Teaching Statistics In Quality Science Using The R-Package qualityTools

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Outline

A (Very) Short Introduction To Quality Sciences

quality

degree to which a set of inherent characteristics fulfils requirements

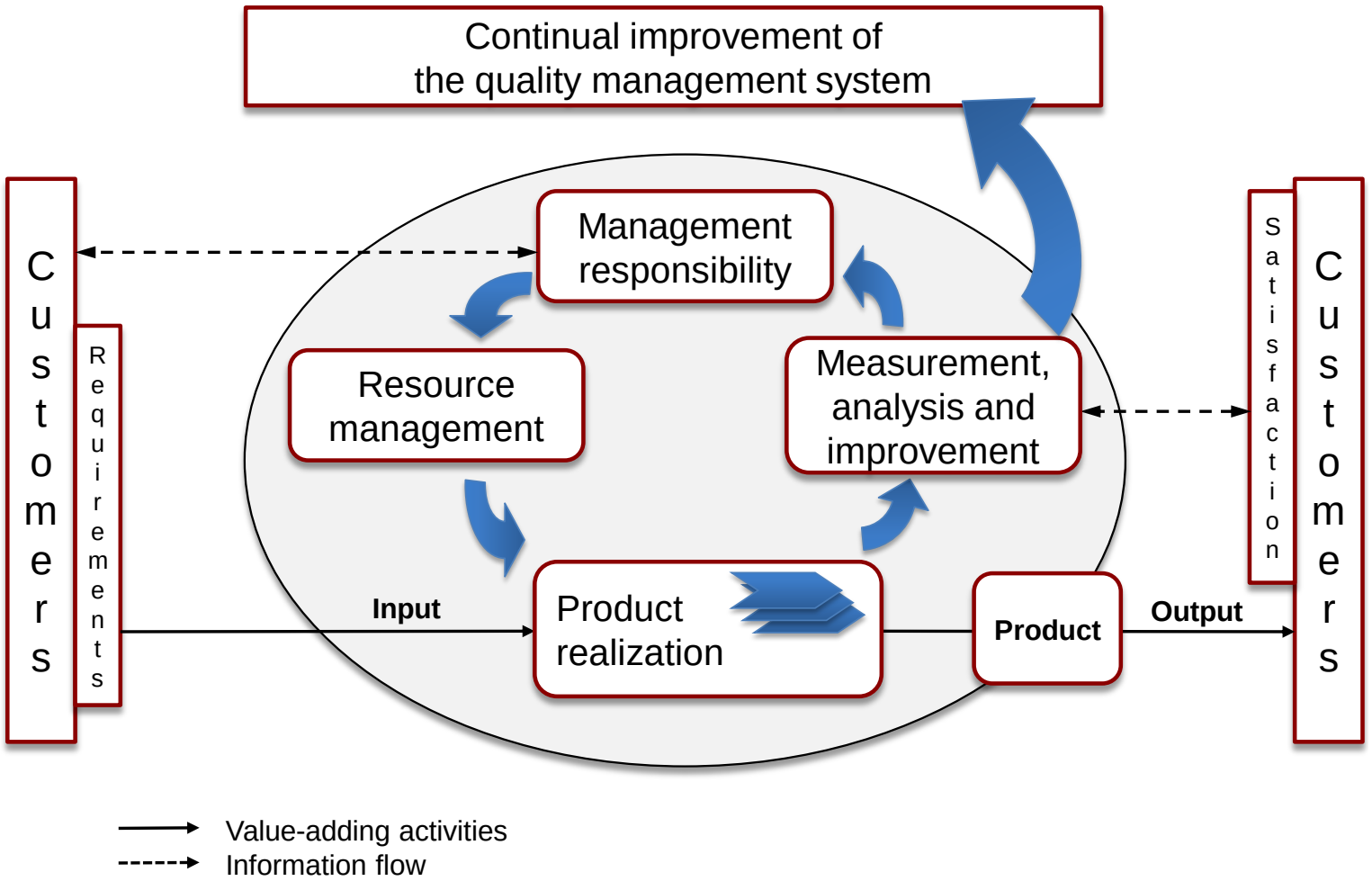
management

coordinated activities to direct and control

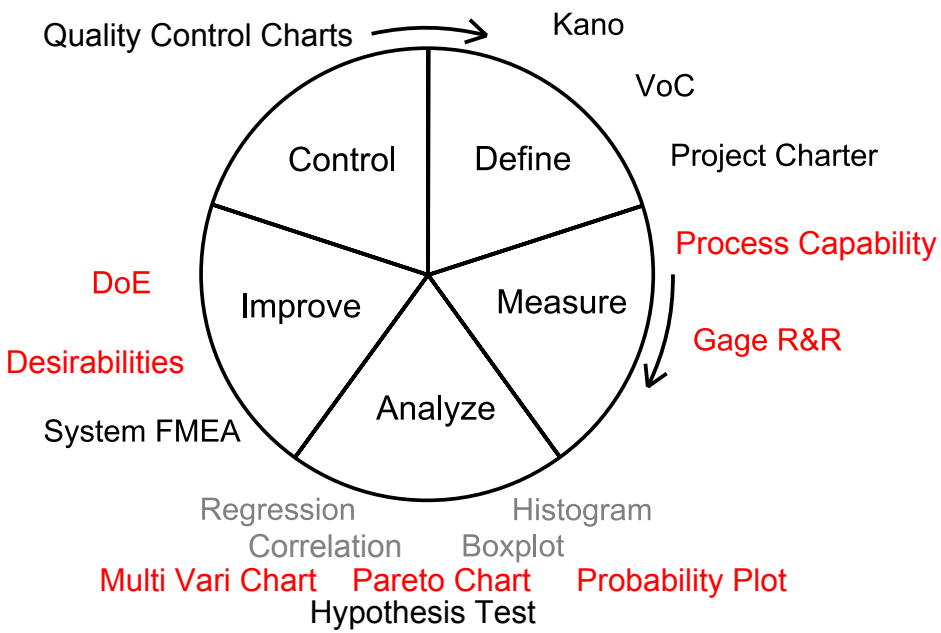
quality management system

to direct and control an organization with regard to quality

Process-based Quality Management System For Continual Improvement (EN ISO 9001:2008)



The Role Of Statistics In The Field Of Quality



Problem 1: engineers dislike statistics or engineers fail to see applications

Solution: exchange statistics with data analysis and problem solving

Problem 2: statistics comprise to much calculations

Solution: Use R with all its favorable aspects

- Use R to keep the focus on methods rather than calculation
- Use R as a software that is available on all platforms
- Use R to visualize important key concepts by simulation

Scope Of The qualityTools Package

Accessibility

give access to the most relevant subset of methods frequently used in industry

DMAIC Driven Toolbox

provide a complete toolbox for the statistical part of the Six Sigma Methodology

Ease of Use

support an intuitive approach to these methods i.e. consequent implementation of generic methods (show, print, plot, summary, as.data.frame, nrow, ...)

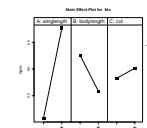
S4 OOP

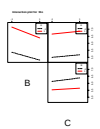
Accessor and Replacement functions as well as Validity functions i.e. check the validity of instances of a class

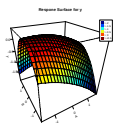
Powerful Visualization

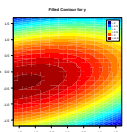
provide powerful visualization that are easy to accomplish

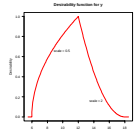
Visual Representation Of The qualityTools Package



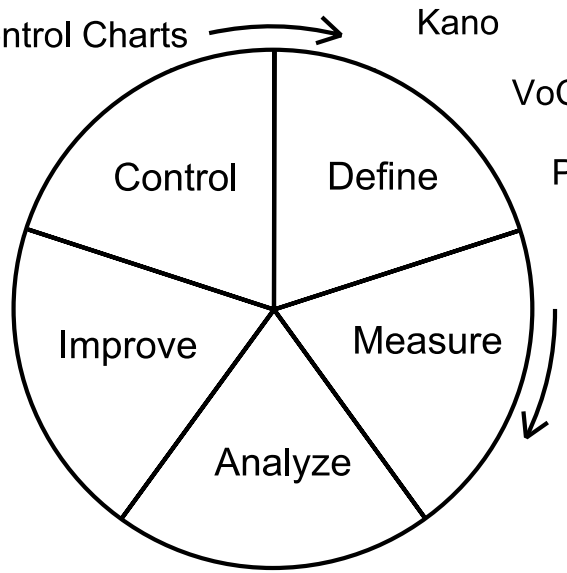


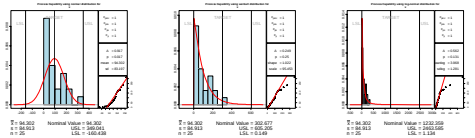


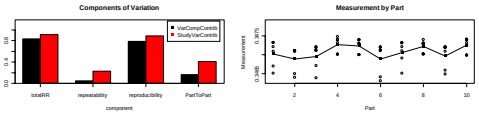


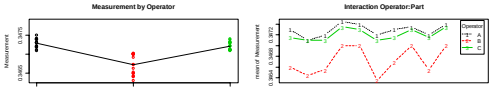


```
composite (overall) desirability: 0.58

        A     B      C
coded 0.0 0.136 -0.816
real  1.2 51.361  1.892

                 y1       y2      y3     y4
Responses   130.660 1299.669 456.937 67.980
Desirabilities 0.213    0.999   0.569  0.936
```

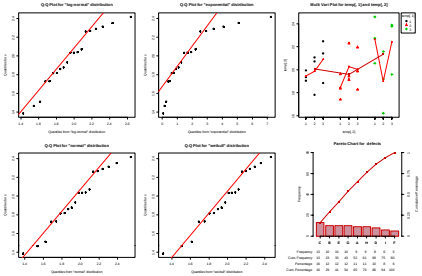


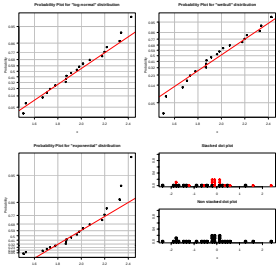




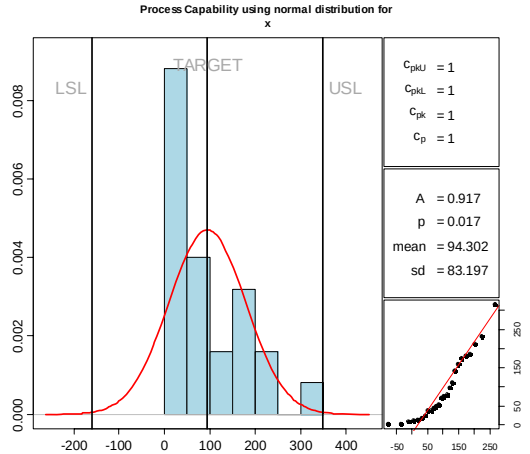


```
Gage R&R
                VarComp VarCompContrib     Stdev StudyVar StudyVarContrib
totalRR        1.06e-07          0.8333 3.25e-04 0.001952          0.913
 repeatability 6.50e-09          0.0512 8.06e-05 0.000484          0.226
 reproducibility 9.93e-08        0.7822 3.15e-04 0.001891          0.884
   Operator    9.37e-08          0.7375 3.06e-04 0.001836          0.859
   Operator:Part 5.67e-09        0.0446 7.53e-05 0.000452          0.211
Part to Part   2.12e-08          0.1667 1.45e-04 0.000873          0.408
totalVar       1.27e-07          1.0000 3.56e-04 0.002138          1.000
```

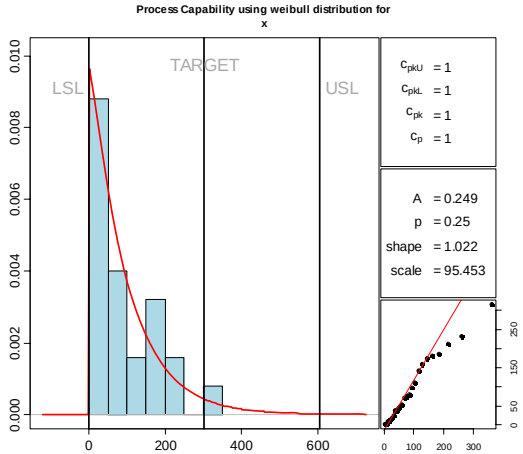




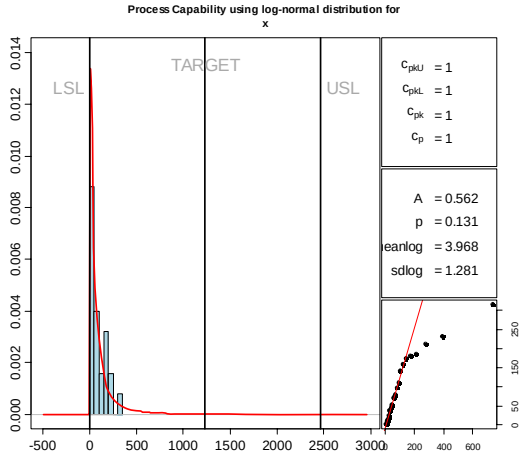
Visual Representation Of The qualityTools Package



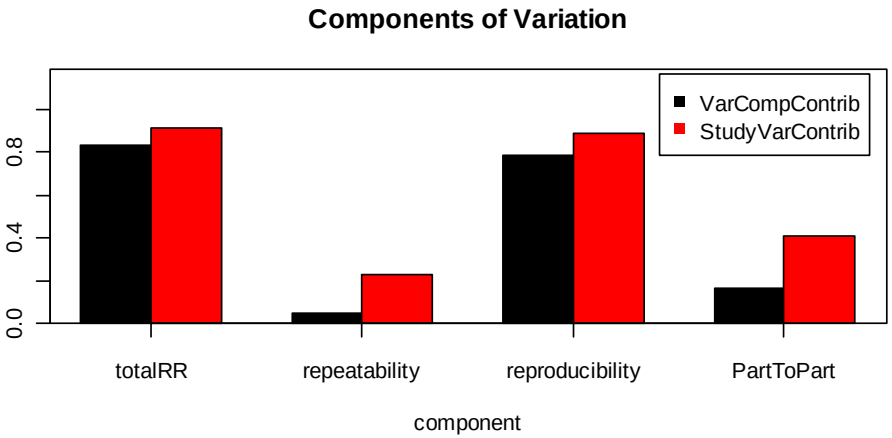
$\bar{x}$ = 94.302 Nominal Value = 94.302
s = 84.913 USL = 349.041
n = 25 LSL = -160.438

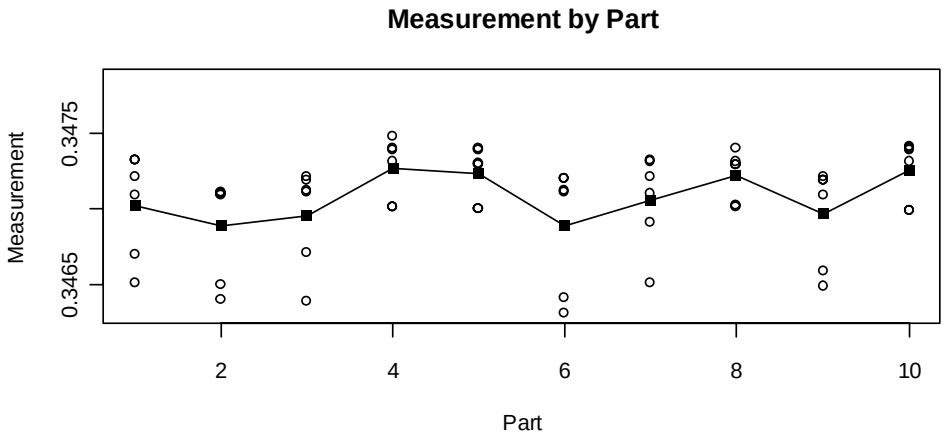


$\bar{x}$ = 94.302 Nominal Value = 302.677
s = 84.913 USL = 605.205
n = 25 LSL = 0.149



$\bar{x}$ = 94.302 Nominal Value = 1232.359
s = 84.913 USL = 2463.585
n = 25 LSL = 1.134





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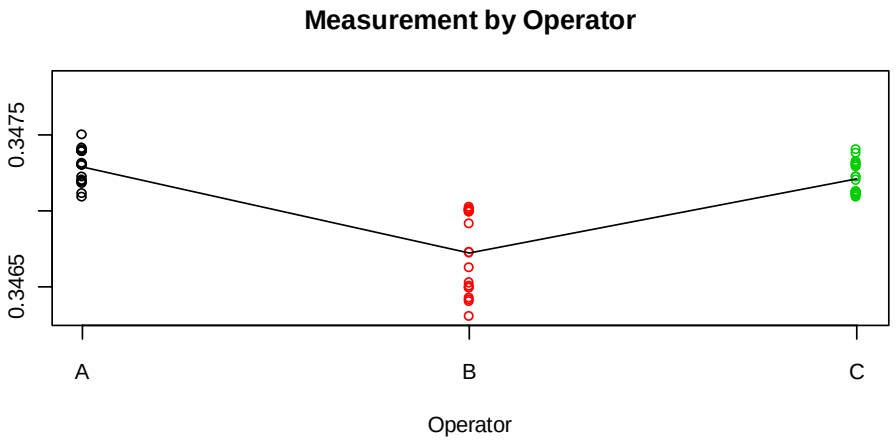

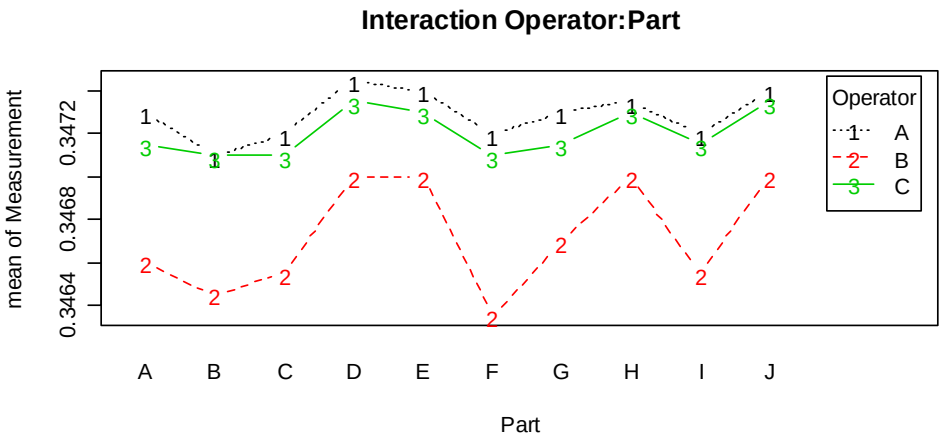

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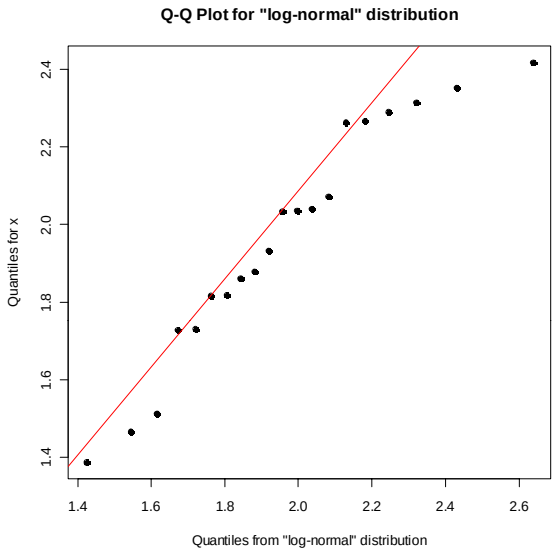

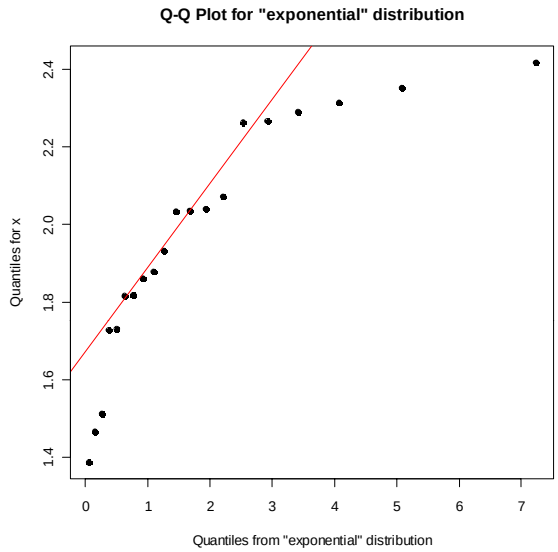

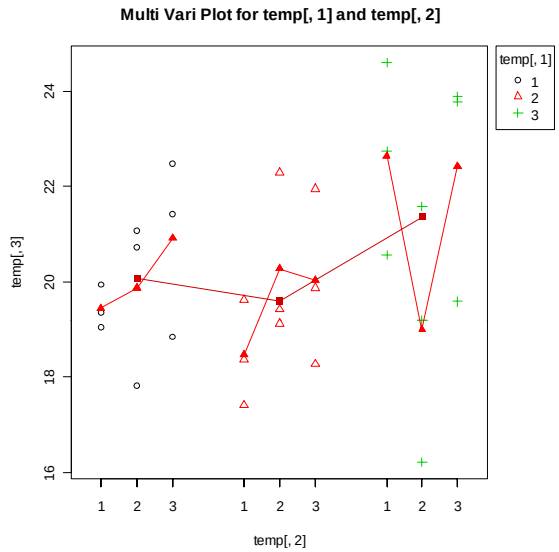

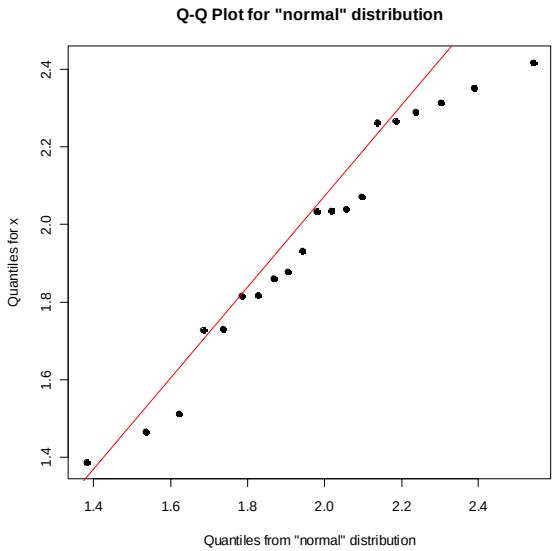

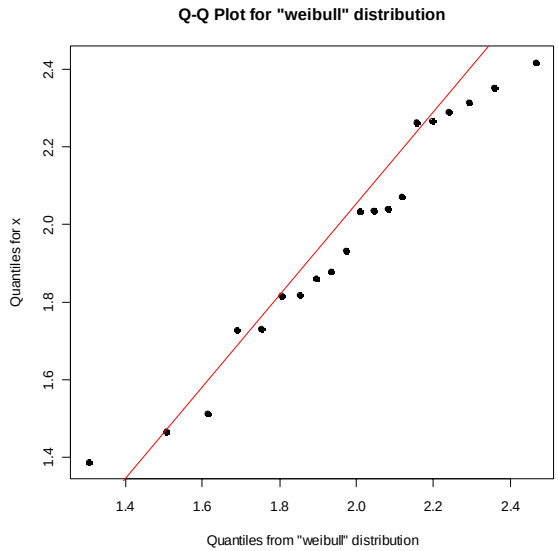

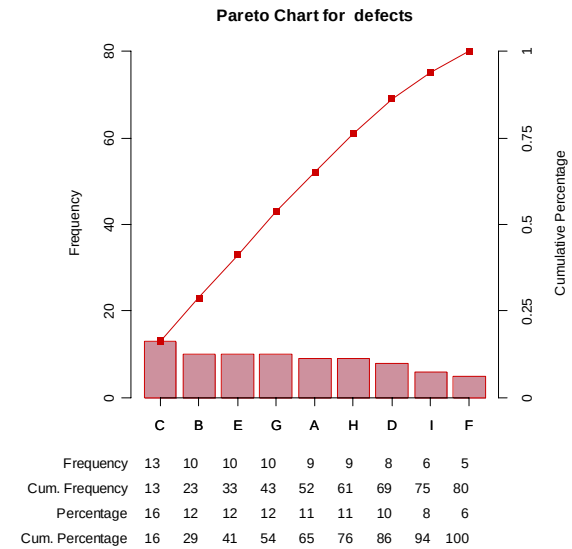

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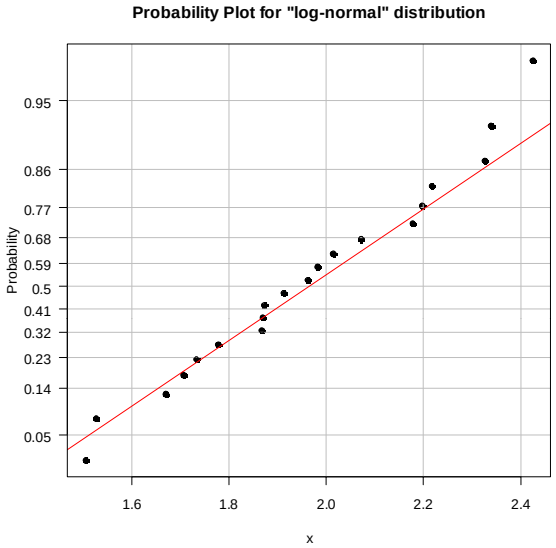

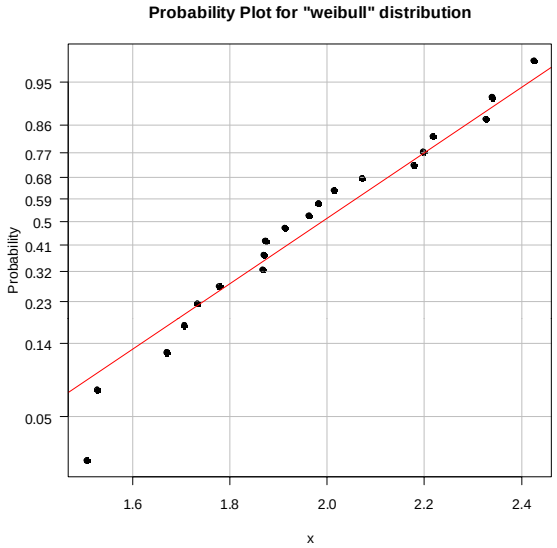

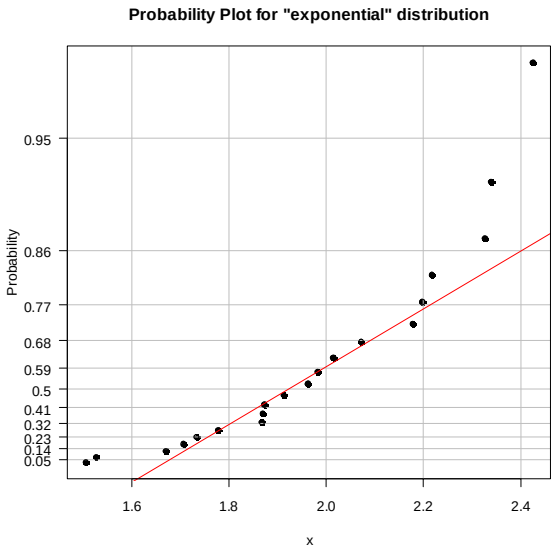

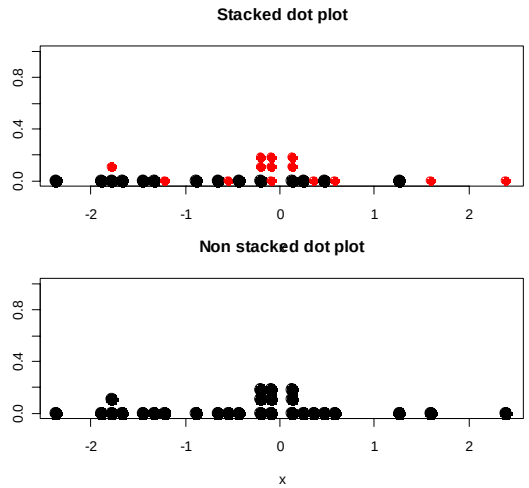

Operator

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Gage R&R

                        VarCom
totalRR                 1.06e-0
 repeatability          6.50e-0
 reproducibility        9.93e-0
   Operator             9.37e-0
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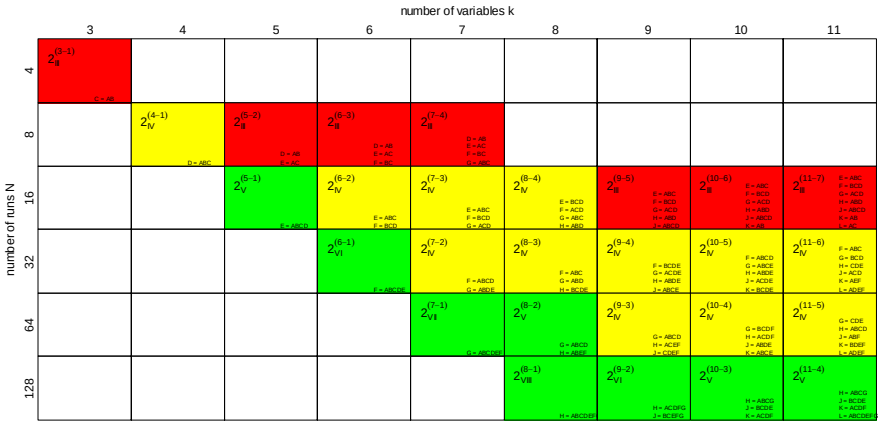

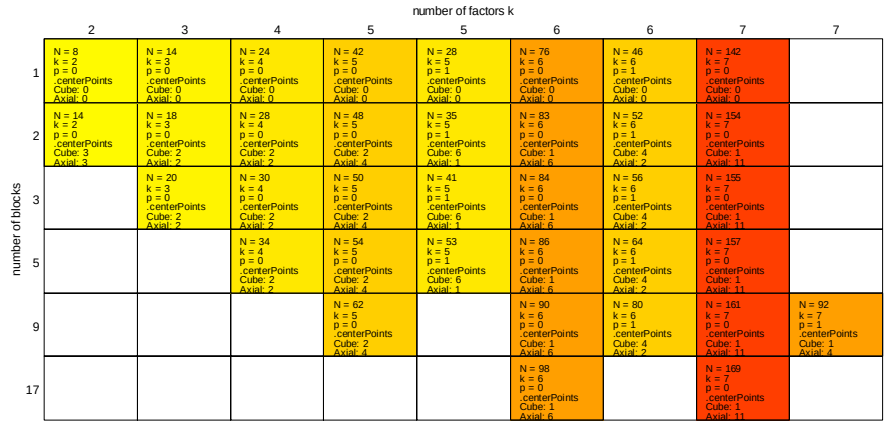

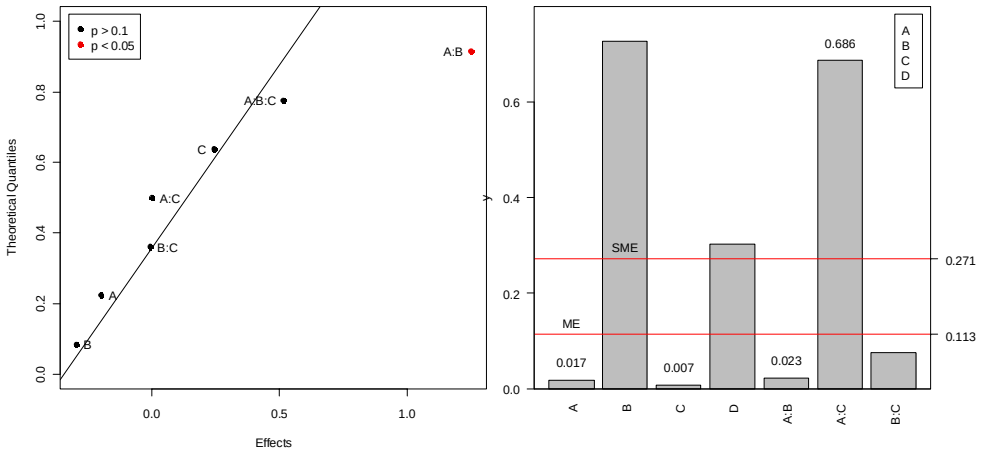

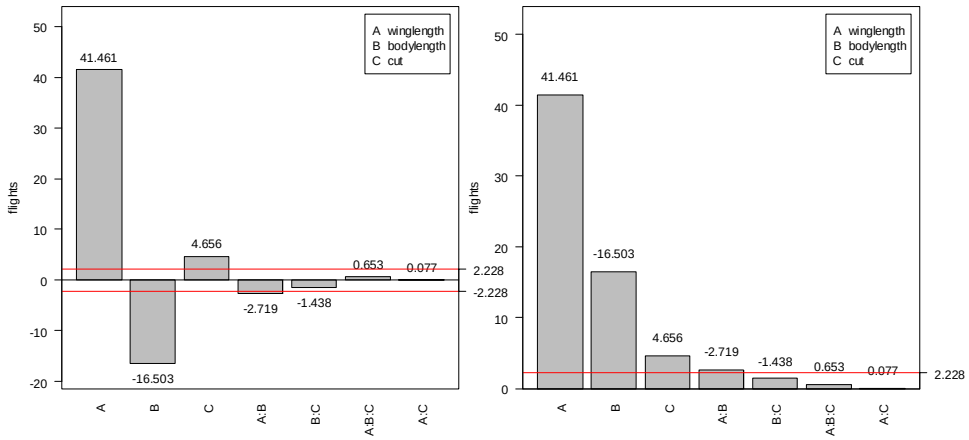

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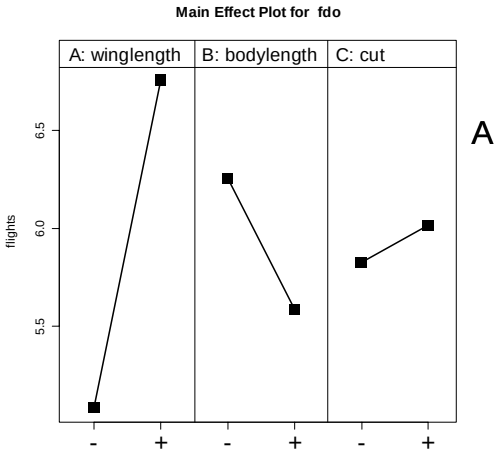

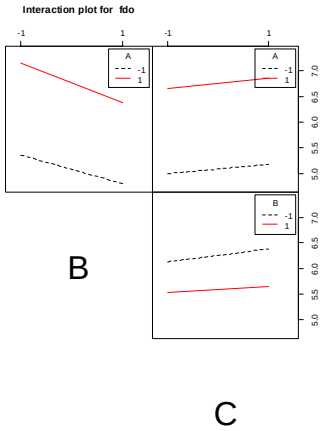

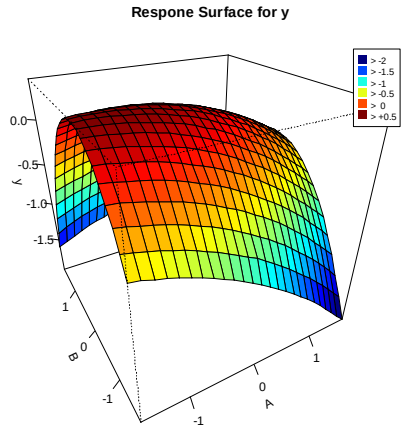

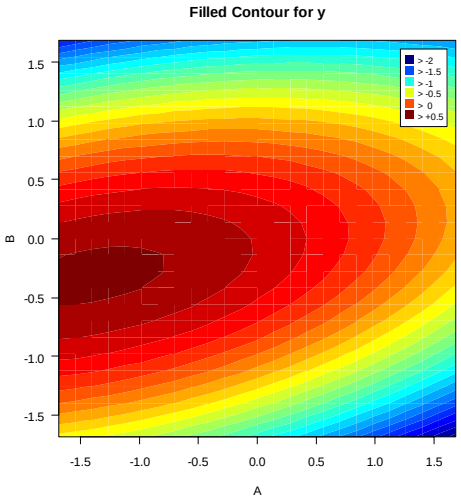

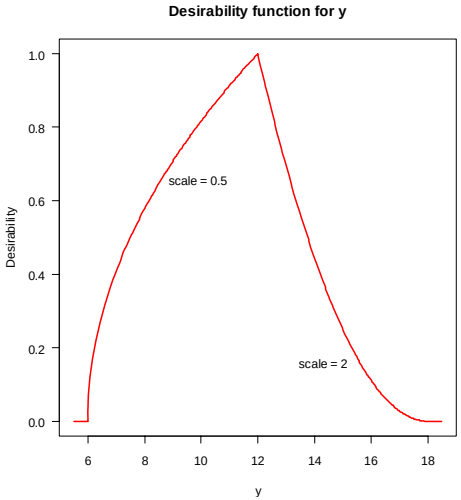


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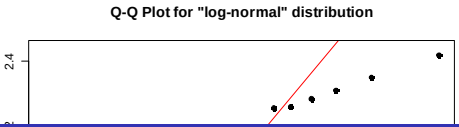
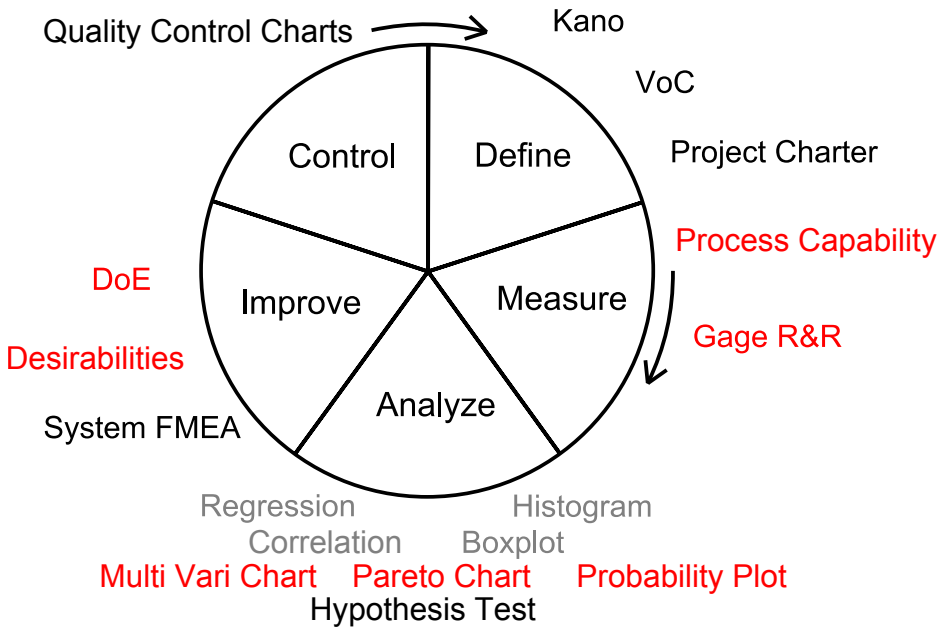


Contents And Teaching Methodology Of The R-Course



Applied Statistics

- Descriptive Statistics
- Inductive Statistics
- Bivariate Methods

Quality Tools (6σ)

- Process Capability
- Gage R&R
- Design of Experiments

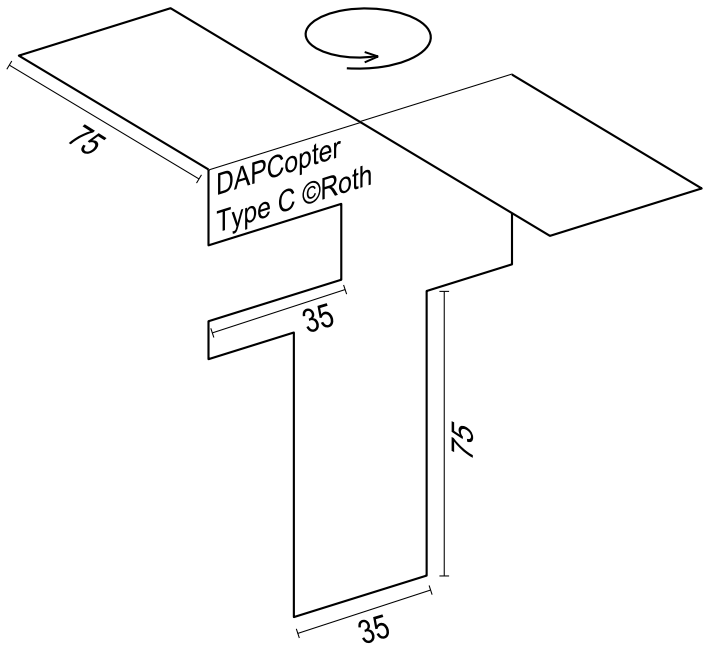
Teaching Methodology

- Lectures and Excercise Sheets
- Improvement Project
- Lecture Notes, Slides and Forum

The (Revised) Helicopter Improvement Project

Problem Statement

Insufficient and unstable helicopter flight times. Come up with a better design. Start by working out a Project Charter (take into account costs) and standardizing the release process of the helicopter.



Project Charter

Define the problem, scope, objective and participants of the project

Process Capability

Reduce the variation of flight times by standardizing the release-process of the helicopter

Design of Experiments

Devise and run a sequential factorial design. Gain knowledge from a model.

Path of steepest ascent

Build and test further prototypes

ProjectCharter - Kick off the improvement project

PROJEKTSTECKBRIEF

Projekt
VERLÄNGERUNG DER FLUGZEIT DES DAP-COPTER

Leitung	**Organisationseinheit**
– Student MB (Bsc)	TU Berlin Fachbereich Qualitätswissenschaft
Teammitglieder – Test-Ingenieur - Datenerfasser - Kosteningenieur – Fertigungsingenieur	**Champion** **Black Belt**

Problemdefinition
Die Flugzeit des DAP-Copters ist zunehmend weniger konkurrenzfähig
Preis des DAP-Copters wird bei annähernd gleicher Leistung von Konkurrenzprodukten unterboten
Test und Optimierung der DAP Copters anhand des bestehenden Designs
Entwurf eines verbesserten Designs auf Grundlage bereits bestehender Fertigungsverfahren

Problembeschreibung aus Kundensicht
Verlängerung der Flugzeit des DAP-Copters gegenüber Konkurrenzprodukten
Erhalten des grundlegenden Designs und der Kompatibilität zu bereits vorhanden Abflugeinrichtungen und Messaufbauten
Deutliche Steigerung des Preis/Leistung Verhältnis

Wirkungsbereich	**Projektbegründung**
Durchführung der Messungen an ausgewählten Stellen in der TU-Berlin	Hohe Priorität um die führende Position in der Copter-Herstellung wieder zu erlangen
Lieferanten Paper Solutions Office Needs Inc. Swotch Timekeeping Wäschebedarf Berlin	**Kunden** Deutscher Sportcopter Verband DRK Luftrettung Macks Planck Institut für Strömungsphysik Aachen
Erwarteter Nutzen Flugzeit: Steigerung auf über 1s/m Qualität: First-Pass-Yield von 98% Kosten: Erhalten der Produktionskosten Gewinnspanne: Steigerung um 10% Forschung: Übertragen der Ergebnisse auf andere Projekte	**Risiken** Neuer Messstand noch nicht geprüft Design könnte bald durch neuartige Konkurrenzprodukte übertroffen werden Sättigung des Marktes absehbar
Personelle Resourcen 1 leitender Ingenieur (100% Arbeitszeit) 4 Ingenieure MB / PI (15% Arbeitszeit)	**Finanzielle Resourcen** 500.000€ Gesamtbudget

Vorgehensweise
1. Meilenstein: Erhebung der Messdaten für das aktuelle Modell des DAP-Copters
2. Meilenstein: Optimierung der Messung und des Messaufbaus
3. Meilenstein: Durchführung eines 2^3-vollfaktoriellen Versuchsplans
4. Meilenstein: Auswerten der Daten, Entwurf und Test von optimierten DAP-Copter Modellen
5. Meilenstein: Bewertung der Daten der optimierten Modelle
6. Meilenstein: Festlegung des neuen optimierten Designs und Übergabe an Produktion

Datum: 17.06.2009	**Unterschrift**

AUFNAHMEBOGEN
ZUR MESSYSTEM- UND MESSMITTELFÄHIGKEITSUNTERSUCHUNG
(Messungen zur Berechnung des Cp - Wertes)

Projektname/ Projektnummer: Projekt DAP - Gruppe

Teilebezeichnung:	DAP-Copter	**Toleranzbreite der Messung:**	0,6 Sekunden
Teilenummer:	0,0,0	**Messmittel:**	Stoppuhr
Merkmal:	Referenzmodell	**Messgenauigkeit:**	0,01sec
Messort:	TU-Berlin, Gebäude MA, Treppe	**Prüfdatum:**	22.06.2009
Messhöhe:	5,3m	**Prüfzeit:**	11:05Uhr

Zuständigkeiten:
Abwurf:
Stoppuhr:
Aufnahme der Messwerte:
Auswertung:

Ergebnisse der Messungen / Messwerte:

1. Messung:	3,78s	11. Messung:	3,92s
2. Messung:	3,92s	12. Messung:	3,85s
3. Messung:	3,66s	13. Messung:	3,93s
4. Messung:	3,75s	14. Messung:	3,80s
5. Messung:	3,82s	15. Messung:	3,91s
6. Messung:	3,90s	16. Messung:	3,82s
7. Messung:	3,82s	17. Messung:	3,87s
8. Messung:	3,90s	18. Messung:	3,82s
9. Messung:	3,82s	19. Messung:	3,90s
10. Messung:	3,85s	20. Messung:	3,87s

Berechnung und Auswertung:

MITTELWERT:	3,846	
STANDARDABWEICHUNG:	0,067	
Cp – WERT:	1,489	Mindestanforderung Cp = 1,33

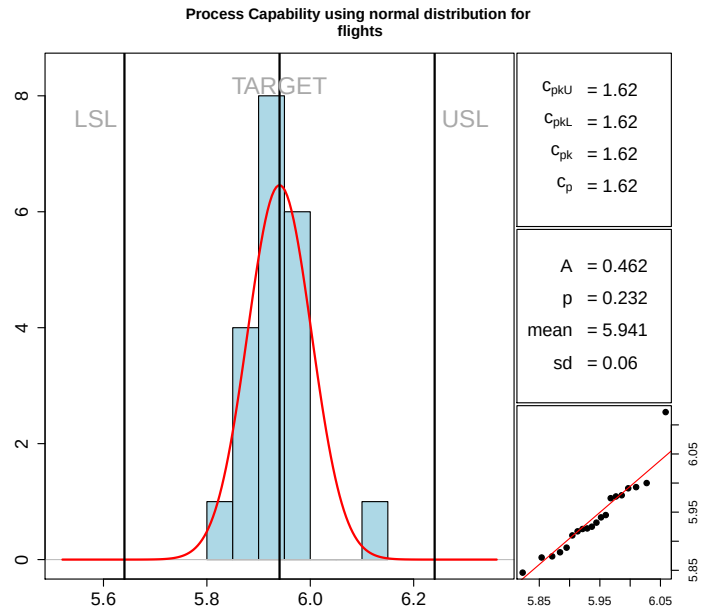
Bemerkungen / Sonstige Auffälligkeiten:
Alle Flüge stabil, gleichmäßiger Einpendelvorgang

Ergebnis:
Messeinrichtung geeignet: ☒ **JA** ☐ **NEIN**

Prüfung:
Abteilung: Kosteningenieur
Datum: 22.06.2009 **verantwortlicher Prüfer:**

Standardization - Improving The Process Capability Ratio

```
> pcr(flights, lsl=mean(flights)-0.3, usl=mean(flights)+0.3)

        Anderson Darling Test for normal distribution

data:  x[, 1]
A = 0.4616, mean=5.941, sd=0.062, p-value=0.2317
alternative hypothesis: true distribution is not equal to normal
```



$\bar{x}$ = 5.941
s = 0.062
n = 20

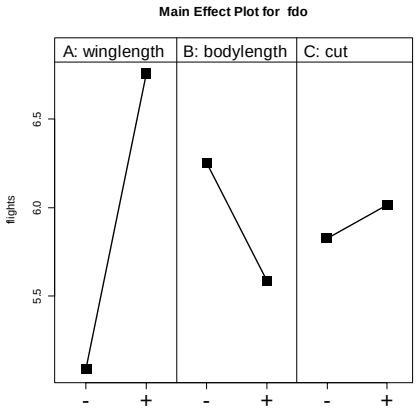
Nominal Value = 5.941
USL = 6.241
LSL = 5.641

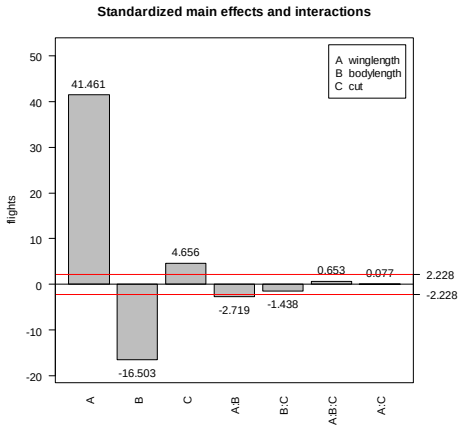
Design Of Experiments - Size And Direction Of Effects

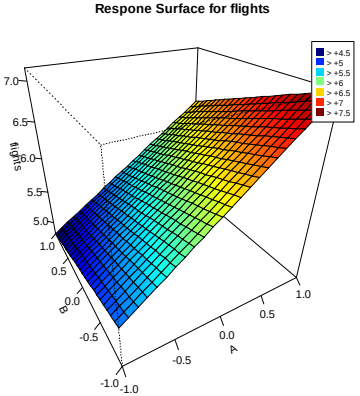
```
> fdo = facDesign(k=3, centerCube = 2, replicates = 2) #factorial design
> names(fdo) = c("winglength", "bodylength", "cut")    #optional
> lows(fdo) = c(60, 50, 0)                             #optional
> highs(fdo) = c(90, 100, 60)                          #optional
> units(fdo) = c("mm", "mm", "mm")                     #optional
> response(fdo)=flights          #generic setter for all designs
> summary(fdo)

Information about the factors:
               A           B        C
low           60          50        0
high          90         100       60
name  winglength bodylength      cut
unit          mm          mm       mm
type     numeric     numeric numeric
-----------
   StandOrd RunOrder Block  A  B  C flights
7         7        1     1 -1  1  1   4.882
1         1        2     1 -1 -1 -1   5.155
8         8        3     1  1  1  1   6.372
...
17       17       17     1  0  0  0   5.948
18       18       18     1  0  0  0   5.826
```

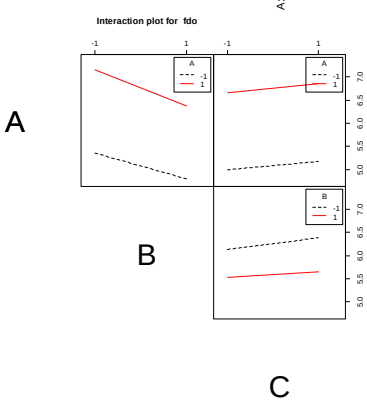
Design Of Experiments - Visualization

```
> effectPlot(fdo)
> interactionPlot(fdo)
> paretoPlot(fdo)
> wirePlot(flights, A, B, data=fdo)
```









Steepest Ascent - Improving The Design

AUFNAHMEBOGEN
Messungen für optimierte Modelle entlang Steepest Ascent

Projektname/ Projektnummer: Projekt DAP -

Teilebezeichnung:	DAP-Copter	**Messmittel:**	Stoppuhr
Teilenummer:	Siehe Versuchsplan	**Messgenauigkeit:**	0,01s
Merkmal:	Siehe Versuchsplan	**Prüfdatum:**	27.06.2009
Messort:	TU-Berlin, Gebäude MA, Treppe	**Prüfzeit:**	15:00Uhr
Messhöhe:	5,3m		

Zuständigkeiten:

Abwurf:
Stoppuhr:
Aufnahme der Messwerte:
Auswertung:

Faktoren

	Startwert	Schrittweite +1 Steepest Ascent
Körperbreite	35 mm	0 mm
Flügellänge	75 mm	+5 mm
Körperlänge	75 mm	-1.64 mm

Ergebnisse der Messungen / Messwerte:

Schritt-weite	Körper-breite	Flügel-länge	Körper-länge	Messung 1	Messung 2	Messung 3	Mittelwert
+1	35mm	80mm	73.36mm	4.81s	4.13s	4.09s	4.34s
+2	35mm	85mm	71.72mm	5.16s	5.28s	5.06s	5.17s
+3	35mm	90mm	70.08mm	5.25s	5.28s	5.37s	5.30s
+4	35mm	95mm	68.44mm	5.63s	5.50s	5.56s	5.56s
+5	35mm	100mm	66.80mm	5.85s	6.32s	6.09s	6.09s
+6	35mm	105mm	65.16mm	6.18s	6.22s	6.22s	6.21s
+7	35mm	110mm	63.52mm	6.09s	4.09s	4.50s	4.89s
+8	35mm	115mm	61.88mm	4.68s	4.82s	5.28s	4.93s

Bemerkungen / Sonstige Auffälligkeiten:

Ab Schrittweite 7 stark unregelmäßiger Flug
Funktion des DAP-Copter bei höheren Schrittweiten nicht mehr gewährleistet

Prüfung:

Abteilung: Kosteningenieur

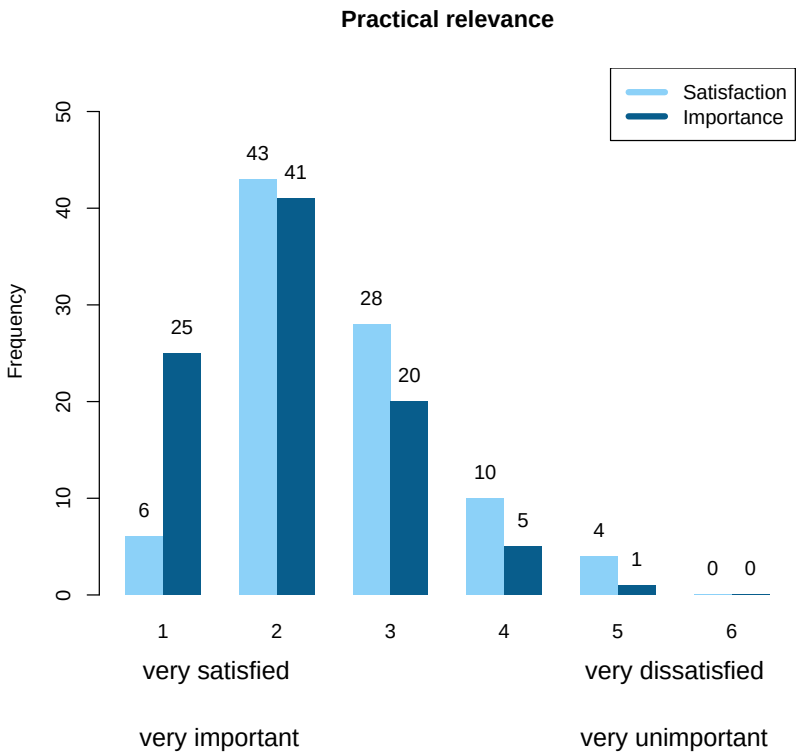
Datum: 27.06.2009 **verantwortlicher Prüfer:**

Flight Time

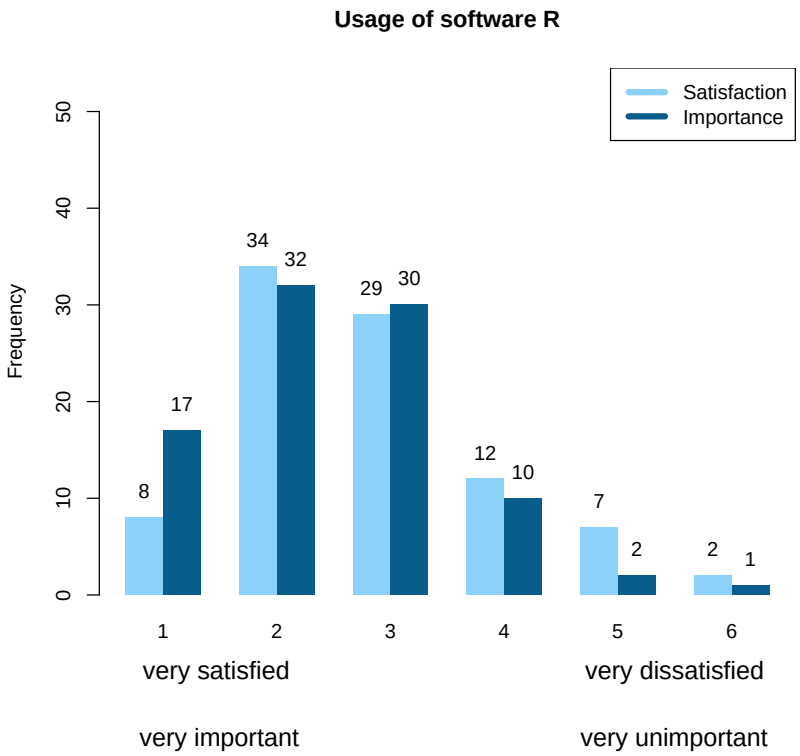
improved by 44%

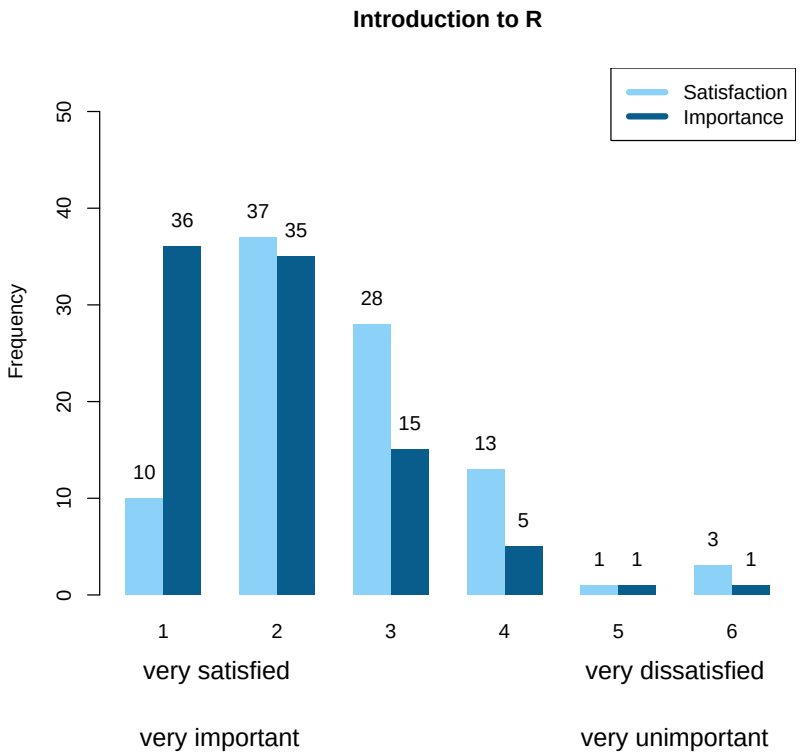
Mittelwert
4.34s
5.17s
5.30s
5.56s
6.09s
6.21s
4.89s
4.93s

Student Survey Results (I)



Student Survey Results (II)





Summary

Summary

- R has become an integral part in the education of engineers
- R is used for an introduction to statistics and their application in quality sciences
- So far about 700 (undergraduate) students successfully conducted an improvement project using R

Use R

- We Use R, do you?