TECHNISCHE UNIVERSITÄT
KAISERSLAUTERN

0101seda010100

software engineering dependability

Quality Management of Software and Systems:

Supporting Methods and Techniques

Contents

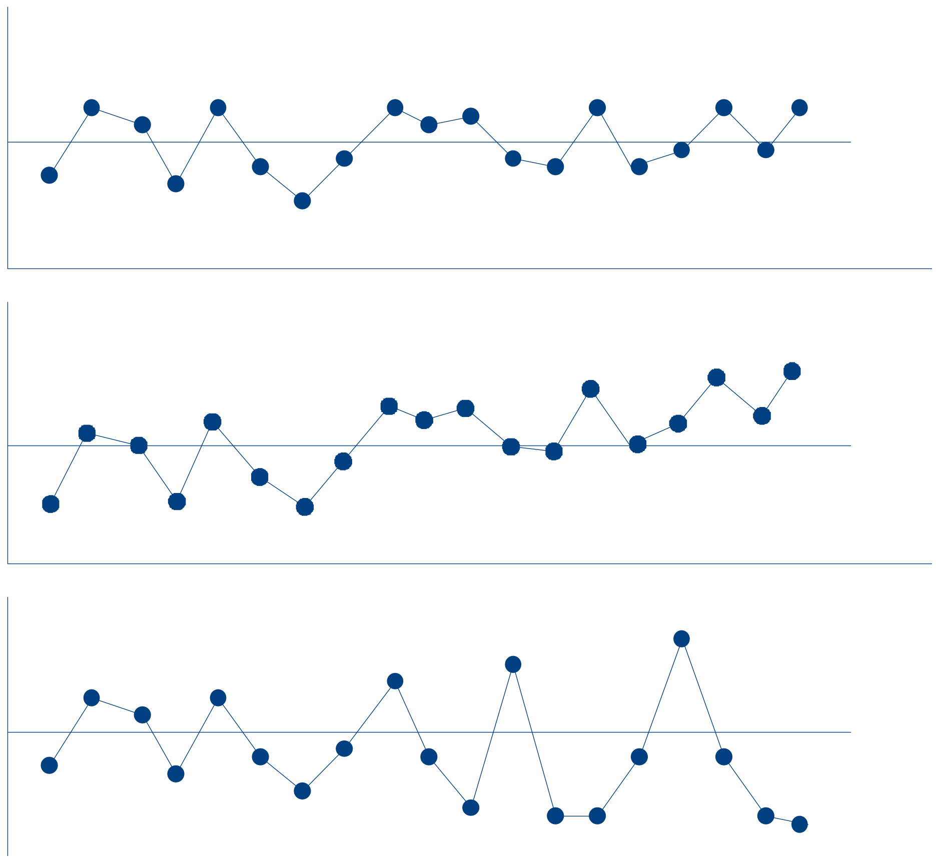
- Methods and Procedures
  - Quality Function Deployment (QFD)
  - Statistical Process Control, SPC
  - Reliability Modeling
  - Quality Circles (Qualitätszirkel)
  - Failure Mode, Effects and Criticality Analysis (FMECA)
- Techniques
  - Cause-and-Effect Diagram (Fishbone Chart, Ishikawa-Diagram)
  - 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)

- Means for differentiating a statistical variation of a process from a systematic one:
  - 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

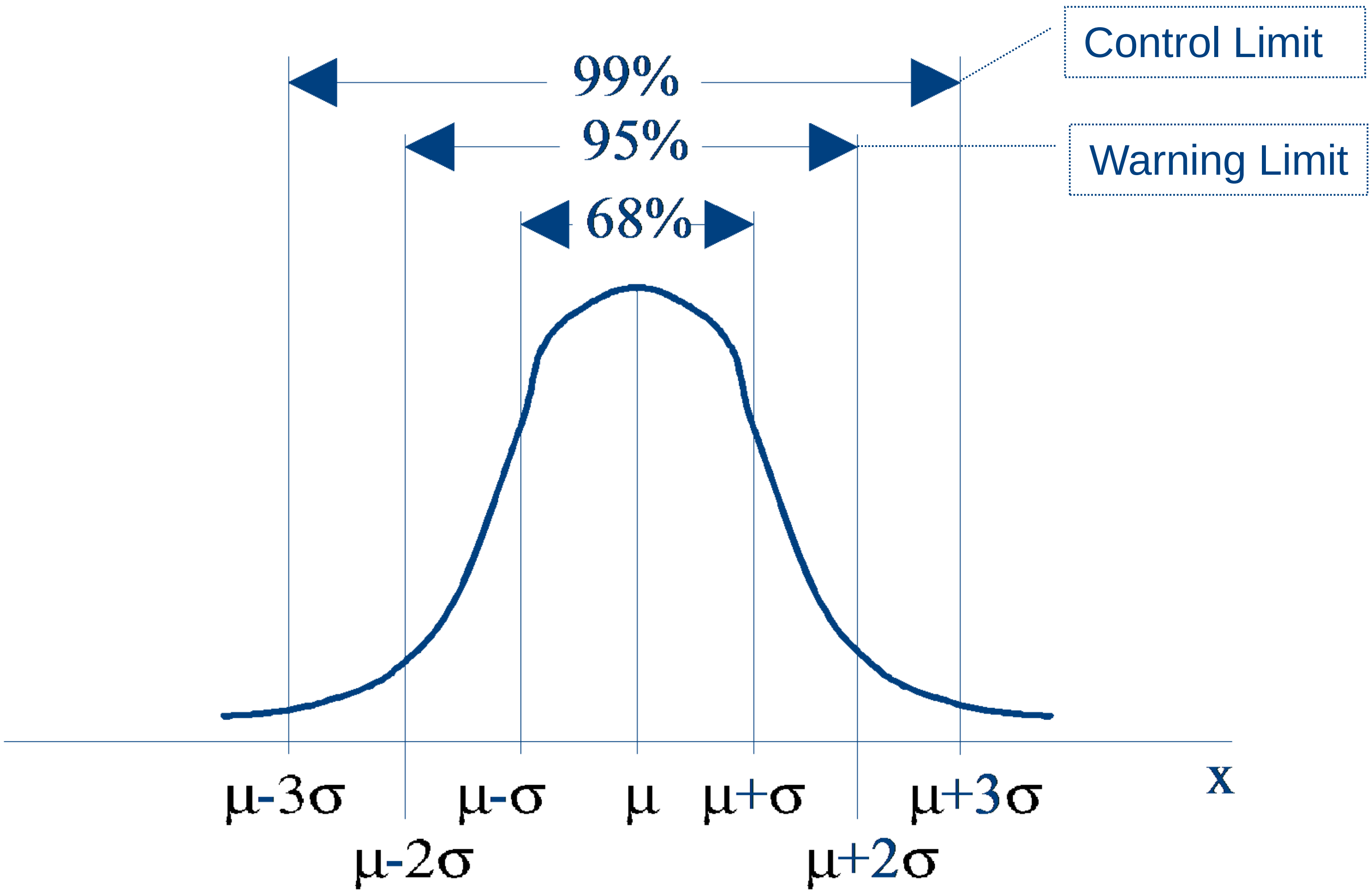


Statistical Process Control (SPC) in Production

- Production tolerances due to machine accuracy (e.g. lathe)
- Production tolerances due to process accuracy (quality of material, staff member qualification)
- Predefined tolerable variations allow parts to be evaluated with respect to their exceedance: Parts, which are outside tolerable variation limits are rejected.
- 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**

- 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 $s = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n-1}}$
  - Standard deviation $\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \mu\right)^2}{n}}$

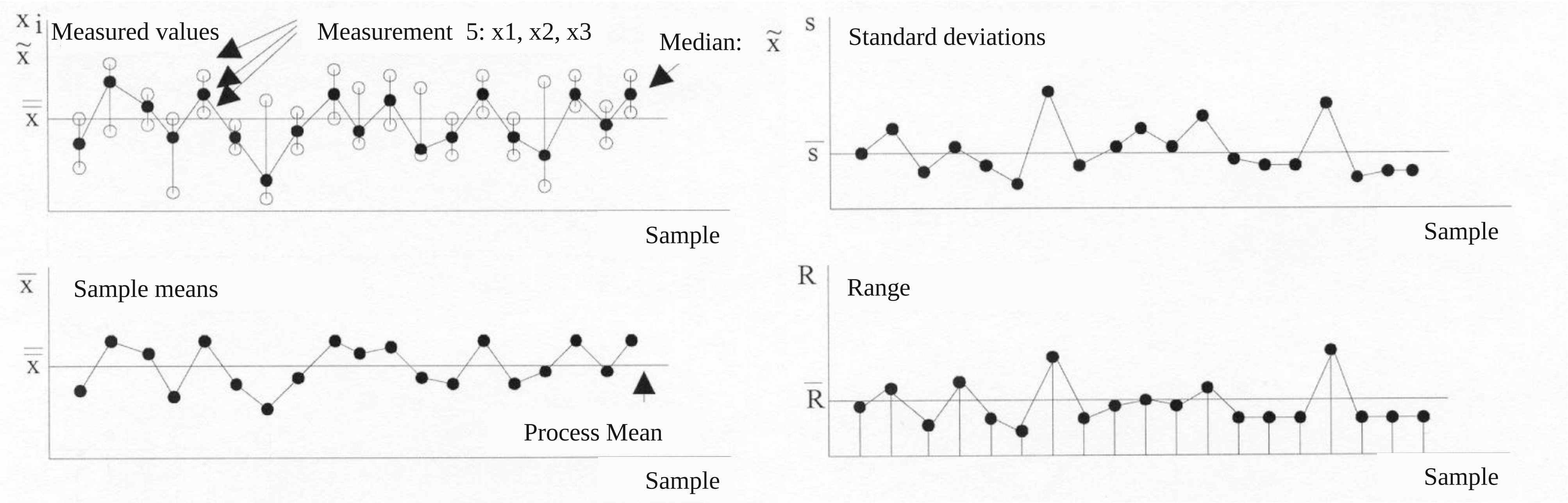
Statistical Process Control (SPC)
Normal Distribution



- 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

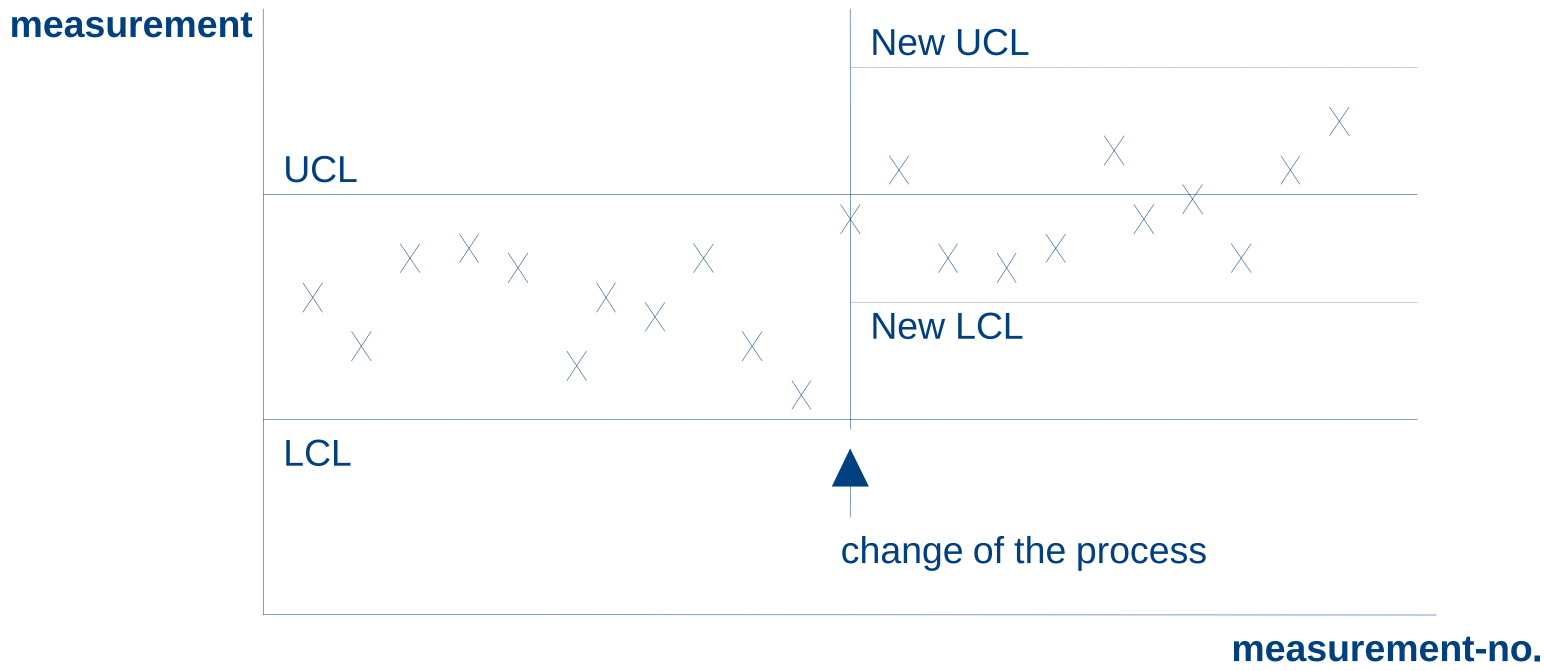


x_i
$\tilde{x}$
$\bar{\bar{x}}$
Measured values
Measurement 5: x1, x2, x3
Median: $\tilde{x}$
Sample
s
Standard deviations
$\bar{s}$
Sample
$\bar{x}$
Sample means
$\bar{\bar{x}}$
Process Mean
Sample
R
Range
$\bar{R}$
Sample

- Two different types of control charts depending on the type of information to be depicted:
  - 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)

- 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



- 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

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

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

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

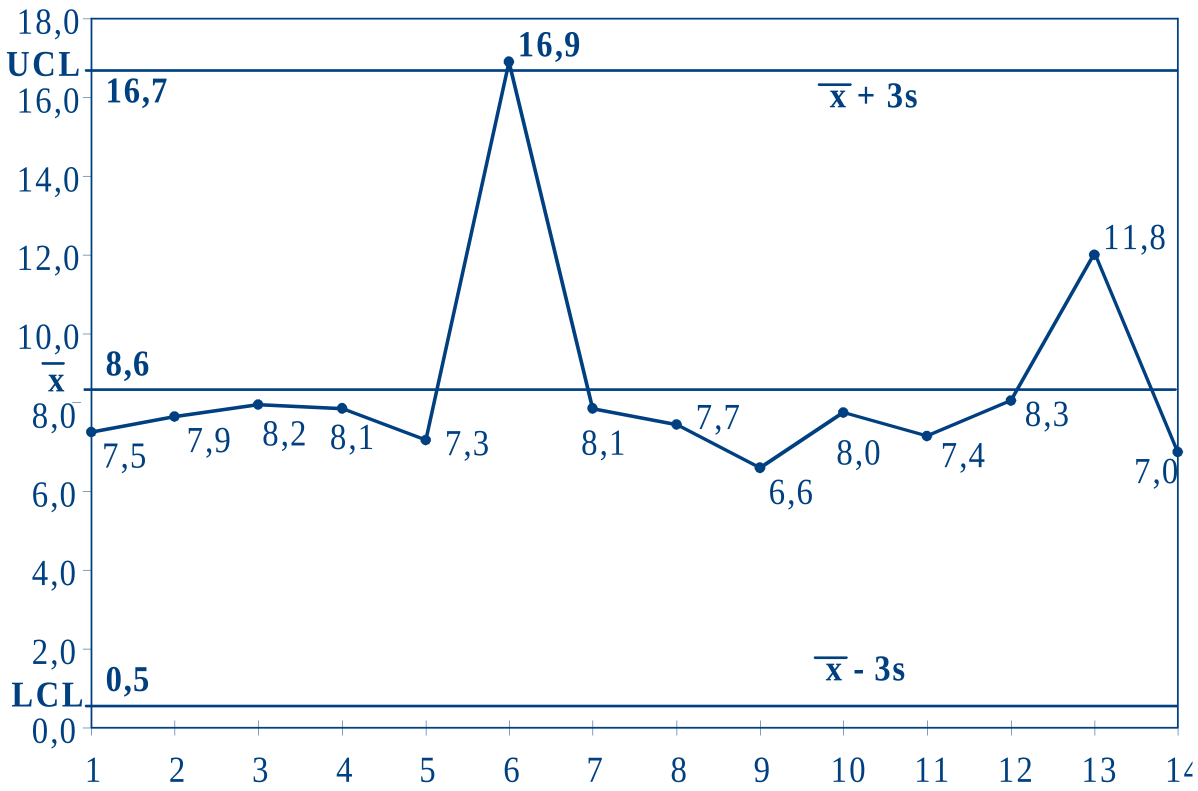
- Example
  - The execution time of a time-critical routine is measured to see if it varies only statistically or if there are systematic influences

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

Example of a Quality Control Chart: The X-Chart



- X-chart: UCL = $\overline{x}+3s=16{,}7$, LCL = $\overline{x}-3s=0{,}5$
- 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 estimated 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

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

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, ...)

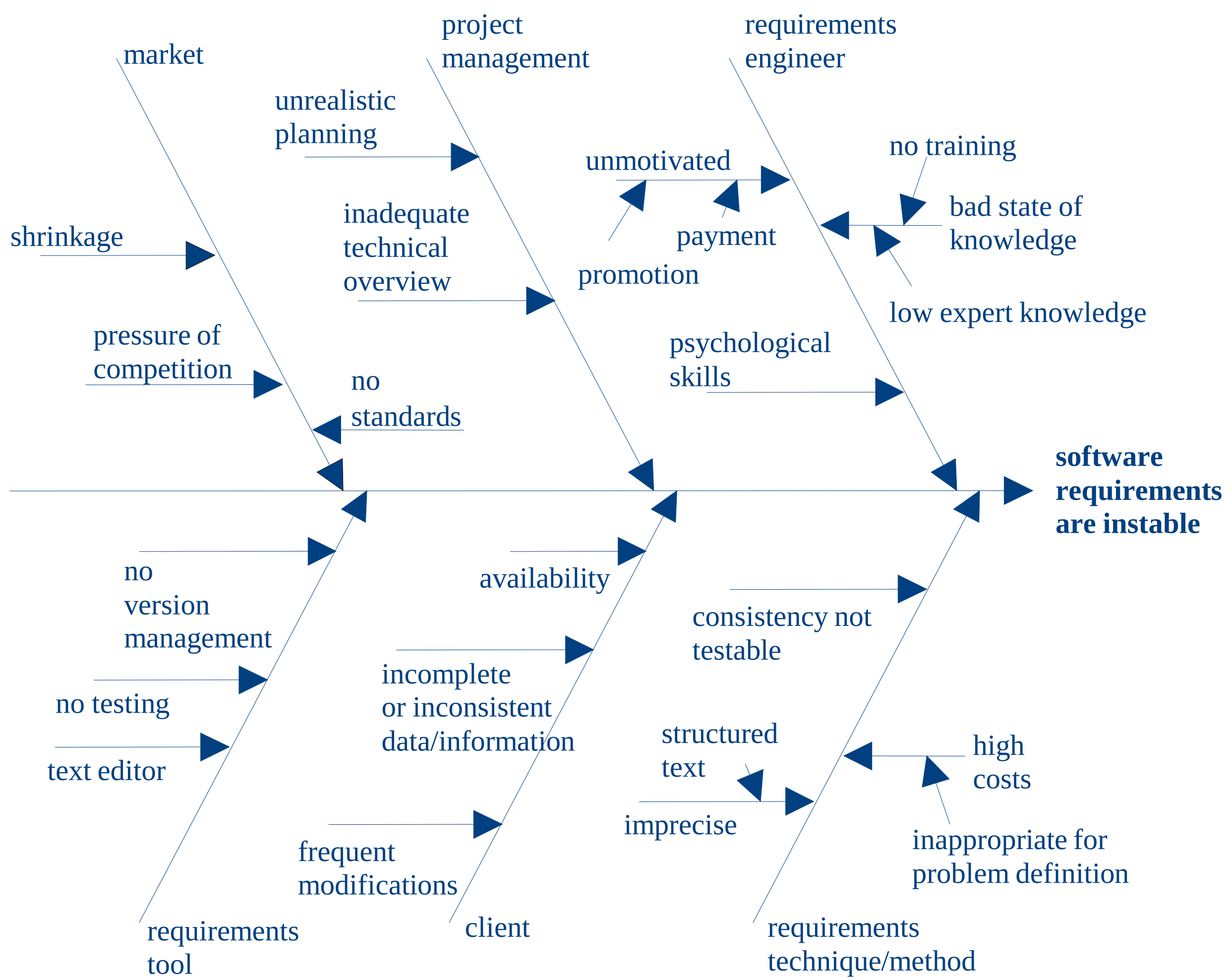
Failure Mode, Effects and Criticality Analysis (FMECA)

- Method that aims at risk prevention by identifying the failure modes of a system their causes and related 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 **R**isk **P**riority **N**umber)
- 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



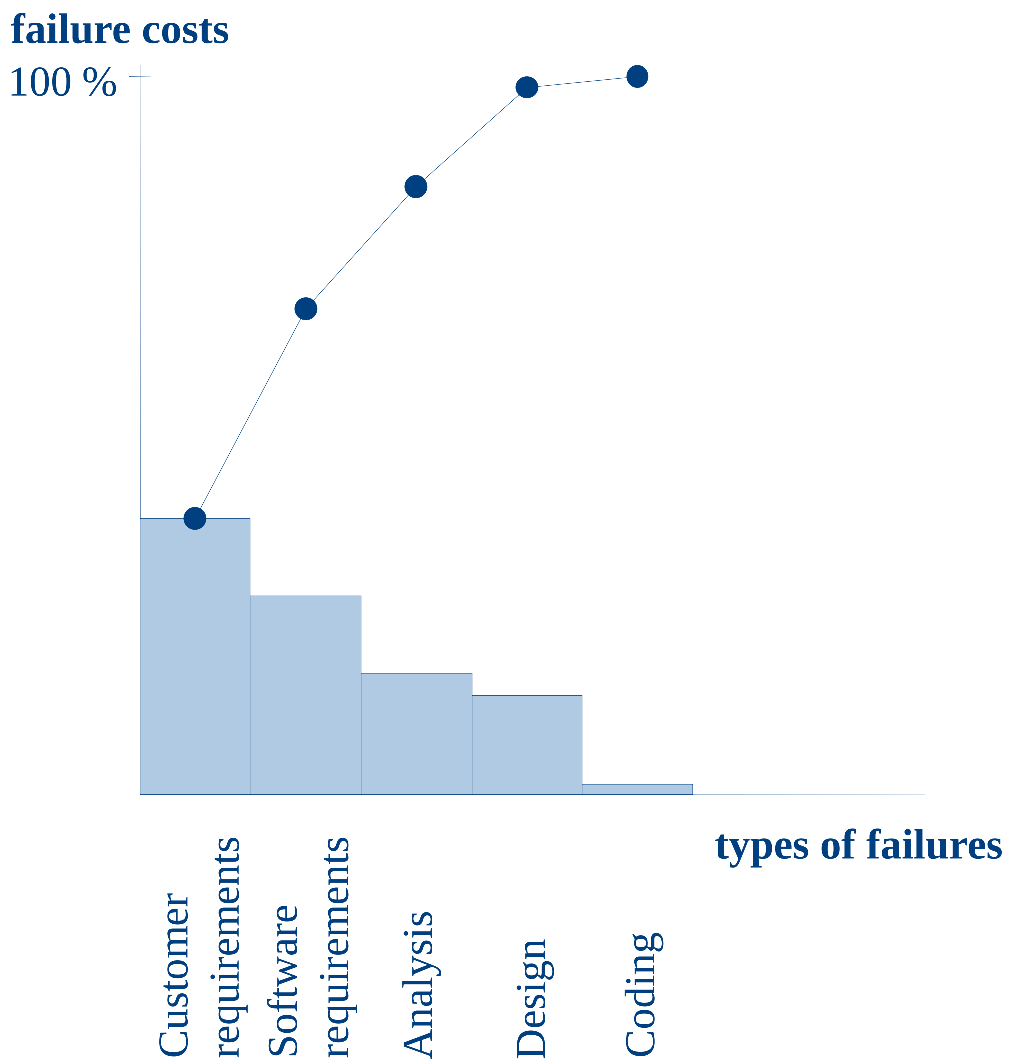
Cause-and-Effect-Diagram (Fishbone Chart, Ishikawa-Diagram) Example

- Procedure
  - Define problem (effect) and attach it to the head of the "fishbone"
  - Attach the major causes to the "sidewise fishbones" (often used: the 6 m: man, machine, method, material, milieu, measuring)
  - Attach minor causes 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

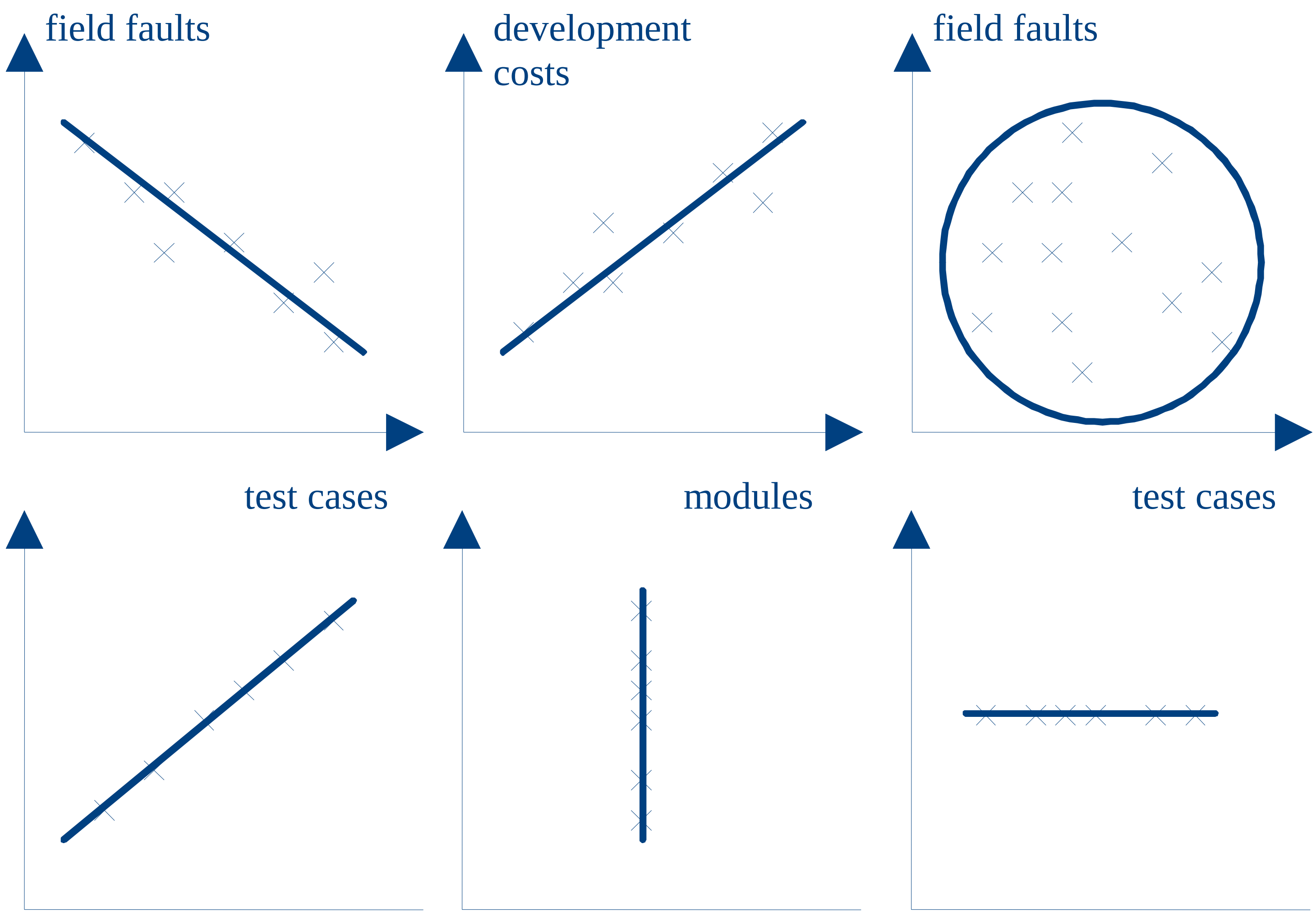
Pareto Analysis



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



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