

Quality Management of Software and Systems

Total Quality Management (TQM)

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TQM Definition

- ☐ DIN / ISO 8402 (1995)
 - Total Quality Management
 - "Management method based on the cooperation of all members of an organization which centers quality and by consumer satisfaction aims at long-term commercial success as well as the utility for the members of the organization and for society."

Quality Strategies

- ☐ Zero Defects Concept
 - A program developed by P. B. Crosby which assumes that only zero defect products are actually acceptable
 - The aim is a zero defect product without rejects and rectification of rejects. "Not the generation of quality causes costs but the non-fulfillment of requirements"
- ☐ Continuous Improvement Process (CIP), Kaizen
 - A program introduced into the Japanese industry by W. E. Deming in the 1950s which revolutionized productivity and quality
 - Comprises the principle of constant improvement (Kaizen) and a 14-points-program (management principles)
 - Kaizen is realized with the aid of the Deming-cycle (Plan-Do-Check-Act)
- ☐ Total Quality Control (Feigenbaum, 1961)
 - System for the development, maintenance, and improvement of quality (marketing, development, production, customer service)

Quality Strategies

- ☐ Company-Wide Quality Control (Ishikawa)
 - Concept which enhances TQC essentially by the component of the staff members orientation
 - Ishikawa is the inventor of the quality circles and the Fishbone-Charts (Ishikawa-Diagram)
- ☐ Quality Trilogy
 - Three-phase, systematic, continuous process developed by J. M. Juran for the quality increase/enhancement (planning of process, implementation and protection/coverage/safeguarding (Absicherung), process improvement)

Quality Strategies Quality Assurance and TQM

	Classic Quality Assurance	TQM
Goals	▪ Better products ▪ Lower costs	▪ Better management ▪ Customer satisfaction ▪ Flexibility
Orientation	▪ Product	▪ Market ▪ Process
Organization	▪ Strong position of quality assurance	▪ All activities focus on quality
Quality responsibility	▪ Quality representative/agent	▪ Line management ▪ Every staff member
Method	▪ Measurements ▪ Checks/inspections/tests ▪ Failure recording and failure evaluation	▪ Institutionalized program for error reduction ▪ Process monitoring and process optimization ▪ Optimization in the own area of operation

Quality Engineering in the Scope of TQM

- ☐ Methods and procedures
 - Quality Function Deployment (QFD)
 - Statistical Process Control (SPC)
 - Reliability Modeling
 - Reviews, Inspections
 - Quality Circles
 - Fault Mode and Effect Analysis (FMEA)
 - ...
- ☐ Techniques
 - Fishbone Chart (Ishikawa-Diagram)
 - Pareto Analysis
 - Quality Control Charts (in terms of SPC)
 - Correlation Diagram
 - ...

Quality Function Deployment (QFD)

- ☐ Complete survey of customer requirements
- ☐ Weighting of customer requirements according to their importance for the customer utility and the commercial success
- ☐ Tracing of requirements through the development process (transparency which activities are connected with which customer requirements)
- ☐ Resources are provided for the realization of important requirements in case of doubt
- ☐ Corresponds to the strong customer orientation of TQM, as basically everything can be attributed to customer requirements

Statistical Process Control, SPC

- ☐ Instrument for the differentiation between a pure accidental distribution of process operating figures of a stable process and systematic changes of the process
 - Accidental dispersion/distribution: production tolerances of a cutter (Frästeil)
 - Systematic change: slow drift of the measure by tool wear, erratic change by clamping of a wrong cutter head
- ☐ Uses statistical tools
- ☐ Is executed with the aid of the quality control chart

QMS - Total Quality Management (TQM)

Statistical Process Control, SPC SPC in Production

- ☐ Production tolerances due to machine accuracy (e.g. lathe)
- ☐ Production tolerances due to process accuracy (quality of material, staff member qualification)
- ☐ Defined tolerable variations the exceedance of which causes rejects
- ☐ Wish to manage with samples as quality control to be able to abandon expensive checking/testing of every work piece (so-called sorting)
- ☐ In production the basis of SPC are the so-called machine capability and process capability. They test the general ability of a machine or a process to generate the required tolerance
- ☐ Always mixture of systematic influences (e.g. tool wear, increase of fetch) and stochastic dispersion/distribution (machine quality)
- ☐ **Application of means of statistics to samples for the separation of noise and real change**

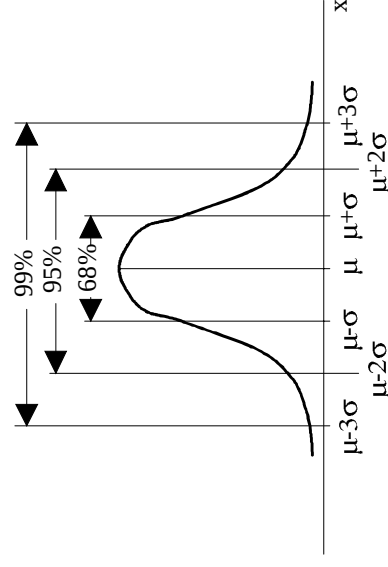
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Statistical Process Control, SPC Example: Normal Distribution

- ☐ Many characteristics are subject to this distribution
- ☐ Characteristics
 - sample average value $\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$
 - Estimation for the standard deviation $s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$
 - Standard deviation $\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \mu)^2}{n}}$

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Statistical Process Control, SPC Normal Distribution

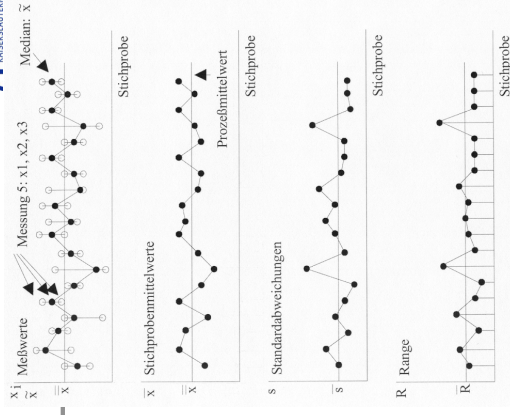


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Statistical Process Control, SPC Normal Distribution

- ☐ The inflection points of the curve are at $\mu - \sigma$ and at $\mu + \sigma$
- ☐ It can be expected (area below the curve) that approximately
 - 68 % of all measurements are between $\mu - \sigma$ and at $\mu + \sigma$
 - 95 % of all measurements are between $\mu - 2\sigma$ and at $\mu + 2\sigma$
 - 99 % of all measurements are between $\mu - 3\sigma$ and at $\mu + 3\sigma$
- ☐ In production besides the mean value/median $\bar{x}$ of a sampling and the estimation for the standard deviation s also its range R and the median $\tilde{x}$ including the corresponding arithmetic mean/average values $\bar{x}, s, R, \tilde{x}$ are used
 - $R = X_{\max} - X_{\min}$
 - The median concerning an uneven number of measurements is the middle value of the measurements ordered according to size. Concerning an even number of measurements in a sampling the median is the arithmetic mean value of the two middle values
 - The process average value $\bar{x}$ is the average value of the sampling average values $\bar{x}$
- ☐ In the scope of SPC the values $\bar{x}, \tilde{x}, R, s$ are presented in so-called quality control charts

Statistical Process Control, SPC

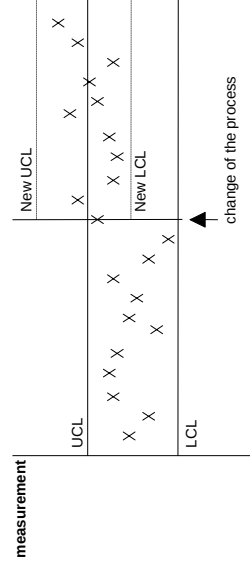


Statistical Process Control, SPC Quality Control Charts

- ☐ Two different types of control charts subject to the presented infotype
 - Charts for variable characteristics (measurements). Average/mean value-chart (x-chart) combined with distribution-chart (s-chart)
 - Charts for attribute characteristics (countable characteristics (faults) or properties (good/bad))
- ☐ Important difference: charts for variable characteristics can reveal trends before problems are generated, charts for attribute characteristics are based on already existent problems (occurred faults)

Statistical Process Control, SPC Quality Control Charts

- ☐ The basis for the definition of the upper and the lower action control limit is the $\pm 3s$ -interval which represents an appropriate compromise between false alarm and unrealized alarm situation



Statistical Process Control, SPC Quality Control Charts for Variable Properties

- ☐ The measurements x of properties of a unit which emanate from a controlled process are normally subject to a normal distribution which is characterized by
 - its average/mean value μ and
 - its variance σ^2

According to the central limit theorem for a random variable generated by the overlap of many small factors independent of each other a normal distribution can be assumed

- ☐ Collection of such values in SPC
 - $\bar{x}$ -charts (also called X-charts) for the average/mean value
 - R-charts or s-charts for the distribution

Statistical Process Control, SPC Quality Control Charts for Variable Properties Example of a Quality Control Chart: The X-Chart

- ☐ X-charts serve for the presentation of measurements. They show a displacement of the process average/mean value (e.g. drift) also if the distribution is retained and they identify "outliers/mavericks": X-charts do not serve primarily for the detection of changes of the distribution

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}, s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

- ☐ Upper Control Limit: UCL: $\bar{x} + 3s$
- ☐ Lower Control Limit: LCL: $\bar{x} - 3s$

Statistical Process Control, SPC Quality Control Charts for Variable Properties Example of a Quality Control Chart: The X-Chart

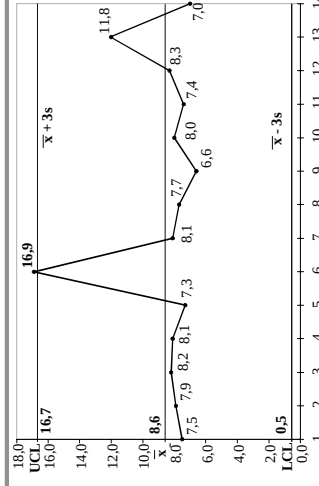
- ☐ Example
 - The execution time of a time-critical routine is measured to see if it varies only statistically or if there are systematic influences

no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
time (ms)	7,5	7,9	8,2	8,1	7,3	16,9	8,1	7,7	6,6	8,0	7,4	8,3	11,8	7,0

$$\bar{x} = (7,5 + 7,9 + 8,2 + 8,1 + 7,3 + 16,9 + 8,1 + 7,7 + 6,6 + 8,0 + 7,4 + 8,3 + 11,8 + 7,0) / 14 = 120,8 / 14 = 8,6$$

$$s = 2,7$$

Statistical Process Control, SPC Quality Control Charts for Variable Properties Example of a Quality Control Chart: The X-Chart



- ☐ X-chart: UCL = $\bar{x} + 3s = 16,7$, LCL = $\bar{x} - 3s = 0,5$
- ☐ Point 6 is above the UCL: cause analysis required

Reliability Modeling

- ☐ Probability that a unit remains functional under predetermined conditions during a particular period of time (in a way: time-referenced quality)
- ☐ Reliability is a statistical value which can be prognosed when corresponding failure models are taken as a basis
- ☐ Typically expressed as
 - Mean failure-free operating time up to failure (MTTF, Mean Time To Failure)
 - Failure rate λ_{t_0} : relative failure number per time unit as function of the time. If $\lambda_{t_0} = \lambda$ is constant it is valid

$$MTTF = \frac{1}{\lambda}$$

Quality Circles

- ☐ Group of few staff members which meets regularly with the aim to solve quality problems occurring in their work area resp. to introduce improvements actively
- ☐ Typically weekly meetings of about an hour within the working time
- ☐ Realization of improvements normally is done by the group itself after a corresponding license is granted; likewise the control of success/result checking
- ☐ Quality circles should apply appropriate methods for the problem identification, analysis and solution (Pareto-diagram, Ishikawa-diagram, brainstorming, ...)
- ☐ Support and participation of the top management is essential

Quality Circles Typical Procedure of Quality Circles

- ☐ Problem identification, problem selection
 - Selection of problems to be analyzed
 - Application of creativity techniques for the problem identification
 - Prioritization of problems (e.g. with Pareto-diagram)
- ☐ Problem handling
 - Authorization by decision making department
 - Coordination with other quality circles
 - Separation of chief causes and secondary causes (e.g. with Ishikawa-diagram)
 - Define goals
 - Search for solutions (e.g. with brainstorming)
 - Evaluate alternatives and choose solutions
- ☐ Presentation of results
 - Present solution to the decision making circle and prepare realization

Quality Circles Typical Procedure of Quality Circles

- ☐ Introduction and control of success
 - Introduce solution
 - Documentation of problem, way of solution and result
 - Control of success (preferably quantitatively)
 - Generalization (transmission to other parts of the organization, ...)

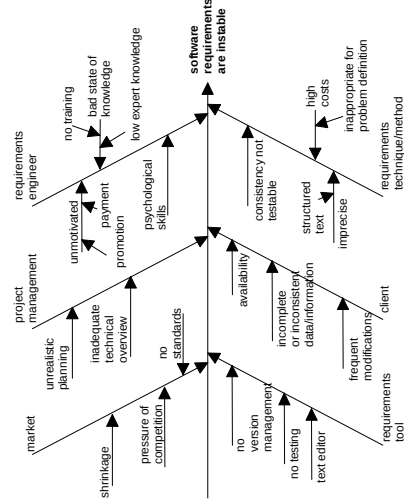
Failure Modes, Effects and Criticality Analysis, FMECA

- ☐ Preventive method for the detection of problems together with their risks and effects
- ☐ Risk evaluation with the aid of the risk priority number
 - $RPN = \text{occurrence probability} * \text{weight of the effects} * \text{probability of non-detection}$
- ☐ Development of proposals for measures
- ☐ Decision of measures
- ☐ Analysis of residual risk (recalculation of the RPZ)
- ☐ Execution of cost benefit analysis

Cause-and-Effect-Diagram (Fishbone Chart, Ishikawa-Diagram)

- ☐ Graphical technique for the analysis of cause-and-effect interrelations. To a problem (effect) the chief causes are identified which are further refined into secondary causes etc.
- ☐ Defined by Ishikawa for the application in quality circles (Ishikawa-diagram)

Cause-and-Effect-Diagram (Fishbone Chart, Ishikawa-Diagram) Example



Cause-and-Effect-Diagram (Fishbone Chart, Ishikawa-Diagram) Example

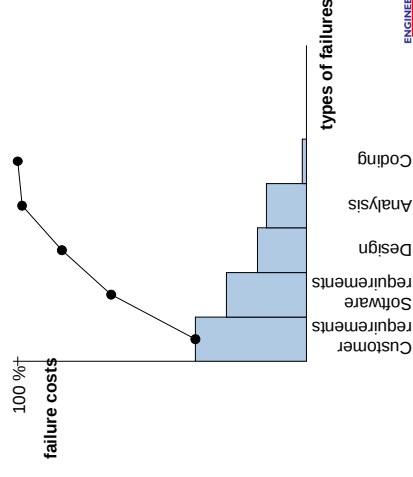
- ☐ Procedure
 - Define problem (effect) and attach it to the head of the "fishbone"
 - Attach the chief causes to the "sidewise fishbones" (often used: the 6 m: man, machine, method, material, milieu, measuring)
 - Attach causes of further order to the branches of the "sidewise fishbones" (brainstorming: identification with the aid of the questions: what, why, how, who, when, where)
- ☐ Identification of real cause
- ☐ Development of solution alternatives and choice of the optimal solution
- ☐ Introduction of solution

Pareto Analysis

- ☐ The Pareto Principle
20 % of the error/defect causes generate 80 % of the defects
- ☐ Histogram (bar chart/diagram) which presents subsets ordered according to decreasing size from left to right
- ☐ Additionally a sum curve of the bar heights can be applied
- ☐ Aims at high efficiency concerning improvements by prioritization
- ☐ Example: Every bar symbolizes a certain type of error. The height of the bar symbolizes the total costs required for the elimination of faults. The Pareto Principle here is "20 % of the faults cause 80 % of the costs". The avoidance of these 20 % of faults will have first priority. These faults are the aim of quality improvements

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Pareto Analysis



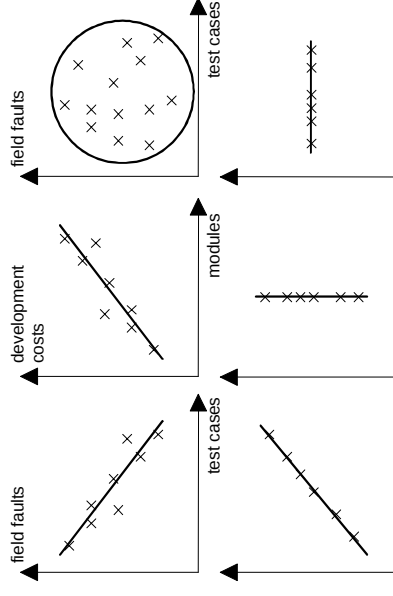
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Correlation Diagram

- ☐ Instrument for the analysis of the dependence between two characteristics based on a set of pairs of characteristics
- ☐ Statistical basis: correlation coefficient
- ☐ Examples
 - Number of software modules and development costs
 - Number of test cases and number of notified failures during the first year of product use

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Correlation Diagram



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Literature

- ☐ Feigenbaum A.V., Total Quality Control, 3rd Edition, New York: McGraw-Hill 1983
- ☐ Frehr H.-U., Total Quality Management: Unternehmensweite Qualitätsverbesserung, München: Hanser 1993
- ☐ Braverman J.D., Fundamentals of Statistical Quality Control, Reston: Reston Publishing Co., Prentice Hall 1981
- ☐ Wheeler D.J., Chambers D.S., Understanding Statistical Process Control, Knoxville: SPC Press 1992
- ☐ Zultner R., Before the house: The voices of the customers in QFD, in: Transactions 3rd Symposium on QFD, Novi, MI, June 1991, pp. 450-464