skills practiced. Also when objective is clear and positive rein forcers are received, learning is helped /10/.

2.1.2 Cognitive orientation to learning

Learning is seen as an internal mental process. Learning results from inferences, expectations and making connections. Instructions should be clearly structured and well organized, this makes remembering and creating logical relationships with key ideas considerably easier. Prior knowledge of subject helps subject to link just heard information to pre-existing information. People perceive environment and information differently, the way problem is presented to subjects is important. Problem must be presented in a way that subject can understand it and make some reference to prior knowledge. When subject succeeds in learning new skill, the reinforcement can come from knowledge of result, rather than simply a reward /10/.

2.1.3 Humanistic orientation to learning

Learning is seen as a personal act to fulfill potential and it is self initiated process. The basic concern is human potential for growth, and concern of people being treated as objects. Personal freedom, choice, motivations and feelings had to have their place. Perhaps the best known example is Abraham Maslow's hierarchy of motivation. Only when lower needs are met is it possible to move to the next level.

1. Physiological needs, such as hunger, thirst, sex, sleep, relaxation and bodily integrity must be satisfied
2. Safety needs, predictable and orderly world
3. Love and belongingness needs, people seek warm and friendly relationships
4. Self-esteem needs, these involve confidence, independence, reputation and prestige
5. Self-actualization, full use and expression of talents, capacities and potentialities /10/

2.1.4 Social/situational orientation to learning

Learning is seen as an interaction in social situations and observation of other people. Learning would be exceedingly laborious and hazardous, if people had to rely solely on the effects of their own actions. Traditionally learning is measured as what is in possession of individuals, inside of their heads. Here learning is in the relationships between people, in conditions that bring people together.

Educators work so people can become part of communities, and participate fully. Learning is part of every day, problem solving and learning from experience become central processes /10/.

2.2 Different learning styles

Learning styles are various ways of learning. There is also some talk about learning styles being a myth. Some people claim that there is identifiable ways that people learn and they have put forward their views of distinct learning styles and had a great deal of support. One such author is David Kolb, with his learning styles model and experimental learning theory (ELT) /9/.

There are some views that these styles are really a myth. Curwin thinks that the way individual learns is topic dependent, visual subject have to be taught visually. Another idea why they are myth is based on brain function and understanding learning process in brain. Experiments on the brain, usually, cannot be done. Because they require lots of equipment and usually require that experimenter is medically/biologically qualified. Even if these experiments could be done, they could change the way the brain works. And according to Coffield there are at least 70 ways of measuring learning. So there are at least 70 different ways that brain stores information, and at least 70 ways to get the information in/out /9/.

Many authors believe that learning of the topic depends on many things like motivation, temperature, emotions and the subject. Also they count experience in subject and the personality of learner contributing factors. And more factors arise when all the things that teachers think could affect learning. For example, how much learned had to drink last night and has he eaten, this list is only limited by ones imagination /9/.

When considering changing teaching style to mach learners learning style, there must be first measurement of how the student learns. After this the teaching material must be created to conform to every learning style. If it is assumed that learning style subject dependent, students must be measured at beginning of every new topic. Learning style might even be used against teacher, for example, ‘I’m an auditory learner and you were teaching visually’.

Some key points on why learning styles are bad idea

- Matching the teaching to the learning does not work
- Learning styles are not measurable
- Changing teaching styles is not ‘doable’
- Knowing your learning style does not make you a better learner /9/

There are also a lot of people who believe that learning styles does exist and there is evidence to support that. People learn at different rates and different ‘depths’, and that ‘proves’ that learning styles does exist. Student A gets always better marks than student B, that ‘proves’ that student A is better learner /9/.

Most widely used model is Fleming’s VAK/VRAK model. This model divides learners in three or four groups (depending on source). Visual -, Auditory -, (Read/Write) - and Kinesthetic learners /7, 8/.

2.2.1 Visual learners

They utilize their visual memory in learning. They create diagrams, maps, images and other symbol to represent ideas and information instead of words. This could also be called graphical learning /7, 8/.

2.2.2 Auditory learners

They may struggle to understand the text that they have just read, but they will experience full understanding of the text when they hear it. When auditory person is memorizing something, he/she will say it out loud. Usually they need some kind of noise to study, it may be music or some background noise like TV or people talking /7, 8/.

2.2.3 Reading/Writing learners

To them organizing information is very important and will learn most with lists, headings, dictionaries and textbooks. They enjoy reading and writing and are usually dependent of power point, internet, calendar and words /7, 8/.

2.2.4 Kinesthetic learners

This is learning style is also called tactile learning. They prefer to learn through experience and considers what they feel when they receive information. Usually they have very good hand-eye coordination /7, 8/.

2.3 Requirements concerning teaching material

Learning material must be developed only from reliable sources. Reliable sources are books and articles from known authors. Using source material from internet requires some prior knowledge of the subject or reading same topic from multiple sources thus making evaluation of information possible. Also evaluating the internet page is usable method, universities pages are generally more reliable than some random page. Reliable articles usually have reference page at the end so you can verify the origin of the information. If used material is debate or some point of view, it must be represented in neutral way, not using it to promote your own agenda. This way the student can learn both sides of ‘argument’ and make his/hers own mind based on facts already learned.

Material must be structured clearly and preceded in logical order. Student can apply new information to what he/she already knows. Topic basics must be explained first and then the more advanced information. Learning the advanced information is really hard or even impossible if the basics are missing.

It is good to use some graphs and pictures in places where it is complicated to use plain words. Like normal distribution and standard deviation concepts in Design of Experiments (DOE) or relationship between costs of quality and organization capability in Statistical Process Control (SPC).

Of course usage of proper and grammatically correct language is required in learning material. So it is possible to translate the information in to your native language.
(P-W. Valtanen, Personal meeting concerning this thesis 4.5.2011)

3 IMPLEMENTATION

At the beginning the work procedure was planned, what to do and in which order. There were five different topics from which to create material packages to support the lectures. These topics were Quality Function Deployment (QFD), Design of Experiments (DOE), Failure Mode and Effect Analysis (FMEA), Statistical Process Control (SPC) and the Taguchi method.

After the work procedure was planned, the material for these topics was acquired from SAMK library and the work supervisor Pasi-Valtteri Waltanen.

The planned work procedure was to familiarize with the basics of all topics at first and then study one topic at a time and complete the material package on that topic. This way there wouldn’t be overlapping of subjects in these material packages. Structure was to familiarize the student to basic tools and methods of every topic. Give an idea what they are for and how they are used, generating readiness for searching information independently from internet.

As quality control of this work, the planned structure of these packages was approved by the supervisor and also these packages were inspected and the information content approved by the supervisor at preplanned intervals.

3.1 Quality Function Deployment (QFD)

QFD is a method for structured product planning, with it the development team can clearly specify customer's wants and needs. QFD consists from several matrices, first one to construct is called 'house of quality' (HOQ). With HOQ everyone involved in development process can clearly see distinction between customer wants and needs and technical capabilities.

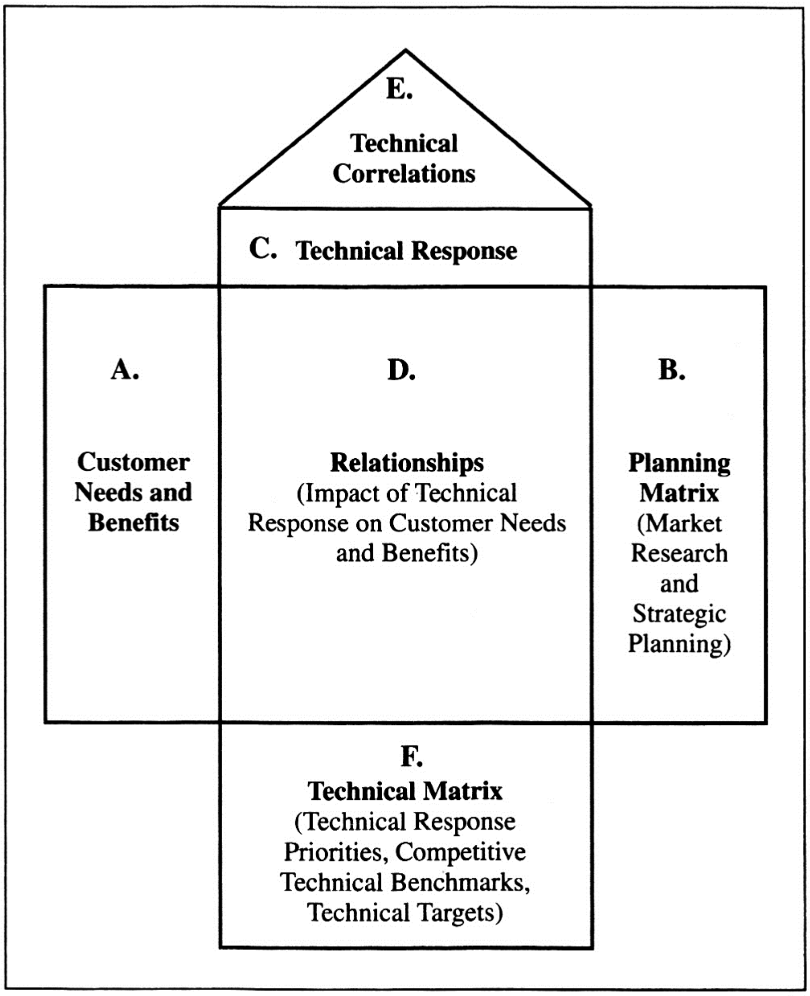


Diagram 1-1. The House of Quality

QFD can help company to

1. Decrease costs by streamlining process and reducing rework and waste
2. Increasing revenue by selling more charging more, this can be achieved by focusing development on what matters to customer and thus meeting customers wants and needs

3. Reduce cycle time by helping make key decisions early in development process.

In Kano's model product characteristics are divided in three categories

1. Dissatisfiers
2. Satisfiers
3. Delighters

Dissatisfiers 'expected quality', customer takes these characteristics for granted and when they are missing they cause dissatisfaction. These include scratches on the surface, missing instructions, broken parts when taken out of box, etc.

Satisfiers 'desired quality', customer wants these characteristics in their product. Usually customer will ask for these characteristics before buying. These include increased capacity, lower cost, greater speed, easier to use, etc.

Delighters 'unexpected quality', these features are pleasant surprises to customer. When these delighters are not present the customer will not be dissatisfied, because customer doesn't know what he/she is missing. Reaction to these delighters is for example to say to a friend 'Hey! Take a look at this!'

These delighters often create new markets or market segments, thereby giving their creators temporary competitive edge. But once the novelty of delighter wears off, and competition adds this feature in their products, customers begin to expect this feature. So delighters become demoted to satisfiers. And after awhile people take this feature as granted and many satisfiers become demoted to dissatisfiers. These migrations of quality attributes happens all the time and in order for the company retain its competitive edge, product developers must continuously search for new delighters /3/.

3.2 Design of Experiments (DOE)

DOE is the set of Statistic tools for acquiring information of what affects the process and how. It means to design course of action in testing a process. Before these Statistic tools were developed, talented scientists have always been able to run experiments. In these experiments one factor at a time was changed (also called 1-FAT experiments), this is really time consuming way to test a process.

Hadamard demonstrated that large amount of information from matrix could be extracted from small amount of numbers from that matrix and all possible test results from a process would add up to group of numbers. This group is considered as mathematical matrix.

A complicated process can have very large amount of different combinations, for example process which has 4 factors and 3 levels, all the possible combinations add up to 81. There is no sense in running all possible combinations, because running 25 carefully designed combinations can reveal almost as much information as running all 81 combinations. Key question is which combinations will provide the desired data.

Designed experiments can also detect special relationships, these relationships are called interactions. 1-FAT experiments by their nature are not capable of finding interactions. For example, two medications, both good for the patient, but when they are taken together, a new strong side effect such as severe nausea overcomes the patient. These two medications would be said to have harmful interaction.

An example of eight-run design where every combination of factors is run, this includes three factors in two levels. When planning this kind of experiment the different levels are usually marked as -1 and +1, and to the work sheets just – and +.

	A	B	C	Y
1	–	–	–	65.3
2	–	–	+	81.3
3	–	+	–	53.3
4	–	+	+	69.9
5	+	–	–	61.8
6	+	–	+	77.4
7	+	+	–	73.9
8	+	+	+	89.9

Figure 8.1 An 8-run design with coded levels of factor

Figure 8.1 represents the designed experiment process and specifies what combination of factors is run. Figure 8.2 is an example of what actual work sheet could look like.

	Temperature, °F	Time, h	Catalyst Conc., %	Yield, %
1	200	1	1	65.3
2	200	1	2	81.3
3	200	2	1	53.3
4	200	2	2	69.9
5	250	1	1	61.8
6	250	1	2	77.4
7	250	2	1	73.9
8	250	2	2	89.9

Figure 8.2 Pattern of design in Fig. 8.1 as applied to a typical worksheet with one response

/4/

3.3 Failure Mode and Effect Analysis (FMEA)

FMEA is a summary of engineer's and the team's thoughts as component or system are designed. It is also analysis of what can go wrong and how it can affect on other components or function of the product. If company have produced similar product or part in past or they are creating revision 2 from existing product. These failure modes are brainstormed and learned from customer complaints and failure research or warranty files.

Process includes estimations of how severe (Severity S) this failure is, how often this failure could occur (Occurrence O) and how likely is to detect (Detection D) these failures. All these are given a number from 1 to 10, 10 being worst. Out of these the Risk Priority Number (RPN) is calculated. RPN = (S)x(O)x(D). Process also includes recommended actions and actions taken to eliminate these failure modes. Corrective action should always be directed first to the items with highest ranking RPN and critical items. After corrective actions are done a new estimation of severity, occurrence and detection are given and new RPN is calculated.

POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
(DESIGN FMEA)

FMEA Number ____________

Page ________ of ________

____ System
____ Subsystem
____ Component ____________

Design Responsibility ____________

Prepared By ____________

Model Year(s)/Vehicle(s) ____________

Key Date ____________

FMEA Date (Orig.) ________ (Rev.) ________

Core Team ____________

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R. P. N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	R. P. N.

/6/

3.4 Statistical Process Control (SPC)

SPC is the application of statistical methods and tools to monitor and control process. To ensure that the process operates at its full potential and behaves predictably, waste produced by the product should be minimized. SPC helps to discover is there variation in the process and what causes this variation

Quality of product or service has two distinct but interrelated aspects

1. Quality of design
2. Quality of conformance to design

If quality of design is low, produced service or product won't meet the requirements or it will meet them only at a low level. Quality of conformance to design is the extent to which service or product achieves the specified design. What the customer actually receives should conform to the design.

Marketing department can't decide the specification of the product alone, producing department must also be involved in this process, so producing department can produce to designed specification.

Costs of quality must be carefully managed, so they stay at desired level. Appraisal costs are the cost of checking it is right.

- Verification of incoming material and final products
- Quality audits to check is quality management system functioning
- Inspection equipment like calibration and maintenance of equipment
- Vendor rating like assessment of suppliers

Prevention costs are planned and are incurred prior to production. These include

- Product or service requirements for incoming materials
- Quality planning; the creation of quality, reliability, supervision, process control
- Quality assurance; the creation and maintenance of overall quality management system

- Inspection equipment; development and/or purchase of equipment for use in inspection work
- Training; quality training for operators, supervisors and managers
- misc; travel, supply, shipping, communications and other general office management activities associated with quality

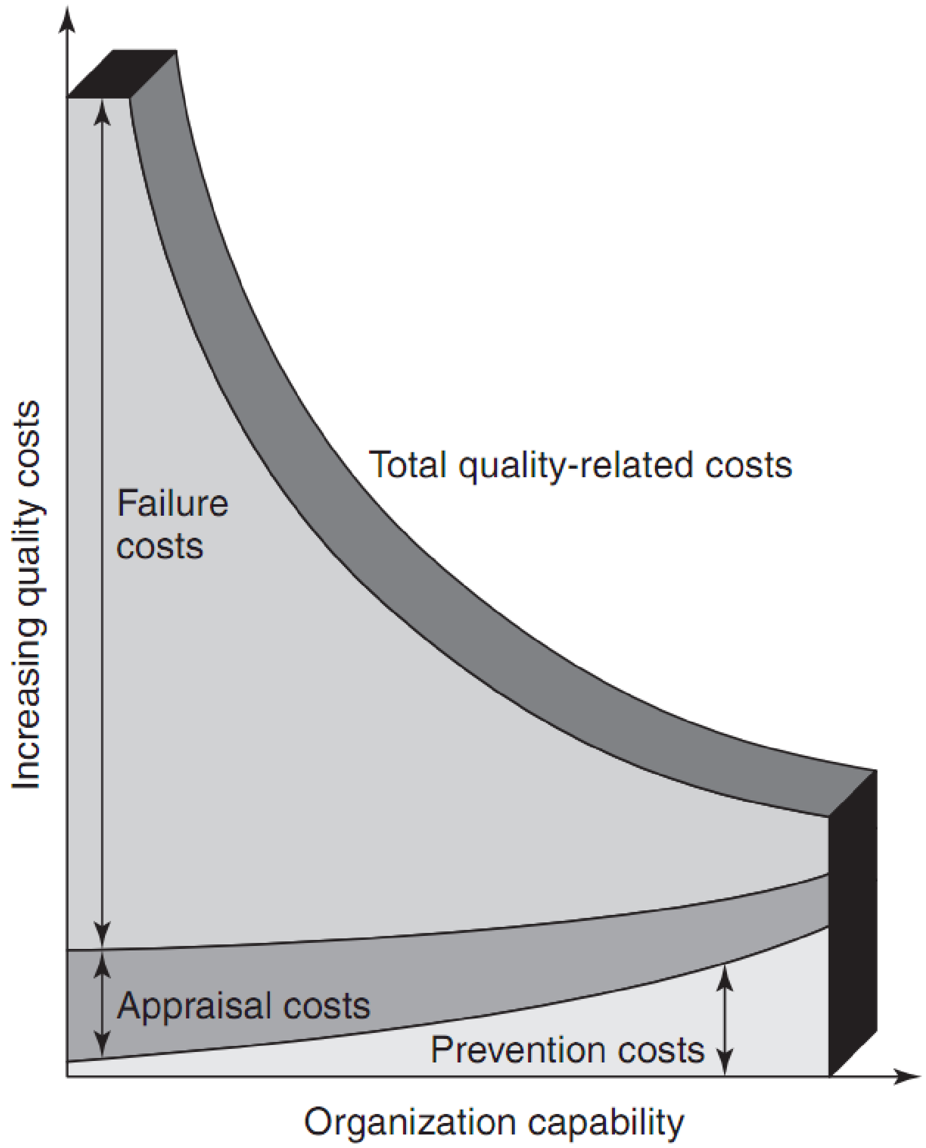


Figure 1.2 Relationship between costs of quality and organization capability

In SPC numbers and information will form basis for decisions and actions and thorough data recording system is essential. There are also a number of basic tools to use measure and asses the process

- Process flowcharting – What is done?

- Check sheets – How often is it done?
- Histograms – What does the variation look like?
- Graphs – Can the variation be represented in a time series?
- Pareto analysis – Which are the big problems?
- Cause and effect analysis and brainstorming – What causes the problems?
- Scatter diagrams – What are the relationships between factors?
- Control charts – Which variations to control and how?

When collecting data, one should remember that there should not be massive amounts of certain data just because it is easy to collect. Full considerations must be given to reasons for collecting data. Also one should remember to collect the data in the way it is easy to use and read.

Control charts are used to measure process variation and evaluate what if any action should be taken and in which direction. Figure 6.11 shows an example of mean and range charts for 30 samples taken from steel rod cutting process. The process is well under control until the sample 11, when the mean almost reaches the Upper Warning Line. When process moves pass the warning line, another sample should be taken immediately rather than wait for next sampling period. If that next sample is also in warning zone corrective action should be taken. The mean of sample 19 is in warning zone and corrective action is taken, but sample 20 shows that corrective action was taken in wrong direction. And the action following sample 20 results in over-correction and sample 21 mean goes below the lower action line.

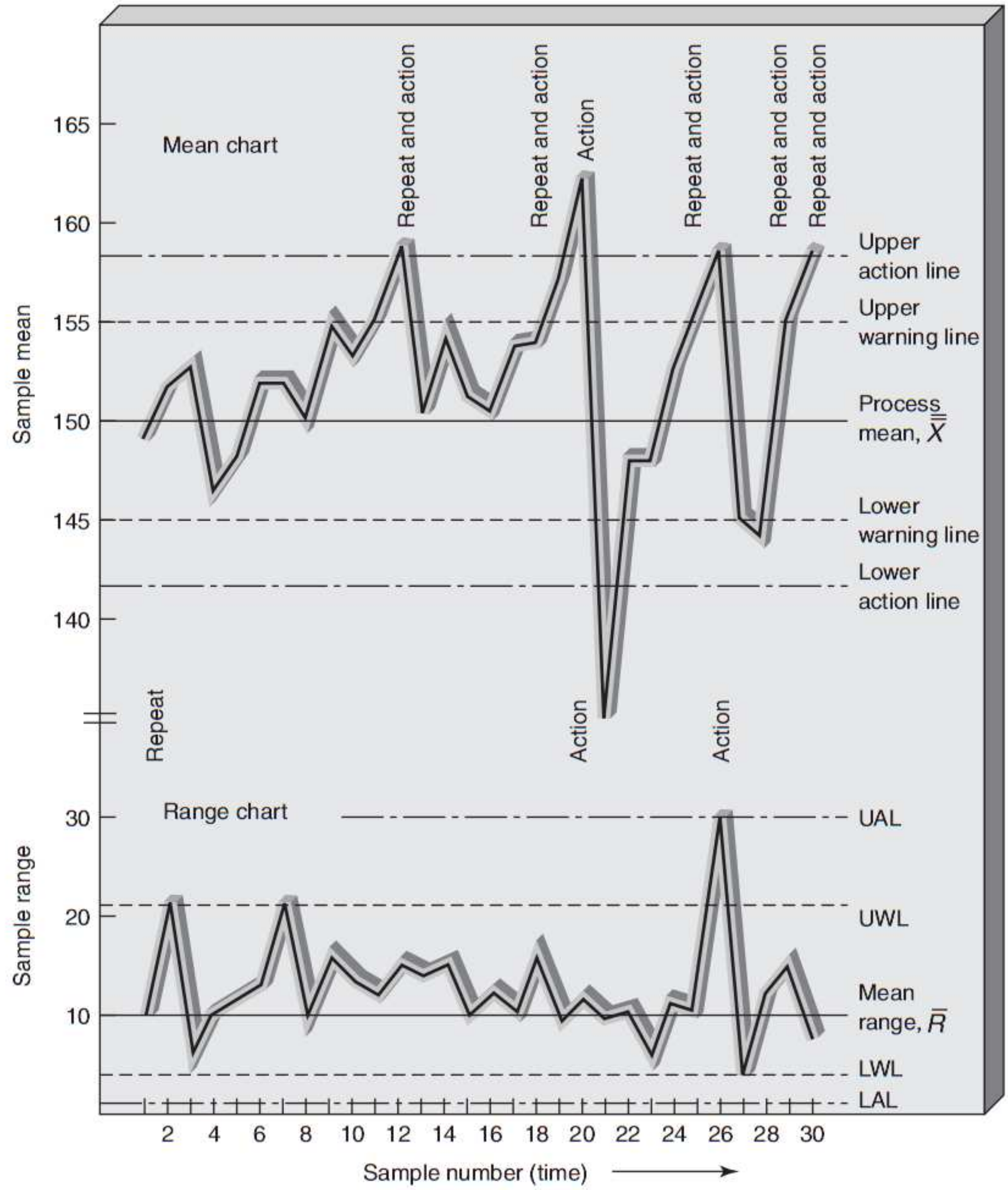


Figure 6.11 Mean and range chart in process control

Problems is process operation is rarely caused just by one cause, but combination of factors. Most frequently met causes of out-of-control situations may be categorized under people, plant/equipment, process/procedures, materials and environment /5/.

3.5 Taguchi method

The Taguchi methods are statistical methods developed by Genichi Taguchi to improve quality of products. Taguchi's contributions to statistical quality control include loss function, off-line quality control and innovations in the design of experiments /1, 2/.

3.5.1 Loss function

Loss function is a formula for calculating financial loss when product doesn’t meet the designed specification. The financial loss comes from reworking a product that is slightly out of specification, or scrapping a product when it can’t be reworked. In ideal condition the financial loss can be assumed to be zero /1, 2/.

3.5.2 Off-line quality control

Taguchi realized that the best way to eliminate variance is to address it is during the design of the product and its manufacturing process. He also developed three staged strategy for quality engineering:

1. System design
2. Parameter design
3. Tolerance design

Ideally, product design departments should design new product that have no

- Manufacturing costs
- Malfunctions
- Damaging environmental effects /1, 2/

3.5.2.1 System design

In this stage the design team must consider all the possible systems that can perform the required functions. If such system doesn’t exist they should consider building new system, which conforms to their needs. Advantage with this solution is that new systems are protected by patents, thus giving competitive edge /1, 2/.

3.5.2.2 Parameter design

When the concept is established, the various dimensions and design parameters need to be set. The purpose is to improve quality and process capability, reduce cost and variation in the process /1, 2/.

3.5.2.3 Tolerance design

After a successfully completed parameter design, design engineers must decide the tolerance specification and grades of materials for all components. Objective is to decide the tradeoff between quality level and cost /1, 2/.

4 CONCLUSION

The purpose of this thesis was to develop learning material to support the Quality tools lectures. The topic of this thesis was generated by Pasi-Waltteri Valtanen, out of need for learning material that supports Quality tools lectures.

Power Point presentations were created from topics Quality Function Deployment (QFD), Design of Experiments (DOE), Failure Mode and Effect Analysis (FMEA), Statistical Process Control (SPC) and the Taguchi method. These topics are closely related to Total Quality Management (TQM) education.

Development process was designed with supervisor prior to starting the development of these material packages. Structure of development process was to create these packages one at a time and to familiarize with all topics before starting to study these topics thoroughly. After the topic was studied thoroughly the material package was created, before packages were finalizes they were checked and approved by supervisor.

Structure of the packages was to familiarize the student to basic principles and quality tools of every topic. Plan was to present information in logical order, so student can apply new information on what he/she already knows

Creating these material packages were demanding task. There were plenty of material to read and study, thing that made the task demanding was evaluation of information, what to include to these packages. How much information of one topic was needed to present to the reader. Fortunately the supervisor gave strict frames for these material packages and amounts of information needed, it helped at information selection.

When one develops learning material, it is important to present information objectively. So reader can make his/hers own opinion about the matter.

The technical implementation of this thesis didn’t present any difficulties. Programs used to create the thesis were familiar already and easy to use.

REFERENCES

1. *Genichi, T. 1992. Introduction to quality engineering: designing quality into products and processes. 9th printing. Tokyo: Asian Productivity Organization*

2. *Genichi, T. 1993. Taguchi on robust technology development: bringing quality engineering upstream. New York: The American Society of Mechanical Engineers*

3. *Cohen, L. 1997. Quality function deployment: how to make QFD work for you. 3rd edition. Massachusetts: Addison-Wesley Publishing Company, Inc.*

4. *Del Vecchio, R, J. 1997. Understanding design of experiments. Munich: Carl Hanser Verlag*

5. *Oakland, J, S. 2008. Statistical process controll. 6th edition Oxford: Butterworth-Heinemann*

6. *Potential failure mode and effect analysis. 1995. 2nd edition.*

7. *Faea.es. Analysis of learning styles and strategies. [Referred 6.5.2011] http://www.faea.es/G1_SKILLS/products/en/Learning_Styles_and_Strategies_EN.pdf*

8. *About.com. Learning styles: Know and use your personal learning style. [Referred 6.5.2011] http://homeworktips.about.com/od/homeworkhelp/a/learningstyle.htm*

9. *Learningstyler.webs.com. Do learning styles exist? [Referred 11.5.2011]* http://www.learningstyles.webs.com/

10. *Infed.org. Learning Theory. [Referred 9.5.2011] http://www.infed.org/biblio/b-learn.htm*

Design of Experiments (DOE)

samk

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management

What are Designed Experiments?

- Someone sits down to consciously plan out some limited course of action
  – To learn about what effects a process and how

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

What are Designed Experiments?

- More effective scientists and technologists have always been able to plan and carry out experiments
  – To generate good data that reveal how things really work

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

What are Designed Experiments?

- Most of the time, they have to work through courses of experimentation
  – Series of small steps
  – One factor at a time was changed in type or level of use (sometimes referred to as 1-FAT experiments)
  – Means a lot of work to understand the process

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

What are Designed Experiments?

- Hadamard demonstrated that it was possible to extract
  – A large fraction of information in a matrix from a smaller fraction of the numbers in that matrix
  – All the test results of all the possible experiments that could be run in complex process would add up to group of numbers

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

What are Designed Experiments?

- This collection of numbers can be considered to be a mathematical matrix
  – This means that running a fraction of all possible experiments will still allow investigator to learn almost as much as if he had run all the experiments

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

What are Designed Experiments?

- Example would be process controlled by 4 main factors in 3 levels, all the possible experiments would add up to 81 (3^4)
  - – Doing 16 of those 81 experiments can reveal great deal about the process
  - – Doing 25 experiments can furnish almost as much information as doing all 81 might

What are Designed Experiments?

- The key question is
  - – Which fraction of all possible experiments will provide the desired information

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Why and Where Should Designed Experiments Be Used

- Designed experiments will detect and quantify special relationships
  - – Two or more factors act differently in how they affect the process
    - Separately
    - Together
- Such relationships are called *interactions*

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Why and Where Should Designed Experiments Be Used

- For example
  - – Two medications, each which are good for the patient, but when both are taken together, a new, strong side effect such as severe nausea overcomes the patient
    - The two medications would be said to have a harmful interaction

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Why and Where Should Designed Experiments Be Used

- Interactions do not always occur, but they are sometimes extremely important
  - – 1-FAT experiments by their nature are not capable of finding interactions

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Why and Where Should Designed Experiments Be Used

- Sometimes a factor affects a process in a nonlinear way
  - – increasing oven temperature
    - 150 ℃ bread bakes in 75 minutes
    - 160 ℃ bread bakes in 50 minutes
    - 170 ℃ bread bakes in 40 minutes
    - 180 ℃ bread bakes in 35 minutes
    - 190 ℃ always burned outside and raw inside

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Why and Where Should Designed Experiments Be Used

- Use of the right design can quickly demonstrate nonlinear factor effects
  - Typically faster than series of 1-FAT experiments

Basic Statistics as Background to Design of Experiments

- A statistic is any number measuring something (age, weight, profit)
- The field of Statistics is a body of concepts and techniques for examining information
  - Statistics is a subtopic in the field of Mathematics, statistics with lower case s are just numbers

Basic Statistics as Background to Design of Experiments

- The two simple uses of Statistics are
  - To help understand what has happened in the past
  - Allow prediction or control of what will happen in future

Normal Distribution

- Normal distribution is approximately 6 standard deviations (SD) wide
  - The distribution in centered on the average and the spread around the average is ±3 standard deviations (SD)
    - -1 SD to +1 SD containing 68,3% of the population
    - -2 SD to +2 SD containing 95,5% of the population
    - -3 SD to +3 SD containing 99,7% of the population

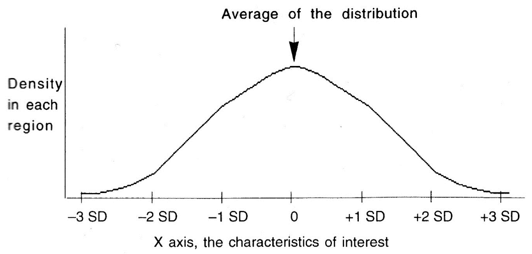


Figure 4.2 Ideal normal distribution

Standard Deviation (SD)

- If you had a distribution of parts that averaged 100 g in weight and had SD of 2g
  - One half of products would weigh 100 g-106 g (100g + 3SD)
  - How many parts weighed 104 g or more?
    - ~4,5% of distribution is outside of ±2SD, which is 96-104 g, only half of that is >104 g
    - Answer is 2,25% (4,5% / 2)

Central Limit Theorem (CLT)

- The two major points of the CLT
  - 1. The averages from a set of samples of any population will be distributed approximately normally around the population average (weather or not the parent population is normally distributed)

Central Limit Theorem (CLT)

- 2. The SD of the population of sample averages (called the *standard error*) will be smaller than the SD of the parent population by factor of $1/\sqrt{n}$, where n is the size of the sample groups
- The larger n is, the more normal the distribution of the sample means will be

Important Points of Basic Statistics

- Many things fall in to normal distributions
  - and if they do, various good analyzing techniques can be applied
- The average and SD is most often used to characterize a distribution
- More data you have and more you know about the information gathered, the better

Important Points of Basic Statistics

- Use of averages from sample groups makes analysis more secure because
  - CLT shows that even if the analyzed property is not distributed normally, the averages will be
- Larger samples will more accurately indicate where the true average of the population lies

Basics of Experimental Designs

- In drawing up experiments, it is a common practice to designate the factor levels by some code
  - If there are two levels, they are usually coded as -1 and +1 levels, and in the matrix only the sign (- or +) is used

Basics of Experimental Designs

- If we have 3 factors (A, B and C) and wanted to run every combination of + & - levels possible

All possible levels are shown in figure 6.2

	A	B	C
Run 1	+	+	+
2	+	+	−
3	+	−	+
4	+	−	−
5	−	+	+
6	−	+	−
7	−	−	+
8	−	−	−

Figure 6.2 Fundamental pattern of a 2-level, 3-factor full-factorial desig

Basics of Experimental Designs

- Statistical theory says
  - From 8 independent pieces of data, 7 independent comparisons can be made
  - Because the experiment will tell us about factors A, B and C, four other comparisons can be made

Basics of Experimental Designs

- X1 is interaction of A-B
- X2 A-C
- X3 B-C
- X4 A-B-C

	A	B	C	X1	X2	X3	X4
Run 1	+	+	+	+	+	+	+
2	+	+	−	+	−	−	−
3	+	−	+	−	+	−	−
4	+	−	−	−	−	+	+
5	−	+	+	−	−	+	−
6	−	+	−	−	+	−	+
7	−	−	+	+	−	−	+
8	−	−	−	+	+	+	−

Figure 6.5 Fully expanded 3 × 2 pattern

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Basics of Experimental Designs

- These four columns can be used primarily in two different ways
  - Assign four more control factors, so seven potential influences can be evaluated
    - Then X columns become D, E, F and G
  - Don't add any other factors
    - In this case it is possible to look interactions between factors

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Scree plot

- Scree plot is used to see what factors/ interactions
  - Are important enough to carry on to next stage of the investigation
  - Affect most on process outcome

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Scree plot

- Scree plot is made by examining the effect levels seen in the data and ranking them by their absolute size
  - Their sign is no important in this ranking, so effect -3 is larger than +2

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

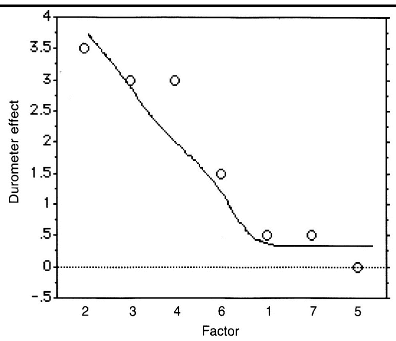


Figure 6.6 Scree plot of durometer effect

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Fractional Designs and Their Uses

- Most of the time, experimenters prefer to avoid using large full-factorial designs
  - Development of numerous types of fractional factorials has been major part of the modern history of design of experiments

Fractional Designs and Their Uses

- Figure 7.1 shows the same three-factor full-factorial design
- Figure 7.2 shows the two separate half designs
  - Complementary to each other
- Figure 7.3 shows interactions from the other half of design

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Factor	A	B	C	(Right or Left)
Run 1	+	+	+	R
2	+	+	−	L
3	+	−	+	L
4	+	−	−	R
5	−	+	+	L
6	−	+	−	R
7	−	−	+	R
8	−	−	−	L

Figure 7.1 Basic 3 × 2 design with right and left halves designated

A	B	C			A	B	C
+	+	+	R	L	−	−	−
+	−	−	R	L	−	+	+
−	+	−	R	L	+	−	+
−	−	+	R	L	+	+	−

Figure 7.2 Complementary half factorials

A	B	C	Interaction =	AB	AC	BC	ABC
+	+	+		+	+	+	+
+	−	−		−	−	+	+
−	+	−		−	+	−	+
−	−	+		+	−	−	+

Figure 7.3 3 × 2 half factorial with interaction patterns

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Fractional Designs and Their Uses

- Among the types of designs available are a set called Plackett-Burman (P-B) designs
  - Invented about 1939 and used with great effect in the World War II British war effort
  - Among P-B designs are subtype called nongeometric designs
    - 12-, 20-, and 24-run designs

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

12-run	A	B	C	D	E	F	G	H	I	J	K
Run 1	+	+	−	+	+	+	−	−	−	+	−
2	+	−	+	+	+	−	−	−	+	−	+
3	−	+	+	+	−	−	−	+	−	+	+
4	+	+	+	−	−	−	+	−	+	+	−
5	+	+	−	−	−	+	−	+	+	−	+
6	+	−	−	−	+	−	+	+	−	+	+
7	−	−	−	+	−	+	+	−	+	+	+
8	−	−	+	−	+	+	−	+	+	+	−
9	−	+	−	+	+	−	+	+	+	−	−
10	+	−	+	+	−	+	+	+	−	−	−
11	−	+	+	−	+	+	+	−	−	−	+
12	−	−	−	−	−	−	−	−	−	−	−

Figure 7.4 Plackett-Burman 12-run design

20-run	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Run 1	+	+	−	−	+	+	+	+	−	+	−	+	−	−	−	−	+	+	−
2	+	−	−	+	+	+	+	−	+	−	+	−	−	−	−	+	+	−	+
3	−	−	+	+	+	+	−	+	−	+	−	−	−	−	+	+	−	+	+
4	−	+	+	+	+	−	+	−	+	−	−	−	−	+	+	−	+	+	−
5	+	+	+	+	−	+	−	+	−	−	−	−	+	+	−	+	+	−	−
6	+	+	+	−	+	−	+	−	−	−	−	+	+	−	+	+	−	−	+
7	+	+	−	+	−	+	−	−	−	−	+	+	−	+	+	−	−	+	+
8	+	−	+	−	+	−	−	−	−	+	+	−	+	+	−	−	+	+	+
9	−	+	−	+	−	−	−	−	+	+	−	+	+	−	−	+	+	+	+
10	+	−	+	−	−	−	−	+	+	−	+	+	−	−	+	+	+	+	−
11	−	+	−	−	−	−	+	+	−	+	+	−	−	+	+	+	+	−	+
12	+	−	−	−	−	+	+	−	+	+	−	−	+	+	+	+	−	+	−
13	−	−	−	−	+	+	−	+	+	−	−	+	+	+	+	−	+	−	+
14	−	−	−	+	+	−	+	+	−	−	+	+	+	+	−	+	−	+	−
15	−	−	+	+	−	+	+	−	−	+	+	+	+	−	+	−	+	−	−
16	−	+	+	−	+	+	−	−	+	+	+	+	−	+	−	+	−	−	−
17	+	+	−	+	+	−	−	+	+	+	+	−	+	−	+	−	−	−	−
18	+	−	+	+	−	−	+	+	+	+	−	+	−	+	−	−	−	−	+
19	−	+	+	−	−	+	+	+	+	−	+	−	+	−	−	−	−	+	+
20	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

Figure 7.5 Plackett-Burman 20-run design

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Fractional Designs and Their Uses

- Two-level designs are used every day to run designed experiments in factories and laboratories
- They
  - Are easy to draw up, run and analyze
  - Often reveal very important information about process

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Fractional Designs and Their Uses

- In many cases
  - Simply knowing which factors are the most significant in a process
  - Whether or not interactions are important it enormously helpful to understanding process and how to more efficiently gain control of it

Examples Using Eight-Run Design

- In figure 8.1
  - Three factors (A, B, and C)
  - Two levels (+ and -)
  - Response shown as Y
- In figure 8.2
  - This is what actual work sheet could look like

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

	A	B	C	Y
1	−	−	−	65.3
2	−	−	+	81.3
3	−	+	−	53.3
4	−	+	+	69.9
5	+	−	−	61.8
6	+	−	+	77.4
7	+	+	−	73.9
8	+	+	+	89.9

Figure 8.1 An 8-run design with coded levels of factor

	Temperature, °F	Time, h	Catalyst Conc., %	Yield, %
1	200	1	1	65.3
2	200	1	2	81.3
3	200	2	1	53.3
4	200	2	2	69.9
5	250	1	1	61.8
6	250	1	2	77.4
7	250	2	1	73.9
8	250	2	2	89.9

Figure 8.2 Pattern of design in Fig. 8.1 as applied to a typical worksheet with one response

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Examples Using Eight-Run Design

- Because this is an example of full factorial
  - Interaction column patterns can be used
    - Leads to matrix shown in figure 8.3
- In the next step Y responses are totaled up
  - First, - level in column A and then + level in column A

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Examples Using Eight-Run Design

- Then total of the - data points are subtracted from the total of + data points
- Giving the difference between the two subgroups
  - This difference is the divided by four (the number of experiments that made up each subgroup)
- This procedure is repeated to each column
- This procedure leads to data in figure 8.4

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

	A	B	C	AB	AC	BC	ABC	Y
1	−	−	−	+	+	+	−	65.3
2	−	−	+	+	−	−	+	81.3
3	−	+	−	−	+	−	+	53.3
4	−	+	+	−	−	+	−	69.9
5	+	−	−	−	−	+	+	61.8
6	+	−	+	−	+	−	−	77.4
7	+	+	−	+	−	−	−	73.9
8	+	+	+	+	+	+	+	89.9

Figure 8.3 Pattern of Fig. 8.1 expanded to show interaction columns

	A	B	C	AB	AC	BC	ABC
+ Total	303.0	287.0	318.5	310.4	285.9	286.9	286.3
− Total	269.8	285.8	254.3	262.4	286.9	285.9	286.5
Difference	33.2	1.2	64.2	48.0	−1.0	1.0	−0.2
Effect on Y	8.30	0.30	16.05	12.00	−0.25	0.25	−0.05

Figure 8.4 Calculation of effects from response data in Fig. 8.3

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Examples Using Eight-Run Design

- A scree plot of the effects on figure 8.4 will show a dramatic contrast between the A, C and AB effects
  - With all the other column effects falling close to zero and each other

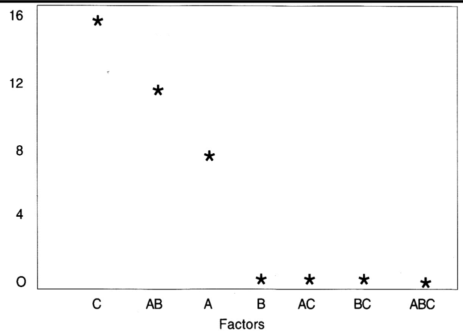


Figure 8.5 Scree plot of effects on process yield

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Failure Mode and Effects Analysis (FMEA)

samk
Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management

History

- The first formal application of the FMEA discipline was innovation of the aerospace industry in the mid-1960s

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Introduction

- FMEA is a summary of an engineer's and the team's thoughts as a component, system or subsystem is designed
  - Including analysis of items that could go wrong

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Team effort

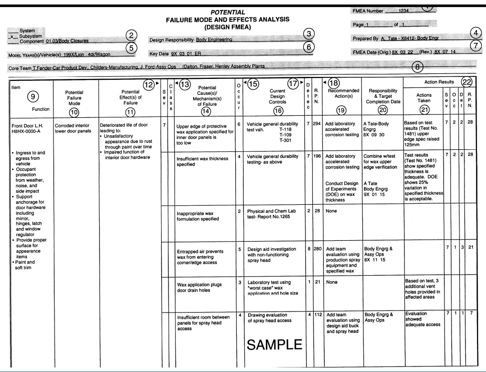
- The FMEA should be a catalyst to stimulate the interchange of ideas between the functions affected
  - In addition, for any (internal/external) supplier designed items, the responsible design engineer <u>should</u> be consulted

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Team effort

- The FMEA is a living document should be
  - Initiated before or at design concept finalization
  - Continually updated

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk



POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
(DESIGN FMEA)

FMEA Number 1234
Page 1 of 1
___ System
_x_ Subsystem
___ Component 01.03/Body Closures (2)
Design Responsibility Body Engineering (3)
Prepared By A. Tate - X6412- Body Engr (4)
Model Years(s)/Vehicle(s) 199X/Lion 4dr/Wagon (5)
Key Date 9X 03 01 ER (6)
FMEA Date (Orig.) 8X 03 22 (Rev.) 8X 07 14 (7)
Core Team T.Fender-Car Product Dev., Childers-Manufacturing, J. Ford-Assy Ops (Dalton, Fraser, Henley Assembly Plants (8)

Item (9) Function	Potential Failure Mode (10)	Potential Effect(s) of Failure (11)	Sev (12)	Class	Potential Cause(s)/ Mechanism(s) of Failure (14) (13)	Occur	Current Design Controls (16) (15) (17)	Detec	R.P.N.	Recommended Action(s) (19) (18)	Responsibility & Target Completion Date (20)	Action Results (22): Actions Taken (21)	Sev	Occ	Det	R.P.N.
Front Door L.H. H8HX-0000-A • Ingress to and egress from vehicle • Occupant protection from weather, noise, and side impact • Support anchorage for door hardware including mirror, hinges, latch and window regulator • Provide proper surface for appearance items • Paint and soft trim	Corroded interior lower door panels	Deteriorated life of door leading to: • Unsatisfactory appearance due to rust through paint over time • Impaired function of interior door hardware	7		Upper edge of protective wax application specified for inner door panels is too low	6	Vehicle general durability test vah. T-118 T-109 T-301	7	294	Add laboratory accelerated corrosion testing	A Tate-Body Engrg 8X 09 30	Based on test results (Test No. 1481) upper edge spec raised 125mm	7	2	2	28
					Insufficient wax thickness specified	4	Vehicle general durability testing- as above	7	196	Add laboratory accelerated corrosion testing Conduct Design of Experiments (DOE) on wax thickness	Combine w/test for wax upper edge verification A Tate Body Engrg 9X 01 15	Test results (Test No. 1481) show specified thickness is adequate. DOE shows 25% variation in specified thickness is acceptable.	7	2	2	28
					Inappropriate wax formulation specified	2	Physical and Chem Lab test- Report No.1265	2	28	None						
					Entrapped air prevents wax from entering corner/edge access	5	Design aid investigation with non-functioning spray head	8	280	Add team evaluation using production spray equipment and specified wax	Body Engrg & Assy Ops 8X 11 15		7	1	3	21
					Wax application plugs door drain holes	3	Laboratory test using "worst case" wax application and hole size	1	21	None		Based on test, 3 additional vent holes provided in affected areas				
					Insufficient room between panels for spray head access	4	Drawing evaluation of spray head access	4	112	Add team evaluation using design aid buck and spray head	Body Engrg & Assy Ops	Evaluation showed adequate access	7	1	1	7

SAMPLE

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 1. FMEA number
  - Enter document number for tracking
- 2. System, subsystem or component name and number
  - Enter name and number of system, *subsystem* or component analyzed

Development of design FMEA

- 3. Design responsibility
  - Enter department or group responsible. Also the supplier name of known
- 4. Prepared by
  - Enter name, telephone number and company of engineer responsible for preparing the FMEA

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 5. Models
  - Enter models that utilizes this specific part
- 6. Key date
  - Enter the initial FMEA due date, witch should not exceed the scheduled production design release date

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 7. FMEA date
  - Enter the date the original FMEA was compiled, and the latest revision date
- 8. Core team
  - List of names of the individuals and departments which have the authority to perform tasks

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 9. Item/function
  - Enter name and number of item being analyzed
  - Enter the function of the item

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 10. Potential failure mode
  - Enter the manner that component or system could potentially fail to meet design intent
  - List each potential failure mode of particular item and item function
    - Assumption is that failure could occur, but may not necessarily occur

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 11. Potential effect(s) of failure
  - Describe the effects of failure in terms of what the customer might notice or experience
    - Remembering that customer may be an internal customer as well as the end user
  - State clearly if the function could impact safety or noncompliance to regulations

Development of design FMEA

- 12. Severity (S)
  - Seriousness of the potential failure mode to the next component or system
  - Reduction in severity ranking index can only be affected through design change
  - Severity should be estimated on a ”1” to ”10” scale

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Suggested Evaluation Criteria:
(The team should agree on an evaluation criteria and ranking system, which is consistent, even if modified for individual product analysis.)

Effect	Criteria: Severity of Effect	Ranking
Hazardous-without warning	Very high severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation without warning.	10
Hazardous-with warning	Very high severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation with warning	9
Very High	Vehicle/item inoperable, with loss of primary function.	8
High	Vehicle/item operable, but at reduced level of performance. Customer dissatisfied.	7
Moderate	Vehicle/item operable, but Comfort/Convenience item(s) inoperable. Customer experiences discomfort.	6
Low	Vehicle/item operable, but Comfort/Convenience item(s) operable at reduced level of performance. Customer experiences some dissatisfaction.	5
Very Low	Fit & Finish/Squeak & Rattle item does not conform. Defect noticed by most customers.	4
Minor	Fit & Finish/Squeak & Rattle item does not conform. Defect noticed by average customer.	3
Very Minor	Fit & Finish/Squeak & Rattle item does not conform. Defect noticed by discriminating customer.	2
None	No Effect.	1

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 13. Classification
  - This could be used to classify any special product characteristics (e.g., critical, key, major, significant)

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 14. Potential cause(s)/Mechanism(s) of failure
  - An indication of a design weakness
    - The consequence of which is the failure mode
  - List every concievable failure cause and/or failure mechanism for each failure mode

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 15. Occurrence (O)
  - The likelihood that specific cause/ mechanism (listed in previous column) will occur
  - Decrease in occurrence ranking in possible only through design change
  - Estimate likelihood of occurrence of potential failure in a ”1” to ”10” scale

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Suggested Evaluation Criteria:
(The team should agree on an evaluation criteria and ranking system, which is consistent, even if modified for individual product analysis.)

Probability of Failure	Possible Failure Rates	Ranking
Very High: Failure is almost inevitable	≥ 1 in 2	10
	1 in 3	9
High: Repeated failures	1 in 8	8
	1 in 20	7
Moderate: Occasional failures	1 in 80	6
	1 in 400	5
	1 in 2,000	4
Low: Relatively few failures	1 in 15,000	3
	1 in 150,000	2
Remote: Failure is unlikely	≤ 1 in 1,500,000	1

Development of design FMEA

- 16. Current design controls
  - List the prevention, design validation/ verification (DV), or other activities (e.g., design review, testing, fail/safe)
  - There are three types of design controls/features to consider
    - 1. Prevention of failure mode, 2. Detect the cause of failure, 3. Detect the failure mode

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 17. Detection (D)
  - Assessment of the ability to detect potential cause/mechanism (design weakness, listed in column 16)
    - or the ability of the proposed **type 3** current design control to detect failure mode

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Suggested Evaluation Criteria:
(The team should agree on an evaluation criteria and ranking system, which is consistent, even if modified for individual product analysis.)

Detection	Criteria: Likelihood of Detection by Design Control	Ranking
Absolute Uncertainty	Design Control will not and/or can not detect a potential cause/mechanism and subsequent failure mode; or there is no Design Control.	10
Very Remote	Very remote chance the Design Control will detect a potential cause/mechanism and subsequent failure mode	9
Remote	Remote chance the Design Control will detect a potential cause/mechanism and subsequent failure mode	8
Very Low	Very low chance the Design Control will detect a potential cause/mechanism and subsequent failure mode	7
Low	Low chance the Design Control will detect a potential cause/mechanism and subsequent failure mode	6
Moderate	Moderate chance the Design Control will detect a potential cause/mechanism and subsequent failure mode	5
Moderately High	Moderately high chance the Design Control will detect a potential cause/ mechanism and subsequent failure mode	4
High	High chance the Design Control will detect a potential cause/mechanism and subsequent failure mode	3
Very High	Very high chance the Design Control will detect a potential cause/mechanism and subsequent failure mode	2
Almost Certain	Design Control will almost certainly detect a potential cause/mechanism and subsequent failure mode	1

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 18. Risk priority number (RPN)
  - It is the product of Severity (S), Occurrence (O) and Detection (D) ranking
    - RPN = (S)x(O)x(D)
  - The RPN must be in between of ”1” and ”1000”

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 19. Recommended action
  - When failure modes have been ranked by RPN, corrective action should be first directed at the
    - Highest ranked items
    - Critical items

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 20. Responsibility (for the recommended action)
  - Enter organization and individual responsible for the recommended actions and target completion date

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

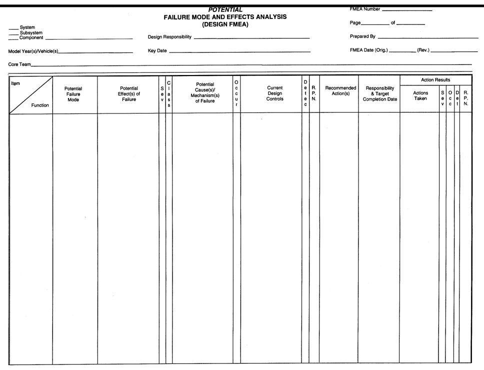
- 21. Actions taken
  - After an action has been implemented, enter brief description of the actual action and effective date

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Development of design FMEA

- 22. Resulting RPN
  - After the corrective action have been identified, estimated and record the resulting severity, occurrence and detection rankings, calculate and record the resulting RPN
    - If no actions are taken, leave the "Resulting RPN" and related ranking columns blank

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk



POTENTIAL
FAILURE MODE AND EFFECTS ANALYSIS
(DESIGN FMEA)

FMEA Number ____
Page____ of ____
___ System
___ Subsystem
___ Component ____
Design Responsibility ____
Prepared By ____
Model Year(s)/Vehicle(s)____
Key Date ____
FMEA Date (Orig.) ____ (Rev.) ____
Core Team____

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R. P. N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	R. P. N.

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Quality Function Deployment (QFD)

samk

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management

QFD

- It is a method for structured product planning
- It enables development team to specify clearly the customer's wants and needs
- QFD process involves constructing one or more matrices

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

QFD

- First matrix is called 'house of quality' (HOQ)
- It displays the customer's wants and needs
  - The voice of Customer
- The matrix consists of several sections and sub matrices

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

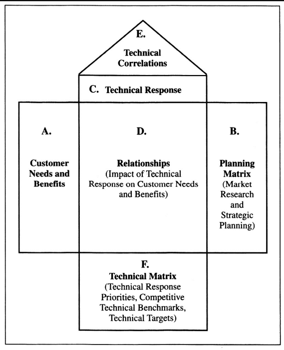


Diagram 1-1. The House of Quality

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

House of Quality

- Section A contains customer wants and needs
- Section B contains 3 main types of information
  - Quantitative market data
  - Strategic goal for new product
  - Ranking of customer wants and needs

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

House of Quality

- Section C contains organization's technical language
  - High-level description of the product or service
- Section D contains the development team's technical response

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

House of Quality

- Section E contains technical correlations
  – development team’s assessments of the implementation interrelationships between elements of the technical response

House of Quality

- Section F contains three types of information
  – Computed rank order of technical responses
    - Based on customer wants and needs from section B and the relationships in section D
  – Comparative information on the competition’s technical performance
  – Technical performance targets

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

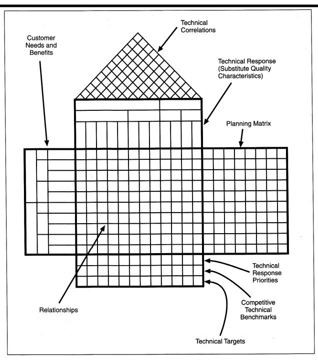


Diagram 4-1. The QFD House of Quality

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

How QFD Fits in the Organization

- QFD can play a major role in helping organizations become
  – Stronger
    - Thus more likely to survive
  – More secure
  – More able to expand

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

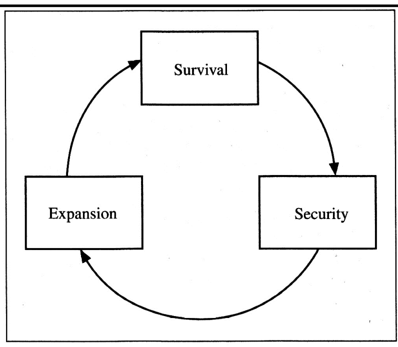


Diagram 2-1. Organizational Motivation

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Decreasing Costs

- Streamlining processes
- Reducing rework and waste
  – Focusing development on the work that matters to customer

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Increasing Revenues

- Selling more
- Charging more
  - Can be achieved by meeting customers needs and wants
    - Making products more attractive

Cycle Time Reduction

- QFD helps making key decisions early in development process
- In competition it is important to make new products available before the competitor
  - Thus competition can be robbed out of business

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

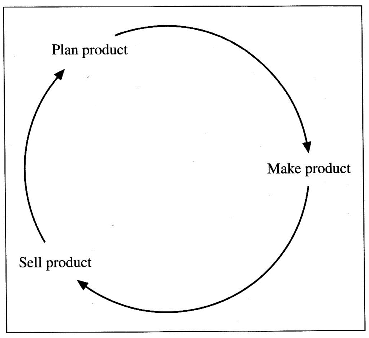


Diagram 2-2. Product Development Cycle

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Obstacles to Rapid Product Development

- Poor understanding of customer needs
- Failure to strategically prioritize efforts
- Willingness to take on unmanageable risks

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Obstacles to Rapid Product Development

- Tendency toward unbuildable design, undeliverable services
- Overreliance on formal specification
- Testing scenarios that fail to find key defects

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Kano’s Model

- Divides product characteristics in three categories
  - Dissatisfiers
  - Satisfiers
  - Delighters

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Dissatisfiers

- Customer takes characteristics for granted
- Causes dissatisfaction when missing
  - Scratches on the surface
  - Missing instruction booklets

Satisfiers

- Customer wants in their product
- Usually will ask for it
  - Increased capacity
  - Lower cost
  - Easier to use
  - Greater speed
  - Higher reliability

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Delighters

- Attributes or features that are pleasant surprises to customer
  - Reaction to delighter is to say to a friend, ”Hey! Take a look at this!”
- If delighters are not present customer will not be dissatisfied
  - Unaware of what they are missing

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

The Seven Management and Planning Tools

- List of tools and actual number of tools vary a bit one source to another
- Following tools are mainstays of QFD
  - Affinity Diagram
  - Tree Diagram
  - Matrix Diagram
  - Prioritization Matrix

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

The Seven Management and Planning Tools

- Other tools often included in the list of the Seven Management and Planning Tools
  - Interrelationship Diagram
  - Process Decision Program Chart
  - Matrix Data Analysis
  - Arrow Diagram

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Statistical Process Controll (SPC)

samk
Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management

The basic consepts

- Organizations compete on quality, delivery and price.
- Quality is defined as meeting the requirements of the customer.
  - The voice of the Customer
- The supplier–customer interface is both internal and external to organizations.

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Quality

- The quality of a product or service has two distinct but interrelated aspects:
  - quality of design;
  - quality of conformance to design.

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Quality of design

- If the quality of design is low
  - service or product will not meet the requirements
  - or it will only meet the requirement at a low level.

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Quality of design

- It is not sufficient that the marketing department specifies a product or service ‘because that is what the customer wants’
- Producing departments must also be able to produce to the specification

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Quality of conformance to design

- This is the extent to which the product or service achieves the specified design
- What the customer actually receives should conform to the design
  - Operating costs are tied firmly to the level of conformance achieved

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

The costs of quality

- Obtaining a quality product or service is not enough
  - The cost of achieving it must be carefully managed

Appraisal costs

- Appraisal is the cost of checking it is right
  - Verification: Of incoming material, final products or services,
  - Quality audits: is the quality management system is functioning satisfactorily
  - Inspection equipment: The calibration and maintenance of equipment
  - Vendor rating: The assessment of suppliers

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Prevention costs

- Prevention costs are planned and are incurred prior to production or operation
- Prevention includes
  - Product or service requirements: incoming materials, processes, intermediates, finished products and services

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Prevention costs

- Quality planning: The creation of quality, reliability, production, supervision, process control, inspection
- Quality assurance: The creation and maintenance of the overall quality management system.

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Prevention costs

- Inspection equipment: The design, development and/or purchase of equipment for use in inspection work.
- Training: Quality training programmes for operators, supervisors and managers
- Misc: Clerical, travel, supply, shipping, communications and other general office management activities associated with quality

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

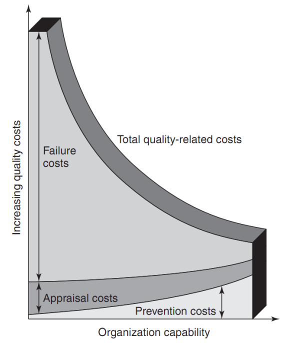


Figure 1.2 Relationship between costs of quality and organization capability

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Basic tools

- In SPC numbers and information will form the basis for decisions and actions
  - thorough data recording system is essential
- In addition to the basic elements of a management system, there exists a set of 'tools'

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Basic tools

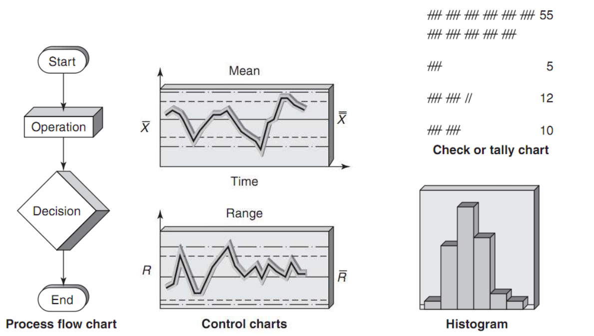
- Process flowcharting – What is done?
- Check sheets – How often is it done?
- Histograms – What does the variation look like?
- Graphs – Can the variation be represented in a time series?
- Pareto analysis – Which are the big problems?

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

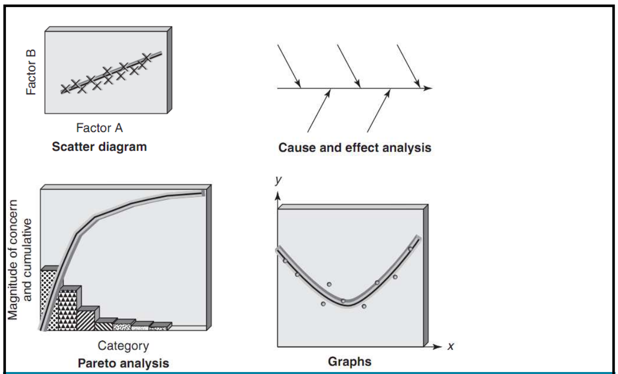
Basic tools

- Cause and effect analysis and brainstorming – What causes the problems?
- Scatter diagrams – What are the relationships between factors?
- Control charts – Which variations to control and how?

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk



Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk



Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Pareto analysis

- In many things we do in life we find that most of our problems arise from a few of the sources
  - 80% of the defects will arise from 20% of the causes; 80% of the complaints originate from 20% of the customers.
    - These observations have become known as part of Pareto's Law or the 80/20 rule

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Pareto analysis

- ABC or Pareto analysis is based on empirical rules which have no mathematical foundation
- The aim is simply to ensure that the maximum reward is returned for the effort expelled

Cause and effect analysis

- The cause and effect diagram, also known as the Ishikawa diagram (after its inventor), or the fishbone diagram (after its appearance)

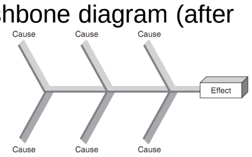


Figure 11.5 Basic form of cause and effect diagram

Cause and effect analysis

- An essential feature of the cause and effect technique is brainstorming
  - is used to bring ideas on causes out into the open
- A group of people freely exchanging ideas bring originality and enthusiasm to problem solving

Scatter diagrams

- Scatter diagrams are used to examine the relationship between two factors to see if they are related
- Scatter diagrams have application in problem solving following cause and effect analyses

Scatter diagrams

- After a sub-cause has been selected for analysis, the diagram may be helpful in explaining
  - why a process acts the way it does
  - how it may be controlled

Process data collection and presentation

- Process improvement requires a systematic approach which includes an
  - appropriate design, resources, materials, people, process and operating instructions
- Narrow quality and process improvement activities to a series of tasks of a manageable size

Process data collection and presentation

- The basic rules of the systematic approach are:
  - no process without data collection
  - no data collection without analysis
  - no analysis without decision
  - no decision without action (which may include no action)

Data collection

- Full consideration must be given to the reasons for collecting data
  - the correct sampling techniques and stratification
- There should not be a disproportionate amount of a certain kind of data simply because it can be collected easily

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Recording data

- For example, the format and data recorded in Figure 3.1 have clearly been designed for a situation in which the daily, weekly and grand averages of a percentage impurity are required
  - Columns and rows have been included for the totals from which the averages are calculated

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Date	Percentage impurity					Week total	Week average
	15th	16th	17th	18th	19th		
Time							
8 a.m.	0.26	0.24	0.28	0.30	0.26	1.34	0.27
10 a.m.	0.31	0.33	0.33	0.30	0.31	1.58	0.32
12 noon	0.33	0.33	0.34	0.31	0.31	1.62	0.32
2 p.m.	0.32	0.34	0.36	0.32	0.32	1.66	0.33
4 p.m.	0.28	0.24	0.26	0.28	0.27	1.33	0.27
6 p.m.	0.27	0.25	0.24	0.28	0.26	1.30	0.26
Day total	1.77	1.73	1.81	1.79	1.73		
Day average	0.30	0.29	0.30	0.30	0.29	8.83	0.29
Operator	*A. Ridgewarth*						

Week commencing 15 February

Figure 3.1 Data collection for impurity in a chemical process

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Variables and process variation

- There are three main measures of the central value of a distribution (accuracy) These are the:
  - mean μ (the average value)
  - the median (the middle value)
  - the mode (the most common value)

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Variables and process variation

- There are two main measures of the spread of a distribution of values (precision)
  - range (the highest minus the lowest)
  - the standard deviation σ
    - The range is limited in use but it is easy to understand, the standard deviation is more accurate, but is less well understood

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Variables and process variation

- SPC is based on basic principles which apply to all types of processes
  - Control charts are used to investigate the variability of processes, help find the causes of changes, and monitor performance

Managing out-of-control processes

- Problems in process operation are rarely due to single causes, but a combination of factors involving the
  - Product or service, plant, programmes and people

Managing out-of-control processes

- The most frequently met causes of out-of-control situations may be categorized under
  - People
  - Plant/equipment
  - Processes/procedures
  - Materials
  - Environment

Taguchi methods

Symbols and their meaning

- Various symbols in this tutorial
  - L = loss function
  - m = target value
  - y = objective characteristics
  - A = cost due defective product

Symbols and their meaning

- Δ = deviation from target value
- k = constant
- σ^2 = mean square error, variation of products
- C_p = process capability index

Process capability index (C_p)

- In normal distribution

$$C_p = \frac{Tolerance}{6 * SD}$$

- In uniformly distribution

$$C_p = \frac{Tolerance}{6 * \left(\frac{Tolerance}{\sqrt{12}}\right)}$$

Loss function

- Is a formula for calculating
  - Financial loss when objective characteristics deviate from target value
- Sometimes the financial loss is referred simply as quality loss
- When y meets the target m
  - The loss L(y) will be at minimum

Loss function

- In ideal condition financial loss can be assumed to be zero

$$L(m) = 0$$

- The loss function is a squared term multiplied by constant k

$$L(y) = k(y - m)^2$$

Loss function

- The value of constant *k* is determined by the following equation

$$k = \frac{\text{Cost of a defective product}}{(\text{Tolerance})^2} = \frac{A}{\Delta^2}$$

- σ^2 = mean value of (y - m)^2

$$\sigma = \sqrt{\frac{1}{n}\left[(y_1 - m)^2 + (y_2 - m)^2 + \ldots + (y_n - m)^2\right]}$$

Loss function

- Cause of σ^2, process capability index is

$$C_p = \frac{Tolerance}{6\sigma}$$

- From that we also get the loss function

$$L = k\sigma^2$$

Product planning and quality

- The major stages of product development are
  - 1. Product planning
    - Market analysis is conducted
    - Primary goals of the product are determined
    - Pricing is set
    - Lifespan of the new product is decided

Product planning and quality

- 2. Product design
  - Product is designed and developed
- 3. Production process design
  - Process for manufacturing the product is designed and developed
- 4. Production
  - Product is manufactured

Product planning and quality

- 5. Sale
  - Product is sold
- 6. Product service
  - After-sale service matter are handled
    - Warranties
    - Claims of defective products

Product planning and quality

- Ideally, product design departments should design new products that have no
  - Manufacturing cost
  - Malfunctions
  - Damaging environmental effects

Duties of design engineers and production technicians

- Both product design and production process design can be divided in to following five stages
  1. System selection (system design)
  2. Parameter design
  3. Tolerance design
  4. Tolerance specification
  5. Quality management for the production process

System selection / design

- Consider all possible systems that can perform the required functions
- In addition to existing systems, new systems should be considered
  - The advantage in developing new systems is that they are usually protected by patents

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Parameter design

- Design engineers should specify appropriate design parameters (system parameters)
  - To improve quality and reduce cost

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Tolerance design

- Must decide the tolerance specifications for all components
- Choose appropriate grades of materials for these components
  - Objective is to decide the tradeoff between quality level and cost

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Tolerance specification

- Grades of the materials and the tolerance limits of the components must be
  - Specified and placed on blueprints
- Sign contracts with material and component suppliers
- Very common to combine the tolerance specification and tolerance design stages

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Quality management for the production process

- Feedback control systems must be designed
  - To control the statistical distribution of critical dimensions of new products
- Design of gauges for measuring quality
  - For use by quality management system
    - Important in this stage

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Off-line quality control

- This includes
  - System design (system selection)
  - Parameter design
  - Tolerance design

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

On-line quality control

- This includes
  - Process diagnosis and adjustment
  - Prediction and correction
  - Measurement and action
  - After sales service

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Process diagnosis and adjustment

- Also known as process control
- Process is diagnosed at regular intervals
  - If it is normal, production is continued
  - If it is not, the cause is found and production is restarted
- Preventive adjustments can be made when imminent failure is diagnosed

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Prediction and correction

- Also known as control
- Quantitative characteristic to be controlled is measure at regular intervals
  - Measured value is used to predict the mean characteristic value of the product
    - If production is continued without adjustment

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Prediction and correction

- If predicted value differs from target value
  - Corrective action is taken to reduce difference
- This method is also called
  - Feedback control
  - Feed forward control

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

Measurement and action

- Also called inspection
- Each unit manufactured is measured
  - If it is out of specification it is reworked or scrapped
- This method of quality control deals only with the product

Satakunnan ammattikorkeakoulu | Tekniikka ja merenkulku
Satakunta University of Applied Sciences | Faculty of Technology and Maritime Management
samk

After sales service

- Customer service
  - Technical support
- Warranty
  - Replacement or repairing of defects