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

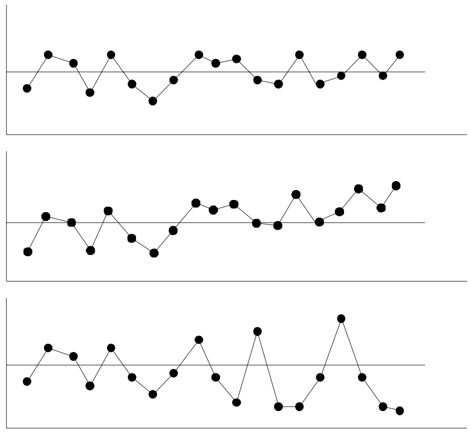
- Methods and procedures
  - Quality Function Deployment (QFD)
  - Statistical Process Control (SPC)
  - Reliability Modeling
  - Reviews, Inspections
  - Quality Circles
  - Fault Mode and Effect Analysis (FMEA)
  - ...
- Techniques
  - Fishbone Chart (Ishikawa-Diagram)
  - Pareto Analysis
  - Quality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



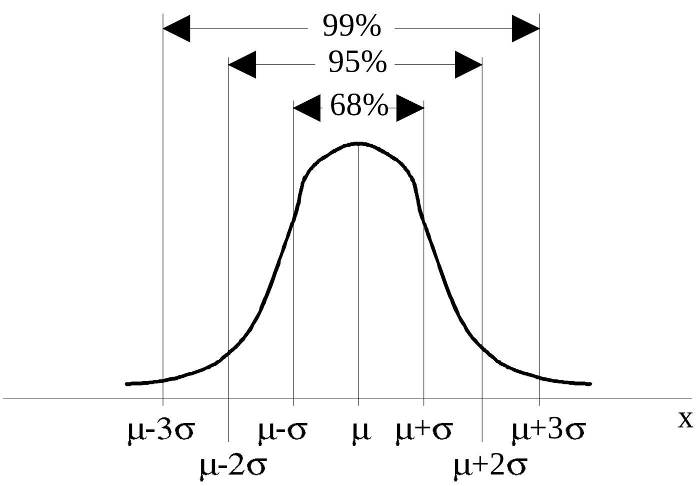
Statistical Process Control, SPC
SPC in Production

- 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**

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 $\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \mu)^2}{n}}$

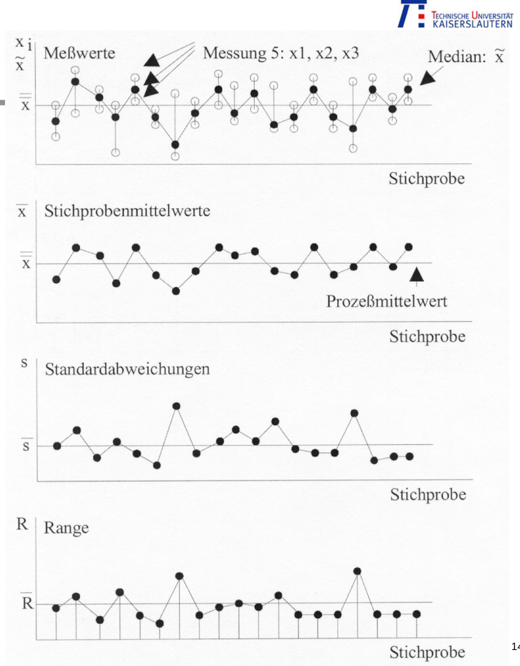
Statistical Process Control, SPC
Normal Distribution



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 $\bar{\bar{x}}, \bar{s}, \bar{R}, \bar{\tilde{x}}$ 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 $\bar{\bar{x}}$ 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

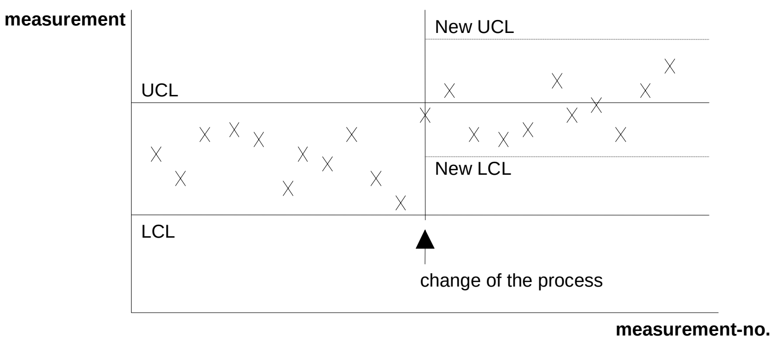


Statistical Process Control, SPC
Quality Control Charts

- ☐ Two different types of control charts subject to the presented infotype
  - Charts for variable characteristics (measurements). Average/mean value-chart ($\bar{x}$-chart) combined with distribution-chart (s-chart)
  - Charts for attributive characteristics (countable characteristics (faults) or properties (good/bad))
- ☐ Important difference: charts for variable characteristics can reveal trends before problems are generated, charts for attributive 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 +/-3s-interval which represents an appropriate compromise between false alarm and unrealized alarm situation



Statistical Process Control, SPC
Quality Control Charts for Variable Properties

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- 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

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- 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

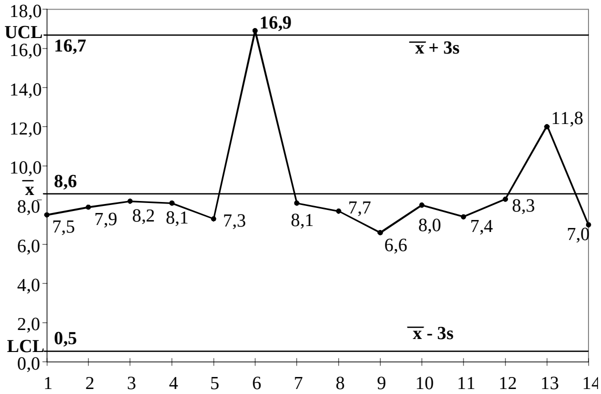
- Example
  - The execution time of a time-critical routine is measured to see if it varies only statistically or if there are systematic influences

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 $\lambda_{(t)}$: relative failure number per time unit as function of the time. If $\lambda_{(t)} = \lambda$ 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, ...)

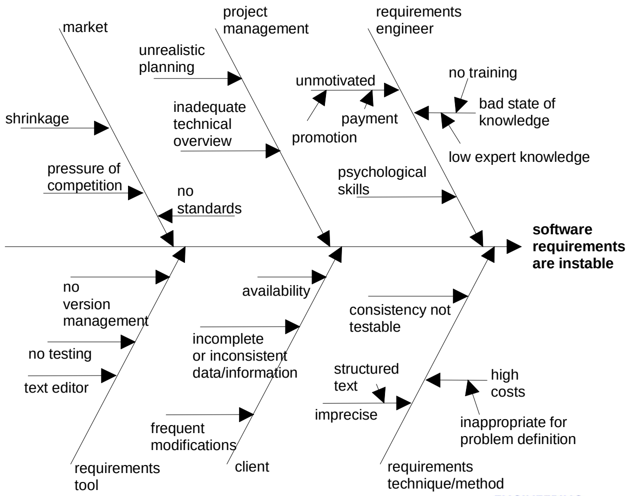
Failure Modes, Effects and Criticality Analysis, FMECA

- Preventive method for the detection of problems together with their risks and effects
- Risk evaluation with the aid of the risk priority number
  - RPN = occurrence probability * weight of the effects * 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



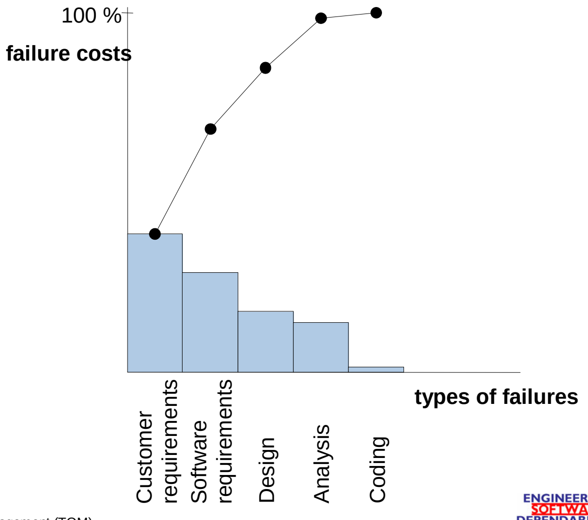
Cause-and-Effect-Diagram (Fishbone Chart, Ishikawa-Diagram) Example

- 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

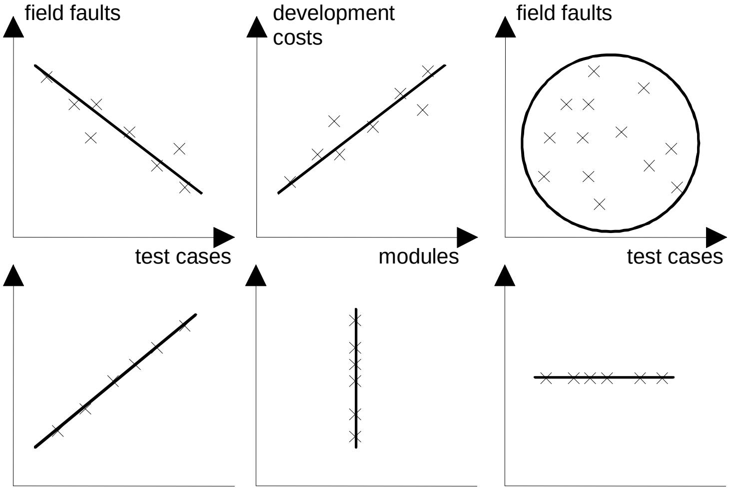
Pareto Analysis



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

Correlation Diagram



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