Quality Management at FEV
Fachhochschule Aachen, 07.06.2004

Six Sigma / Design for Six Sigma
— CTQ Management

Dirk Rompf
FEV Motorentechnik GmbH, Aachen

Six Sigma / Design for Six Sigma
Agenda

- About FEV Motorentechnik
- **Informations and Knowledge**
  - History of Six Sigma!
  - Why Six Sigma?
  - What is Six Sigma?
    - Risk - Process
    - Definitions of Six Sigma / Design for Six Sigma
- **Six Sigma / DFSS overview**

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Six Sigma / Design for Six Sigma
History

1979: Motorola
1985: Motorola: first steps (Bill Smith)
1987: Motorola „Six Sigma Quality Program" launched (Bob Galvin)
1988: Motorola University: 1st course on implementing Six Sigma
1988: Motorola: Malcom Baldridge Award
1992: IBM starts Six Sigma
1992: Smarter Solution founded
1994: Six Sigma Academy founded (M. Harry, R. Schroeder)
AlliedSignal starts Six Sigma
1995: General Electric starts Six Sigma (Jack Welch)
~ 1996: Design for Six Sigma (DFSS)
....
~ 1999/2000: Six Sigma / Design for Six Sigma in Europe/Germany

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Six Sigma / Design for Six Sigma
Why Six Sigma?

- **We don`t know what we don`t know!**
- **If we can`t express what we know in form of numbers, we really don`t know much about it.**
- **If we don`t know much about it, we can`t control it.**
- **If we can`t control it, we are at the mercy of our processes!**

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Six Sigma / Design for Six Sigma
Why Six Sigma?

- **Six Sigma is about improving profitability, although improved quality and efficiency are immediate by-products of Six Sigma.**
- **The focus is not so much on the number of defects per million opportunities, but a systematic road map to reduce variability in a process through assimilation and organization of information that increases bottom-line €-savings.**

(M. Harry, R. Schröder)

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Six Sigma / Design for Six Sigma
Motorola (2000) - Web Site

For more than a decade Motorola has implemented the Six Sigma process with remarkable results

- Increased productivity an average of 12.3 % per year
- Reduced the cost of poor quality by more than 84 %
- Eliminated 99.7 % of in-process defects
- Saved more than $11 Billion in manufacturing costs
- Realized an average annual compounded growth rate of 17 % in revenues, earnings, and stock price

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Six Sigma / Design for Six Sigma
General Electric (2004)

13

Financial Highlights 2003

- Revenues: $134.2 billion
- Earnings: $15.6 billion ($1.55 per share) before cumulative effect of accounting changes; $15.0 billion ($1.49 per share) after changes.
  Cash Flow from Operating Activities: $12.9 billion
- Dividends: 12/31/03 Shares Outstanding: 10,063 million
- Stock Splits: GE shareowners have approved nine stock splits, most recently a 3-for-1 stock split in April 2000. Shareowners have also approved four 2-for-1 stock splits since 1983. One GE share purchased before 1926 is now worth 4,608 shares.
- International Revenues: $60.8 billion (45% of total revenues)
- R&D Expenditures: $2.7 billion
- Total Assets: $647.5 billion
- $0.20 per share quarterly. Dividends, paid every quarter since 1899, have increased every year since 1975.

GE is a diversified technology and services company dedicated to creating products that make life better from aircraft engines and power generation to financial services, medical imaging, television programming and plastics. GE operates in more than 100 countries and employs more than 315,000 people worldwide.

The company traces its beginnings to Thomas A. Edison, who established Edison Electric Light Company in 1878. In 1892, a merger of Edison General Electric Company and Thomson-Houston Electric Company created General Electric Company. GE is the only company listed in the Dow Jones Industrial Index today that was also included in the original index in 1896.

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Six Sigma / Design for Six Sigma
General Electric (2004)

14

Honors

- 2004 Catalyst Award - *Catalyst (2004)*
- 100 Best Companies for Working Mothers - *Working Mother (2003)*
- World's Most Respected Company - *Financial Times (1999, 2000, 2001, 2002, 2003, 2004)*
- The Scientific American 50 Award - *Scientific American (2002)*
- Global Most Admired Company - *Fortune (1999, 2000, 2001, 2002)*
- America's Most Admired Company - *Fortune (1999, 2000, 2001, 2002)*
- 10 Best Board of Directors - *Business Week (2002)*
- First place: The Super 500 - *Forbes (2003)*
- Fifth - *Fortune 500.* If ranked separately, all 11 GE businesses would appear on the *Fortune 500.*

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Six Sigma / Design for Six Sigma
What is Six Sigma?

15

„[...] it finally gives us a route to get to the control function, the hardest thing to do in a corporation.“

Jack Welch, former CEO General Electric

„[...] is a methodology of using statistical processes to reduce defects to virtually zero as a means to achieve Total Customer Satisfaction.“

Brochure, The Six Sigma Institute

„[...] is nearly nothing new, but a systemic and consequent methodology with an entire view and a systematically way to analyse processes to reduce risk/defects.“

Dirk Rompf, FEV Motorentechnik

„[...] is about the abatement of risk in all its forms.“
„[...] is a long-term, forward-thinking initiative [...]“

Mikel Harry, CEO Six Sigma Academy

„[...] should not replace other initiatives, but instead offer a tactical methodology to determine the best approach for a given situation/process.

Forrest W. Breyfogle III, CEO Smarter Solutions

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Six Sigma / Design for Six Sigma
Definitions of Six Sigma

16

Six Sigma Breakthrough Strategy = RDMAICSI

(Recognize, Define, Measure, Analyse, Improve, Control, Standardize, Integrate)

R = recognize functional problems that link to operational issues
D = define the processes
M = review of the types of measurement systems and their key features
A = statistical methods and tools
I = focuses on discovering the key variables
C = ensures that the same problems don´t reoccur
S = standardize the methods and processes
I = integrate standard methods and processes into the design cycle

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Six Sigma / Design for Six Sigma
Definitions of Design for Six Sigma

17

DMADV = Define, Measure, Analyse, Design, Verify

- D = develop design goals, project objectives and deliverables
- M = develop CTQ
- A = assess available options and process capabilities, select a best-fit concept
- D = develop detailed design, determine tolerances, optimise the design
- V = monitor performance of the design

IDOV = Identify, Design, Optimise, Validate

I²DOV = Invent/Innovate, Design, Optimise, Verify

- I = systems engineering, CTQ flow-down, VOC
- D = design engineering, quality prediction, identify functional requirements
- O = design optimisation, capability flow-up, determine tolerances
- V = test / verification of the design, (pre-)production, implement control plan

Look that your „DFSS methodology“ is compatible with your „Six Sigma“ tools and principles

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Six Sigma / Design for Six Sigma
Process

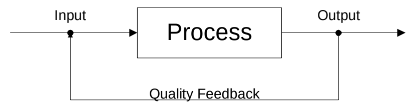
18

Global:

A process is a series of activities or steps that create a product or service.

Local:

A process is any activity or group of activities that takes an input, adds value to it, and provides an output to an internal or external customer.



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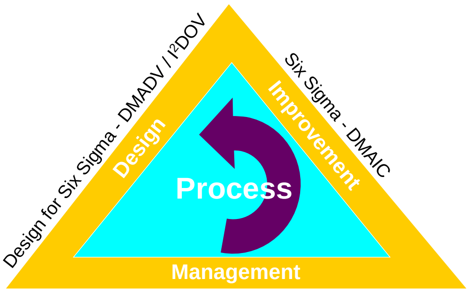
Six Sigma / Design for Six Sigma
Six Sigma / DFSS Overview II



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Six Sigma / Design for Six Sigma
Agenda

- About FEV Motorentechnik
- Informations and Knowledge
- Six Sigma / DFSS overview
- **Statistics**
  - Good to know
  - Risk - Distribution - Specification
  - Shift
  - Motivation
  - Quality level and defect rate
  - Examples

Six Sigma / Design for Six Sigma
What is Six Sigma? - Statistics

„Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write.“

H. G. Wells (1925)

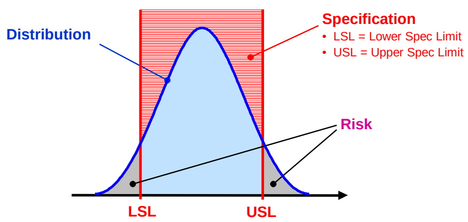
„We believe that statistical knowledge is to the information and technological age what fossil fuel was to the industrial age.“

M. Harry, R. Schroeder (2000)

Six Sigma / Design for Six Sigma
What is Six Sigma? - Risk

All defects represent risk – but not all risk is represented by defects!

Risk = quantil of the distribution outside the specification



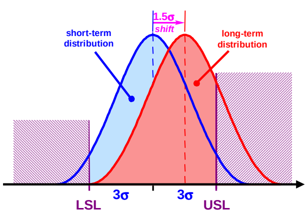
Six Sigma / Design for Six Sigma
Motivation for 6 Sigma

In a 3 Sigma company ±3σ (= 6σ) have to fall within your specification limits.

This means acceptance of 2,700 defects per million right from the start.

In time your processes will shift approximately by 1.5 σ (this number is found empirically).

This means a rate of 66,811 defects per million in the long-term perspective



Σ: This is nearly a 25-fold deterioration!

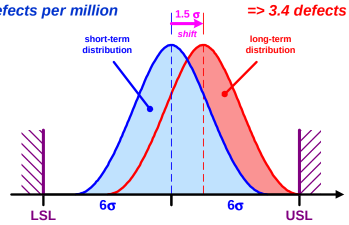
Six Sigma / Design for Six Sigma
Motivation for 6 Sigma

Let's look at a 6 Sigma company:

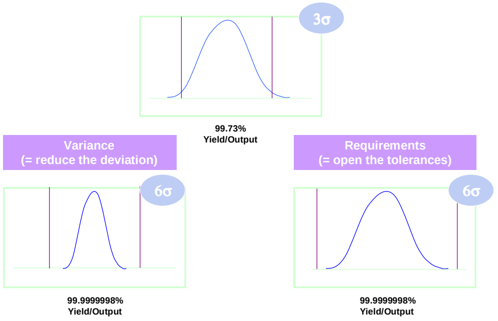
=> 0.002 defects per million

with the 1.5 Sigma shift:

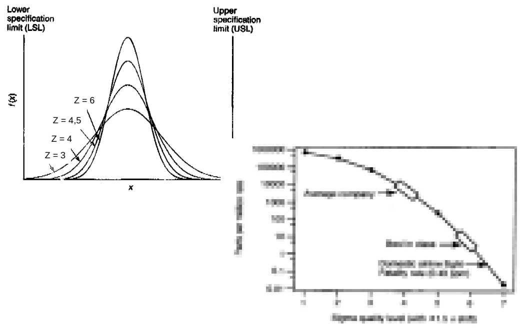
=> 3.4 defects per million



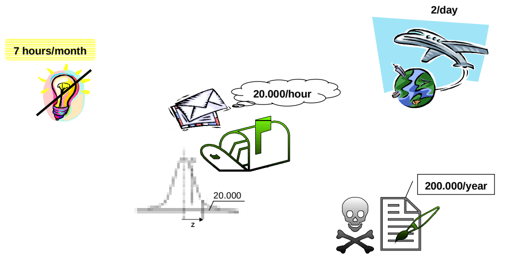
Six Sigma / Design for Six Sigma
How to reach Six Sigma?



Six Sigma / Design for Six Sigma
Quality Level and Defect Rate



Six Sigma / Design for Six Sigma
Examples for Z = 4 (= 99.379%)



Six Sigma / Design for Six Sigma
Agenda

- About FEV Motorentechnik
- Informations and Knowledge
- Six Sigma / DFSS overview
- Statistics
- **Six Sigma**
  - **Toolbox**
  - **Cost of Quality**
  - **Summary**

Six Sigma / Design for Six Sigma
Toolbox of Six Sigma I

Define
- Quality Function Deployment (QFD)
- Cause-and-Effect Diagram
- Failure Mode and Effects Analysis (FMEA)

Measure (review of the types of measurement systems and their key features)
- Process Flowchart/Process Mapping
- Basic Tools
  - Descriptive Statistics
  - Check Sheets
  - Control Chart
- Measurement System Analysis
  - Gage R&R
  - **D**efects **P**er **M**illion **O**pportunities (DPMO)
- Basic Control Charts
- Process Capability and Process Performance
  - Short Term versus Long Term
  - Standard Deviation
  - Process Capability (C_p, C_{pk})

Six Sigma / Design for Six Sigma
Toolbox of Six Sigma II

Analyse (statistical methods and tools to isolate key pieces of information)
- Tolerance stack up
- Scorecard (performance, process, reliability, ...)
- Transfer Function

Improve (focuses on discovering the key variables that cause the problem)
- Design of Experiments (DoE)
- Regression Analysis
- Distribution (LOG, Normal, Weibull, ...)
  - ANOVA
  - ...
- Kneading Scorecard

Control (ensures that the same problems don´t reoccur by continually monitoring)
- Ongoing inspection
- ...

Six Sigma / Design for Six Sigma
Cost of Quality

35

4managers Damit aus Strategien Handeln wird

Six Sigma senkt die Qualitätskosten

Zusammenhang zwischen Sigma-Niveau, Fehlerquote und Qualitätkosten

Sigma-Niveau	Fehler pro Million Möglichkeiten	Qualitätskosten	amount of improvement needed
2	308 537 (nicht wettbewerbsfähige Unternehmen)	Nicht anwendbar	
3	66 807	25 - 40 % des Umsatzes	
4	6210 (Durchschnitt)	15 - 25 % des Umsatzes	10x
5	233	5 - 15 % des Umsatzes	30x
6	3,4 (Weltklasse)	< 1 % des Umsatzes	70x

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Six Sigma / Design for Six Sigma
Summary

36

- **Six Sigma/DFSS means CTQ Management**
- **CTQ Management is the key to success** and means
  - **work in a systemic and systematically way**
  - **use scorecards**
  - **need teamwork**
    - teamwork = courage not to be the expert in all fields
  - **need communication**
    - communication = human work and not only computer work
  - Ability to **manage dyna**mics and complex**ity** (= **DYNAXITY**[1])
- **Successful projects means "Change Management"**

[1] Prof. Dr. H. Rieckmann, Klagenfurt (Austria)

Six Sigma / Design for Six Sigma
Agenda

38

- About FEV Motorentechnik
- Informations and Knowledge
- Six Sigma / DFSS overview
- Statistics
- Six Sigma
- **Examples (2)**
  - (1) Geometric Compression Ratio
  - (2) Making coffee with Six Sigma

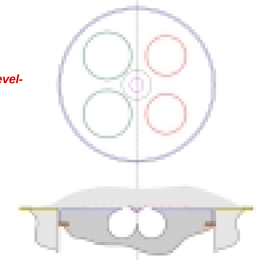
Six Sigma / Design for Six Sigma
Example 1: Geometric Compression Ratio

39

$$\varepsilon_{geometric} = 1 + \frac{V_{Stroke}}{V_{TDC}}$$ ← ***Top-Level-CTQ***

Lower-Level-CTQs

- Swept Volume (V_{Stroke})
  - bore diameter
  - stroke
- Compression Chamber Volume (V_{TDC})
  - cylinder head geometry
  - piston geometry
    - bowl & ringland volume
  - cylinder head gasket geometry
  - ...



Transfer Function

$$\varepsilon_{geom} = 1 + \frac{\frac{\pi d^2 s}{4}}{\frac{\pi d^2 h_0}{4} + \frac{\pi h_1 (d_{inlet}^2 + d_{exhaust}^2)}{2} - \pi h_{Injector} d_{Injector}^2 (\frac{19}{96}) + \frac{\pi h_{Ring} (d^2 - d_{Piston}^2)}{4} + \pi r_{Bowl}^3 (\pi + \frac{203}{60})}$$

Six Sigma / Design for Six Sigma
Example 2

40

„To make coffee with the Six Sigma Strategy“

Six Sigma / Design for Six Sigma
Project

41

The ideal and customer related way to make coffee.

For this we will develop a new coffee-machine.

Six Sigma / Design for Six Sigma
Customer requirements

Goal: Customer brainstorming for a good coffee process
Method: brainstorming / -writing

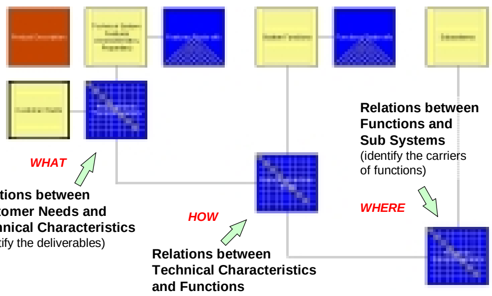
Coffee requirements:
- **good taste (right temperature, fresh, no bitter taste)**
- **medium coffee ("colour")**
- **ingredients (caffeine, ...)**
- **acceptable warm (after nearly 2 h)**

Six Sigma / Design for Six Sigma
System Analysis - Process: cooking coffee

- Temperature:
  - brew temperature of the water
  - drinking temperature
    - of fresh made coffee
    - class of isolation
    - ...
- Ingredients:
  - caffeine
  - coffee brand (is significant for the result but also it depends on the customers taste)
  - brew temperature
  - ...
- Other factors:
  - drinking temperature (warm coffee over a defined time - nearly 2 h)
  - ratio of coffee and brew water
  - plate warmer or something similar
  - ...

⇨ **make a QFD (Quality Function Deployment) for further details**

Six Sigma / Design for Six Sigma
Quality Function Deployment (QFD) => CTQ



Six Sigma / Design for Six Sigma
Quality Function Deployment (QFD)

WHATs (Customer requriements)

- **good taste**
  - right temperature
  - fresh
  - no bitter taste
- **medium coffee**
- **ingredients**

Six Sigma / Design for Six Sigma
QFD I

Prioritizitation of customer requirements in a scale of 1- 10

1.	**no bitter taste (good taste)**	**10**
2.	**right temperature (good taste)**	**8**
2.	**fresh (good taste)**	**8**
4.	**ingredients (caffeine)**	**7**
5.	**medium coffee (colour)**	**5**

Six Sigma / Design for Six Sigma
QFD II

WHATs (customer requriements)	**HOWs (system parameter)**
good taste	**brew temperature**
■ right temperature	**"Warmhaltedauer"**
■ fresh	**isolation/plate warmer**
■ no bitter taste	**drinking temperature**
medium coffee (colour)	**coffee brand**
ingredients (caffeine)	**ratio of coffee/brew water**

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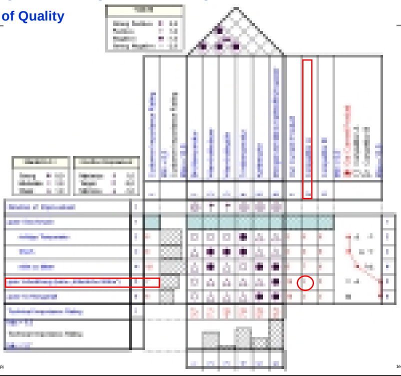
House of Quality



Six Sigma / Design for Six Sigma
Results of the QFD

Ranking of the system parameter from QFD:

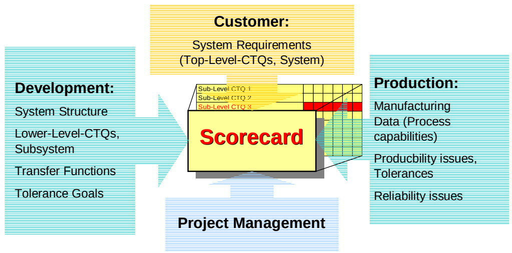
1. ratio of coffee/brew water 9,3
2. drinking temperature: 7,6
3. "Warmhaltedauer": 7,1
4. coffee brand: 5,8
5. class of isolation: 4,6
6. brew temperature: 3,7

The ranking shows the importance of the system parameter to reach the customer requirements.

Six Sigma / Design for Six Sigma
Next steps

- **FMEA**
- **Scorecard**
- **Design of Experiments (DOE)**
  - bitterness = f (ratio coffee/brew water, drinking temperature, "Warmhaltedauer")
  - bitterness will be measured on a scale from 1 - 10
  - target: 6

Six Sigma / Design for Six Sigma
CTQ => Scorecards



Six Sigma / Design for Six Sigma
Scorecard

Scorecard for: **Kaffeemaschine** (● System ○ Assembly ○ Part)

Design Responsible: **E. D. Uscho**

No.	Description	Nominal Value	Dim.	LSL	USL	MEAN	SDEV	COV	T		Z_{ST}	Z_B
Performance												
1	Bitterkeit									2		
2	Frische									2		
3	Temperatur									2		
4	Schwärzung									2		
5	Koffeingehalt									2		
6										2		
Process												

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Six Sigma / Design for Six Sigma
Example - Integration of development and manufacturing

#	CTQ Name	Dim.	Development LSL	Development USL	Manufacturing MEAN	Manufacturing SDEV	short/long term	Z_{Bench}	source of statistical data
1	stroke	mm	80,000	80,100	80,040	0,010	L	4,00 ☺	supplier SPC data
2	bore diameter	mm	90,000	90,050	90,020	0,008	L	2,49 ☹	supplier SPC data
3									

- **Forecast: LSL, USL from design department**
- **Real process capabilities (MEAN, SDEV) from manufacturing**
- **Z-Value shows how good the requirements can be realized**

55

Six Sigma / Design for Six Sigma
CTQ Management with Scorecards

All identified CTQs are listed in so-called Scorecards, no matter where they come from (QFD, Systems Engineering, FMEA, DOE, Brainstorming, Drawing Control, …).

Scorecard — Overview and Control

- Show all critical elements of a design and their performance
- The characteristics are measurable!
  - Part specifications (LSL, USL)
  - Manufacturing information (MEAN, SDEV)
- Have the same Benchmark for all CTQs („six sigma")
- Evaluating how well the design is supported by manufacturing and production processes

Σ: Only what you can measure can be controlled!

Scorecard — Project Management

- System structure information
- Document and assess quantitatively the project progress
- Store the learning process
- Interrelationship information (Transfer Function) and design optimization
- Enabling communication

Σ: You see the total picture in one spreadsheet!

57

Six Sigma / Design for Six Sigma
Transfer Function

The quantitative connection or interaction between CTQs called Transfer Function (TF).

How to discover the TF?

- **analytical** (when physical or geometrical connections known: geometric compression ratio)
- **with "planned" experiments (DOE)**
  - **empirical experiments**
  - **through computer simulations (Monte-Carlo-Analysis)**

58

Six Sigma / Design for Six Sigma
Design of Experiments (DOE)

„designed experiment" with 3 factors	Specification limits (min, max):
ratio (coffee/water)	1:4 (0,25) - 1:1 (1)
drinking temperature	25 °C - 45 °C
"Warmhaltedauer"	5 min - 120 min

60

Six Sigma / Design for Six Sigma
Regression

bitterness = **b_0** *(constant)*
+ (b_1 • ratio)
+ (b_2 • drink temperature) } main effects
+ (b_3 • "Warmhaltedauer")
interrelated effects {
+ (b_4 • ratio • drinking temperature)
+ (b_5 • ratio • "Warmhaltedauer")
+ (b_6 • drinking temperature • "Warmhaltedauer")
+ (b_7 • ratio • drinking temperature • "Warmhaltedauer")
}
+ failure

61

Six Sigma / Design for Six Sigma
DOE results and interpretation

Estimated Effects and Coefficients for Bitterke (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		5,3750	0,3375	15,93	0,000
Block 1		0,2550	0,3697	0,69	0,505
2		-0,1050	0,3697	-0,28	0,782
3		-0,0050	0,3697	-0,01	0,989
Mengenve	6,7500	3,3750	0,3375	10,00	0,000
Trinktem	-1,2500	-0,6250	0,3375	-1,85	0,091
Warmhalt	0,6000	0,3000	0,3375	0,89	0,393
Mengenve*Trinktem*Warmhalt	0,7000	0,3500	0,3375	1,04	0,322
Ct Pt		-0,7500	0,4357	-1,72	0,113

Σ: only two parameters are statistically significant **p-Wert $\overset{!}{<}$ 0,05**

62

Six Sigma / Design for Six Sigma
DOE - results of regression calculation

Estimated Coefficients for Bitterke using data in uncoded units

Term	Coef
Constant	1,58036
Block 1	0,252139
2	-0,108997
3	-0,004269
Mengenve	9,02485
Trinktem	-0,0620563
Warmhalt	0,0054659
Mengenve*Trinktem*Warmhalt	-0,000011358
Ct Pt	-0,750000

Transfer Function:

„Bitterkeit" = 1,580 + (9,025 • „Mengenverhältnis")

Six Sigma / Design for Six Sigma
DOE - Results (I)

Regression

„Bitterkeit“ = 1,580 + (9,025 • „Mengenverhältnis“)

with **”Bitterkeit” = 6**

=> ”Mengenverhältnis” = 0,49

Six Sigma / Design for Six Sigma
Optimisation

Regression:

„Bitterkeit“ = 1,580 + (9,025 • „Mengenverhältnis“)

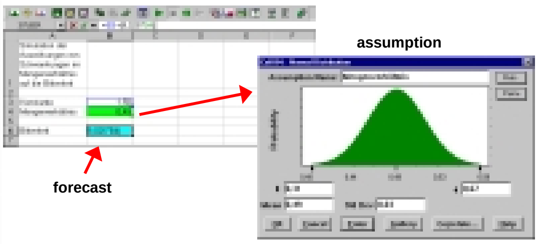
use a distribution instead of a nominal value and make a

=> Monte-Carlo-Analysis

then you can answer the following questions:

- **Which is the exact dose of coffee and water?**
- **The variation of “Bitterkeit” is like ...?**

Six Sigma / Design for Six Sigma
Monte-Carlo-Analysis



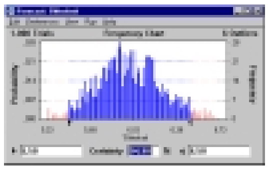
Six Sigma / Design for Six Sigma
Monte-Carlo-Analysis (I)

Crystal Ball Report
Simulation started on 23.8.00 at 12:58:13
Simulation stopped on 23.8.00 at 12:58:16

Forecast: Bitterkeit

Summary:
Display Range is from 5,33 to 6,71 °Bitterkeit
Entire Range is from 4,93 to 6,86 °Bitterkeit
After 1.000 Trials, the Std. Error of the Mean is 0,01

Statistics:	Value
Trials	1000
Mean	6,01
Median	6,01
Mode	---
Standard Deviation	0,27
Variance	0,07
Skewness	-0,06
Kurtosis	3,21
Coeff. of Variability	0,04
Range Minimum	4,93
Range Maximum	6,86
Range Width	1,93
Mean Std. Error	0,01



- **Mean: 6,01**
- **StdDev: 0,27**
- **Max: 6,86**
- **Min: 4,93**

Six Sigma / Design for Six Sigma
Monte-Carlo-Analysis (II)

94,9 % of all bitterness values are between the interval of [5,5; 6,5]
=> ca. 5 % are outside the interval or ...

... every 20th person will be bitter disappointed from this coffee!!!

Six Sigma / Design for Six Sigma

The End!

Any questions?

Thank you for your attention!

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Appendix - „Six Sigma companies“

- Allied Signal
- Siemens
- Mitsubishi Semiconductor GmbH
- Micro Compact Car France S.A.S.
- Whirlpool

General Electric Company, Ford Motor Company, VOLVO, ZEISS, Ford, GM, TOSHIBA, BOSCH, Opel, Shell, ABB, Coca-Cola, SONY, bp, DAIMLERCHRYSLER, ERICSSON, MOTOROLA

Six Sigma / Design for Six Sigma

Diplomarbeiten / Studienarbeiten - Schlagworte

- **Six Sigma / DFSS als Geschäftsprozessmanagement in der F&E**
- **Six Sigma / DFSS — Einsatz in KMU - Sinn oder Unsinn?**

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Appendix A - Abbreviations

ANOVA	**an**alysis **o**f **va**riance	
C_p	capability index	
C_{pk}	measures long-term performance capability	
DFMEA	design FMEA	
DFSS	**d**esign **f**or **s**ix **s**igma	
DMAIC	**d**efine, **m**easure, **a**nalyse, **i**mprove, **c**ontrol	
DMADV	**d**efine, **m**easure, **a**nalyse, **d**esign, **v**alidate	
DOE	**d**esign **o**f **e**xperiments	Konstruktions-FMEA
FMEA	**f**ailure **m**ode and **e**ffects **a**nalysis	Fehler-Möglichkeiten und Ausfall-Analyse
Gage R&R	**r**epeatability and **r**eproducibility	Vergleichs- und Wiederholpräzision
IDOV	**i**dentify, **d**evelop, **o**ptimize, **v**alidate	
I^2DOV	**i**nvent/**i**nnovate, **d**evelop, **o**ptimize, **v**erify	
LSL	**l**ower **s**pecification **l**imit	untere Spezifikationsgrenze
MSA	**m**easurement **s**ystem **a**nalysis	Meßsystemanalyse
PFMEA	process FMEA	Prozess-FMEA
QFD	**q**uality **f**unction **d**eployment	
RDMAICSI	(s. page 16)	
RPN	**r**isk **p**riority **n**umber	Risikoprioritätszahl
USL	**u**pper **s**pecification **l**imit	obere Spezifikationsgrenze
VOC	**v**oice **o**f the **c**ustomer	Stimme des Kunden

Six Sigma / Design for Six Sigma

Appendix B - Literature

- **Design for Six Sigma**; C. M. Creveling, J. L. Slutsky, D. Antis Jr.
- **The Six Sigma Way**; P. S. Pande, R. P. Neuman, R. R. Cavanagh
- **Managing Six Sigma**; Forrest W. Breyfoggle III
- **Implementing Six Sigma – 2nd Edition**; Forrest W. Breyfogle III
- **Six Sigma-The Breakthrough Management Strategy**; M. Harry, R. Schroeder
- **Design for Six Sigma**; K. Yang, B. El-Haik
- **Mit Six Sigma zu Business Excellence**; R. Rehbehn, Z. B. Yurdakul
- **Managen und Führen am Rande des 3. Jahrtausend**; H. Rieckmann; 2000²

Normen

- **DIN EN ISO 9001:2000**
- **QS 9000**
- **ISO/TS 16949:2002**
- **VDA 4.2 / DIN 25448**

Six Sigma / Design for Six Sigma

Appendix C - Links

- www.dgq.de
- www.asq.com
- www.6-sigma.com
- www.aircad.com
- www.rathstrong.com
- www.sixsigmaforum.com
- www.4managers.de
- www.amazon.de
- www.rieckmann.at
- ....