

Teaching Statistics In Quality Science Using The R-Package qualityTools

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Outline

- 1 Introduction To Quality
 - Quality And Quality Management
 - Process-Model For Continual Improvement
 - Statistics In Problem Solving
- 2 The qualityTools Package
 - Scope Of The qualityTools Package (S4)
 - Overview Of Methods Within The qualityTools Package
- 3 Contents Of The R-Course
 - Contents And Teaching Methodology
 - Improvement Project
 - A Students Example
 - ProjectCharter
 - Process Capability
 - Design Of Experiments
- 4 Résumé
 - Opinions Regarding The Contents
 - Opinions Regarding R
 - Summary

A (Very) Short Introduction To Quality Sciences

quality

degree to which a set of inherent **characteristics** fulfils **requirements**

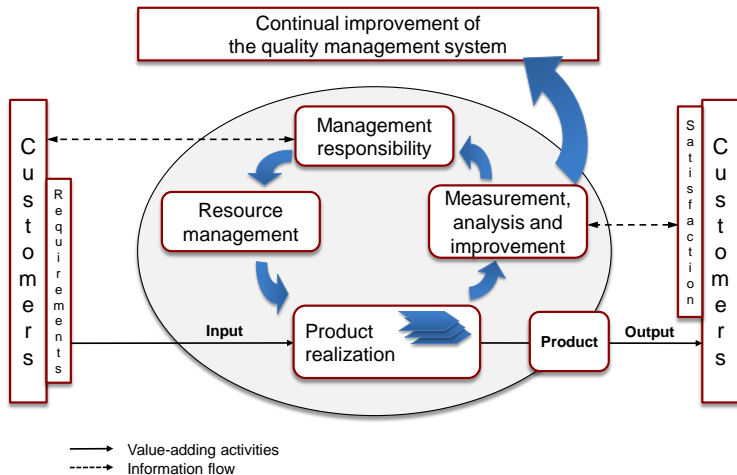
management

coordinated activities to **direct** and **control**

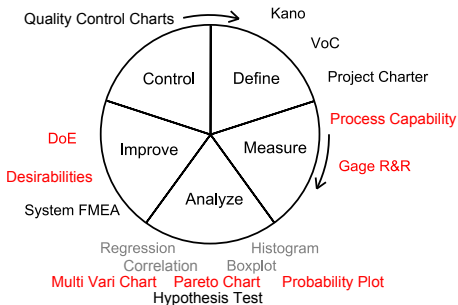
quality management system

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 too 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, ...)

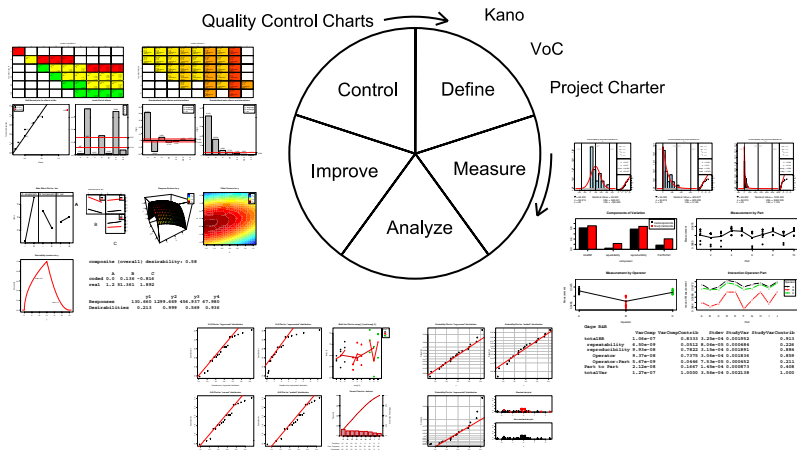
S4 OOP

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

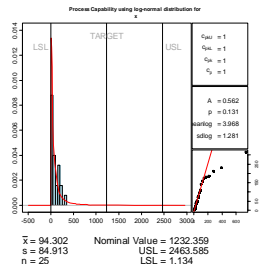
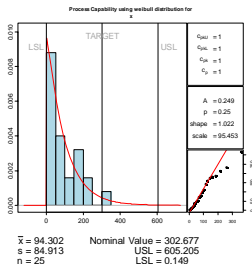
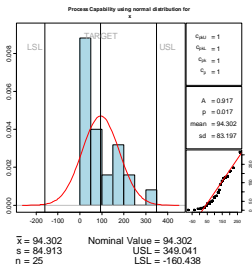
Powerful Visualization

provide powerful visualization that are easy to accomplish

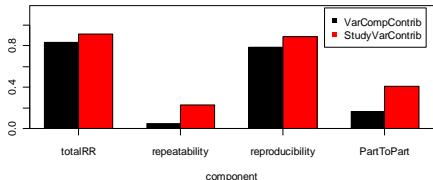
Visual Representation Of The qualityTools Package



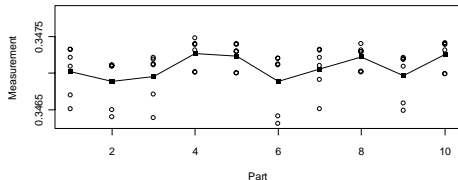
Visual Representation Of The qualityTools Package



Components of Variation

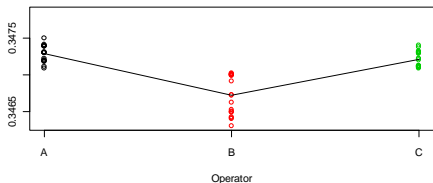


Measurement by Part

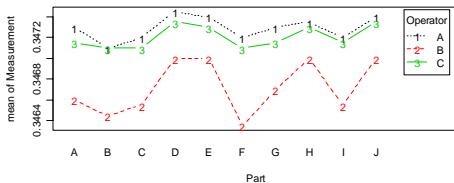


Visual Representation Of The qualityTools Package

Measurement by Operator



Interaction Operator:Part

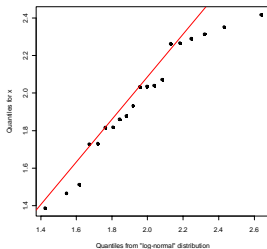


Gage R&R

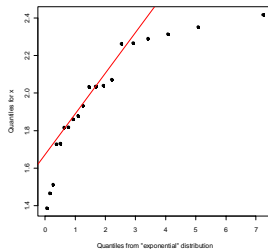
	VarComp	VarCompContrib	Stdev	StudyVar	StudyVarContrib
totalRR	1.06e-07	0.8333	3.25e-04	0.001952	0.913
repeatability	6.50e-09	0.0512	8.06e-05	0.000484	0.226
reproducibility	9.93e-08	0.7822	3.15e-04	0.001891	0.884
Operator	9.37e-08	0.7375	3.06e-04	0.001836	0.859
Operator:Part	5.67e-09	0.0446	7.53e-05	0.000452	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

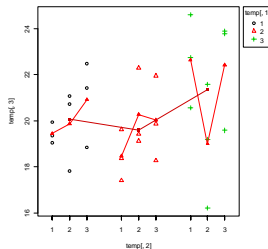
Q-Q Plot for "log-normal" distribution



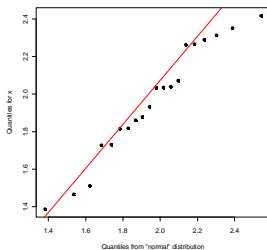
Q-Q Plot for "exponential" distribution



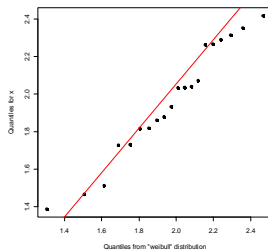
Multi Vari Plot for temp[, 1] and temp[, 2]



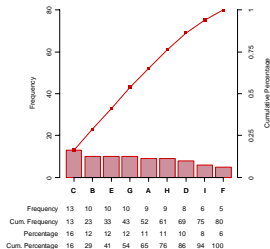
Q-Q Plot for "normal" distribution



Q-Q Plot for "weibull" distribution

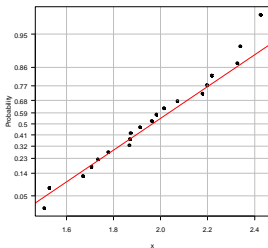


Pareto Chart for defects

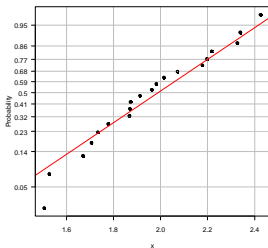


Visual Representation Of The qualityTools Package

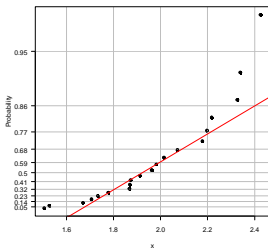
Probability Plot for "log-normal" distribution



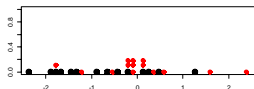
Probability Plot for "weibull" distribution



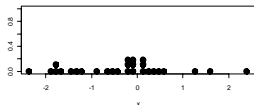
Probability Plot for "exponential" distribution



Stacked dot plot



Non stacked dot plot

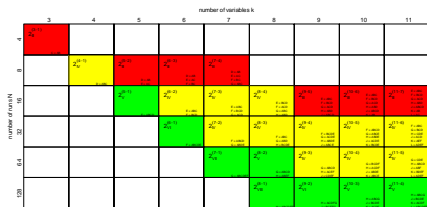


Operator

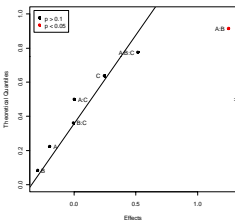
Gage R&R

	VarCom
totalRR	1.06e-0
repeatability	6.50e-0
reproducibility	9.93e-0
Operator	9.37e-0
Operator:Part	5.67e-0
Part to Part	2.12e-0
totalVar	1.27e-0

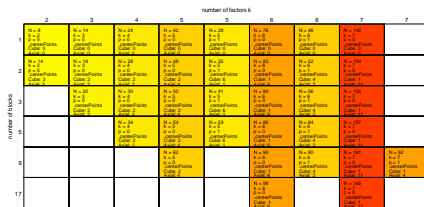
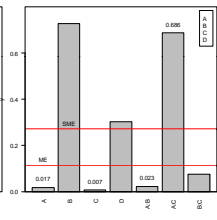
Visual Representation Of The qualityTools Package



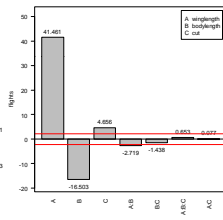
Half-Normal plot for effects of fdo



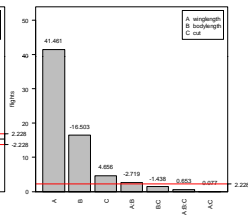
Lenh Plot of effects



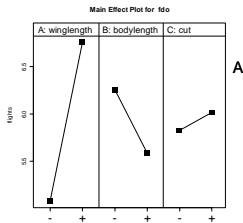
Standardized main effects and interactions



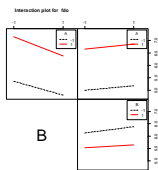
Standardized main effects and interactions



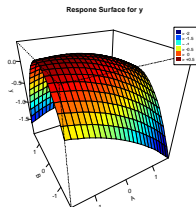
Visual Representation Of The qualityTools Package



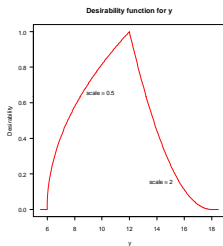
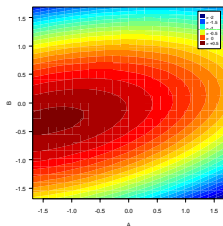
A



C



Filled Contour for y

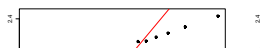


composite (overall) desirability: 0.58

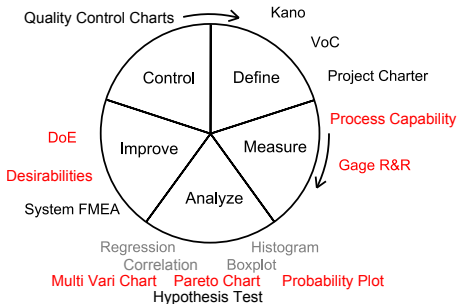
	A	B	C
coded	0.0	0.136	-0.816
real	1.2	51.361	1.892

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

Q-Q Plot for "log-normal" distribution



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

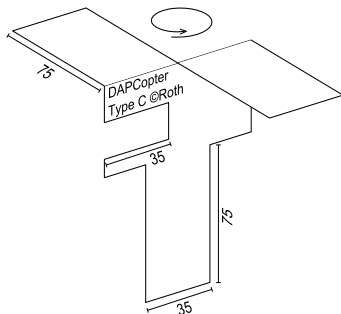
Teaching Methodology

- Lectures and Exercise 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

TU PROJEKTSTECKBRIEF	
Projekt VERLÄNGERUNG DER FLUGZEIT DES DAP-COPTER	
Leitung - Student MB (Bsc)	Organisationseinheit TU Berlin Fachbereich Qualitätswissenschaft
Teammitglieder - Test-Ingenieur - Datenrechner - 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 vorhandenen Abflugeinrichtungen und Messaufbauten Deutliche Steigerung des Preis/Leistungs Verhältnis	
Wirkungsbereich Durchführung der Messungen an ausgewählten Stellen in der TU-Berlin	Projektbegründung 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 Sportcoper Verband DRK Luftrettung Macks Planck Institut für Strömungsphysik Aachen
Erwarteter Nutzen Flugzeit: Steigerung auf über 15m 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 baß durch neueartige Konkurrenzprodukte übertriften werden Sättigung des Marktes absehbar
Personelle Ressourcen 1 leitender Ingenieur (100% Arbeitszeit) 4 Ingenieure: MB / FI (15% Arbeitszeit)	Finanzielle Ressourcen 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 ⁴ -faktoriellen 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 MESSSYSTEM- UND MESSMITTELFÄHIGKEITSUNTERSUCHUNG (Messungen zur Berechnung des Cp - Wertes)		
Projektname/ Projektnummer: Projekt DAP - Gruppe		
Teilbezeichnung: DAP-Copter	Toleranzbreite der Messung: 0,6 Sekunden	
Teilnummer: 0,0,0	Messmittel: Stoppuhr	
Merkmalt: 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: Messereinrichtung geeignet: <input checked="" type="checkbox"/> JA <input type="checkbox"/> NEIN		
Prüfung:		
Abteilung: Kosteningenieur		
Datum: 22.06.2009	verantwortlicher Prüfer:	

Standardization - Improving The Process Capability Ratio

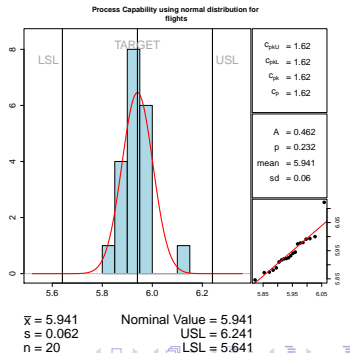
```
> pcr(flights, lsl=mean(flights)-0.3, usl=mean(flights)+0.3)
```

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
```



Design Of Experiments - Size And Direction Of Effects

```
> fdo = facDesign(k=3, centerCube = 2, replicates = 2) #factorial design
> names(fdo) = c("wavelength", "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)
```

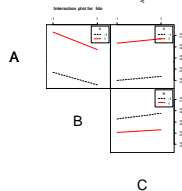
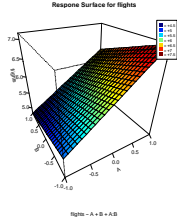
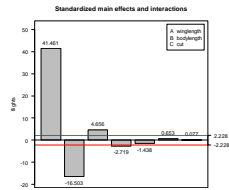
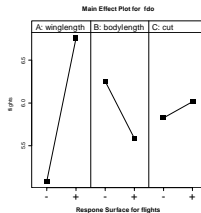
Information about the factors:

	A	B	C
low	60	50	0
high	90	100	60
name	wavelength	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

Flight Time

improved by 44%

AUFNAHMEBOGEN

Messungen für optimierte Modelle entlang Steepest Ascent

Projektname/ Projektnummer: Projekt DAP -

Teilbezeichnung: 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
Flügelänge	75 mm	+5 mm
Körperlänge	75 mm	-1,64 mm

Ergebnisse der Messungen / Messwerte:

Schrittweite	Körperbreite	Flügelänge	Körperlänge	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:

Mittelwert

4.34s

5.17s

5.30s

5.56s

6.09s

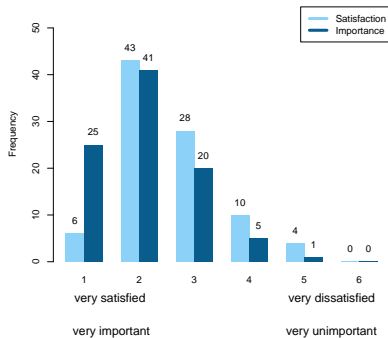
6.21s

4.89s

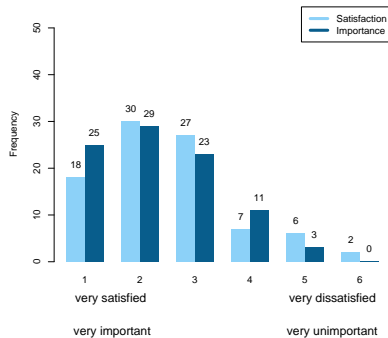
4.93s

Student Survey Results (I)

Practical relevance

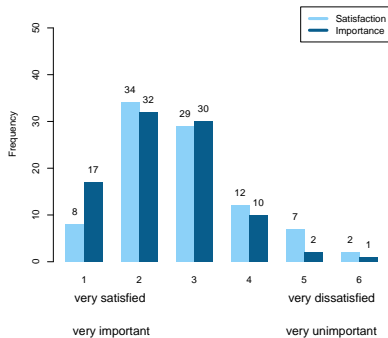


Improvement project

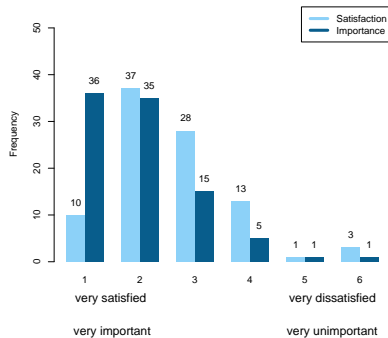


Student Survey Results (II)

Usage of software R



Introduction to R



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?