Customer Orientation

Lean Six Sigma

Agile Processes

Project Estimations

Transfer Functions

# Using AHP in QFD – The Impact of the ISO 16355 Standard


Thomas M. Fehlmann, QFD Architekt, Euro Project Office AG, Zürich
E: info@e-p-o.com H: www.e-p-o.com

Glenn H. Mazur, QFD Red Belt® and QFD Architekt, QFD Institute
E: glenn@mazur.net H: www.qfdi.org


QFD-Institut
QFD Institut Deutschland e.V. (QFD-ID)

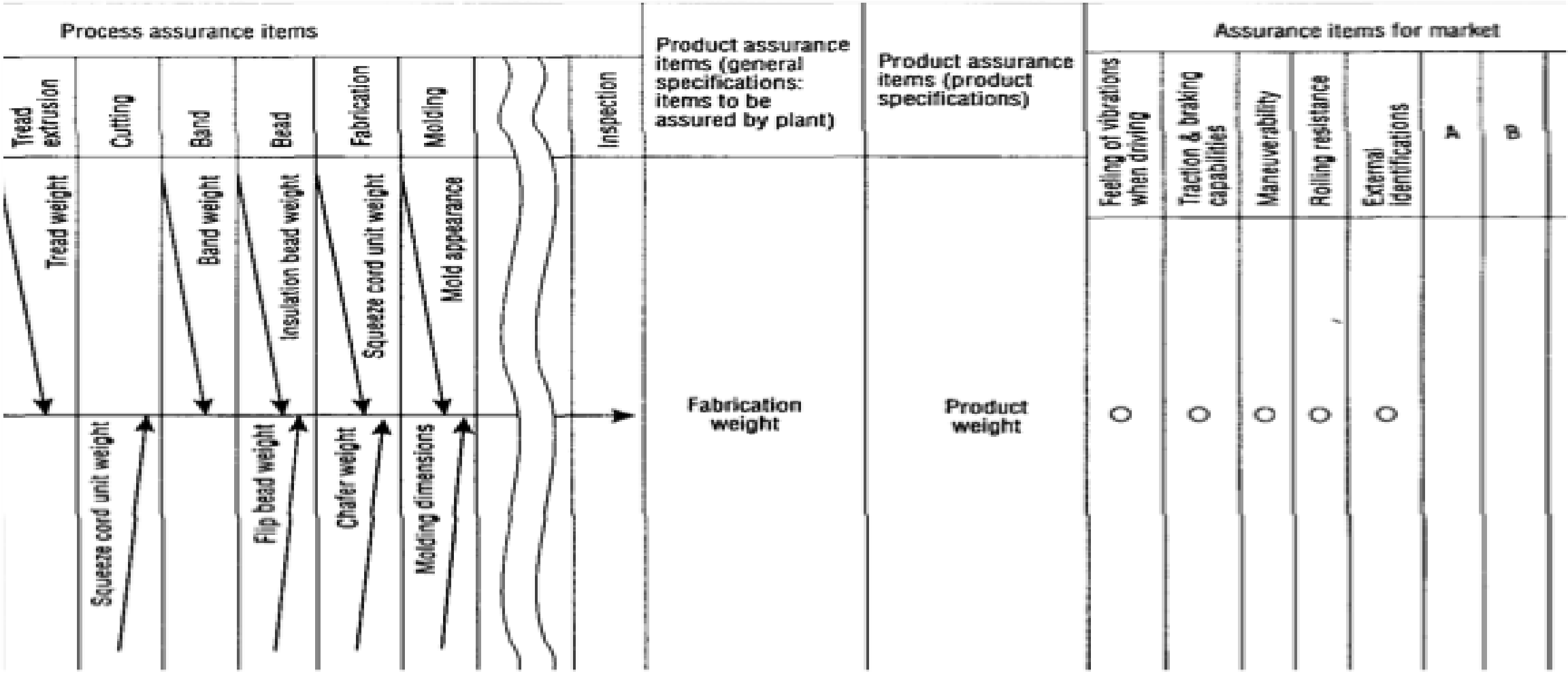
euro project office
Master your project.

# Dr. Thomas Fehlmann

- 1981: Dr. Math. ETHZ
- 1991: Six Sigma for Software Black Belt
- 1999: Euro Project Office AG, Zürich
- 2001: Akao Price 2001 for original contributions to QFD
- 2003: SwissICT Expert for Software Metrics
- 2004: Member of the Board QFD Institute Deutschland – QFD Architect
- 2007: CMMI for Software – Level 4 & 5
- 2011: Net Promoter® Certified Associate
- 2012: Member of the DASMA Board
- 2013: Vice-President ISBSG

# Cause-Effect Diagram for Tire Design (Mizuno & Akao, 1994)

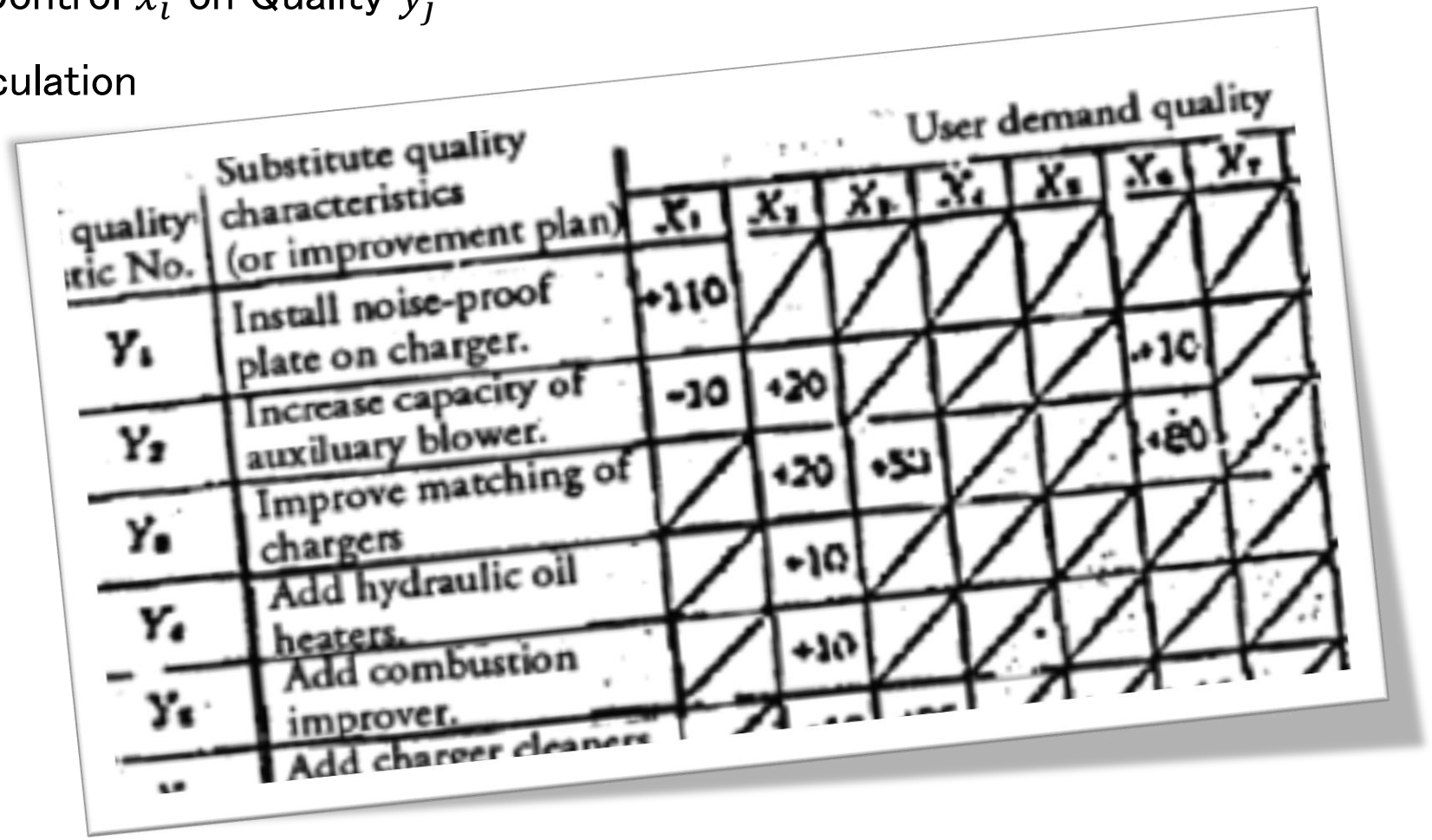




# First Example of QFD matrix (Suzuki, 1972)



- Impact of Control $x_i$ on Quality $y_j$
- Manual calculation

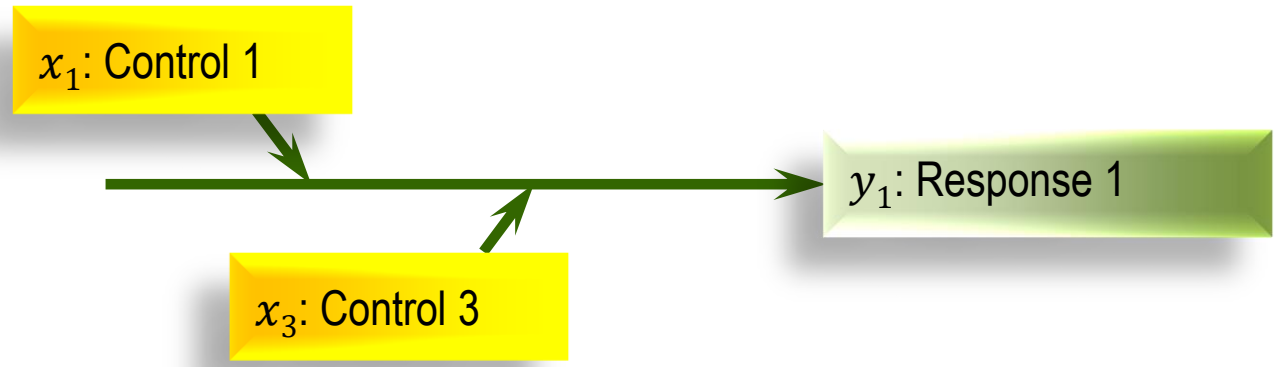


| quality tic No. | Substitute quality characteristics (or improvement plan) | User demand quality $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ |
|---|---|---|---|---|---|---|---|---|
| $Y_1$ | Install noise-proof plate on charger. | +110 | | | | | | |
| $Y_2$ | Increase capacity of auxiliary blower. | -10 | +20 | | | | +10 | |
| $Y_3$ | Improve matching of chargers | | +20 | +50 | | | +80 | |
| $Y_4$ | Add hydraulic oil heaters. | | +10 | | | | | |
| $Y_5$ | Add combustion improver. | | +10 | | | | | |
| | Add charger cleaners | | | | | | | |

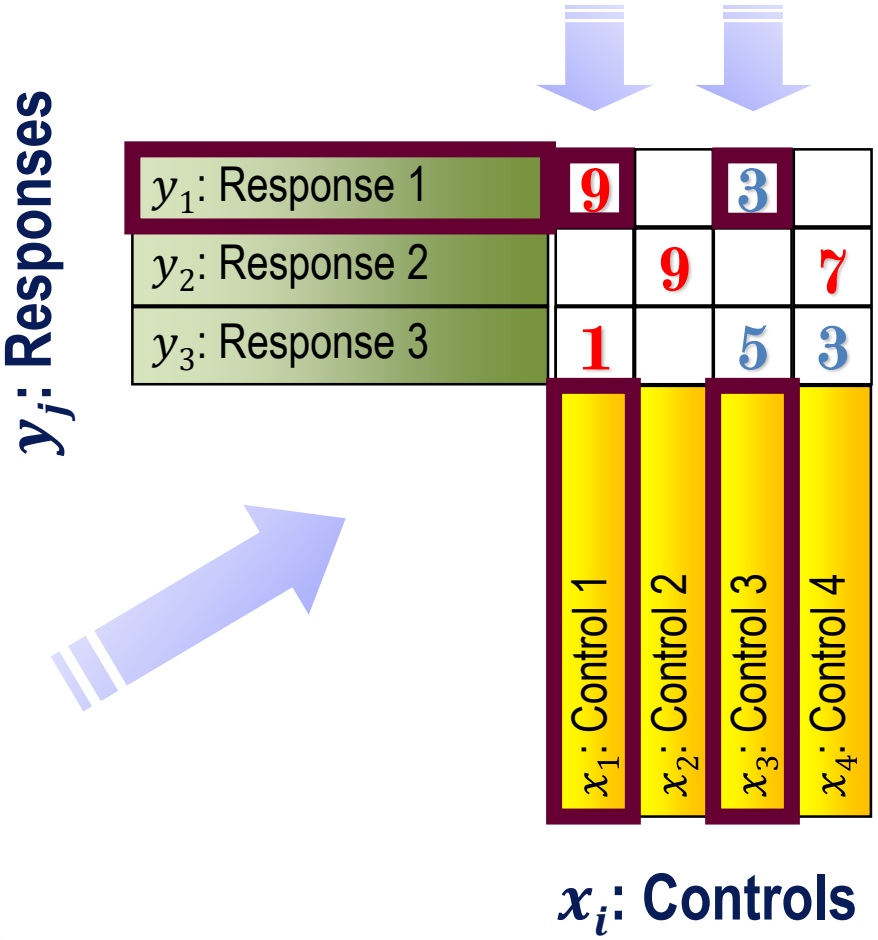
# How Cause-Effect Diagrams become QFD Matrices



$$\{\{x_1, x_2, \ldots, x_n\} \rightarrow y | x_1, x_2, \ldots, x_n, y \in \mathcal{L}\}$$




$$\{x_1, x_3\} \rightarrow y_1$$

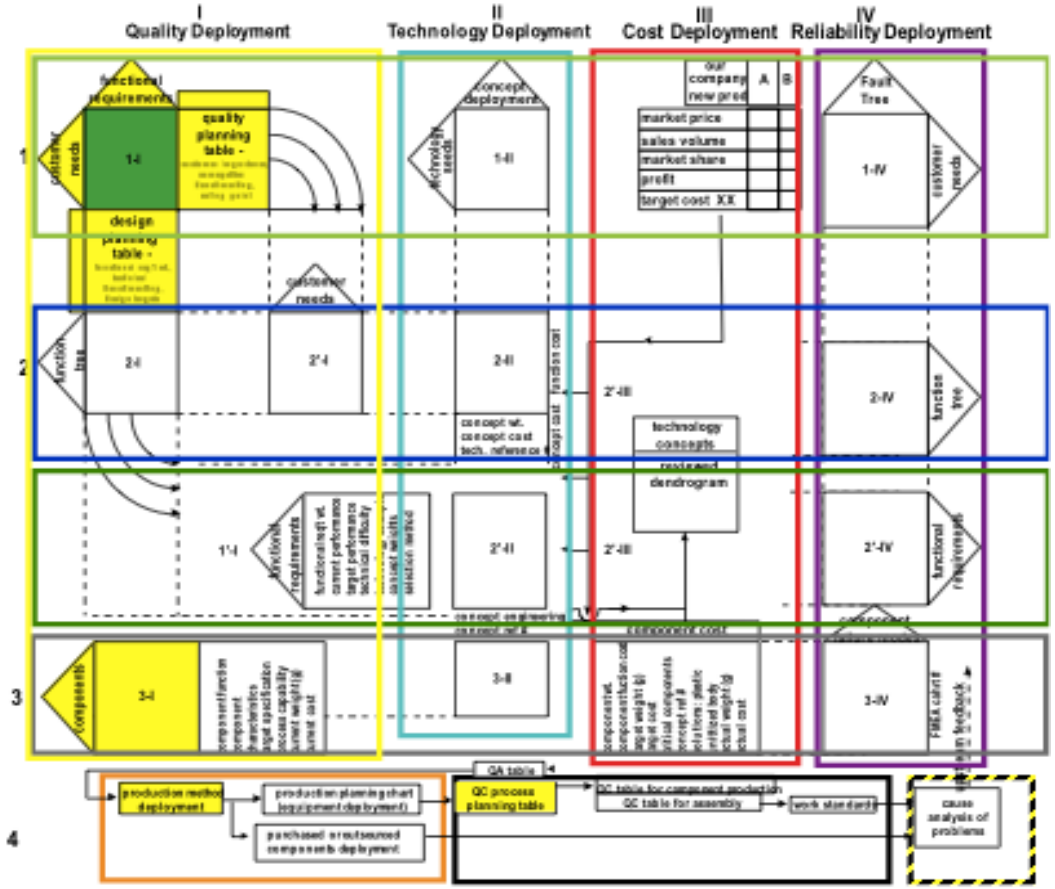


# Comprehensive QFD (Akao, 1990)



- Including quality, technology, cost, and reliability deployments

House of Quality
4-Phase QFD for part suppliers
Quality Deployment
New Technology Deployment
Cost Deployment
Reliability Deployment
Customer Deployment
Function Deployment
New Concept Deployment
Components Deployment
Manufacturing Deployment
Production Deployment
Process Improvement



# Profiles for Ratio Scales according ISO 16355

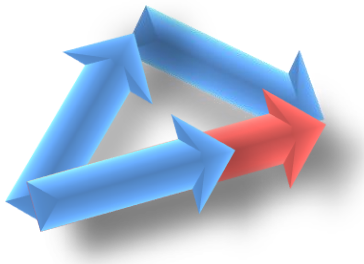


- Let $\boldsymbol{y} = \langle y_1, \ldots, y_m \rangle$ be a vector of dimension $m$. The Euclidian norm for vectors is:

$$\|\boldsymbol{y}\| = \sqrt{\sum_{j=1}^{m} {y_j}^2}$$

- A vector becomes a Profile by dividing components through its length (normalization):

$$\boldsymbol{y}' = \frac{\boldsymbol{y}}{\|\boldsymbol{y}\|} = \langle \frac{y_1}{\|\boldsymbol{y}\|}, \ldots, \frac{y_m}{\|\boldsymbol{y}\|} \rangle$$



- Profiles are vectors of length = 1
- Profiles can be added, subtracted and compared as any other vector
  - ➔ Sum of vectors become profiles again be normalization
  - ➔ Profiles allow for statistical methods – they show Directions in some event space

# Analytic Hierarchy Process (AHP)



**AHP Priorities**

| Customer's Needs | y1 Target 1 | y2 Target 2 | y3 Target 3 | Weight | Profile | Ranking |
|---|---|---|---|---|---|---|
| y1 Target 1 | 1 | 2 | 1 | 41% | 0.69 | 1 |
| y2 Target 2 | 1/2 | 1 | 2 | 33% | 0.56 | 2 |
| y3 Target 3 | 1 | 1/2 | 1 | 26% | 0.45 | 3 |

**AHP Priorities** $\tau_y$

| Customer's Needs | y1 Target 1 | y2 Target 2 | y3 Target 3 | 0.41 | 0.33 | 0.26 | | Weight | 1/Weight | | | Profile | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| y1 Target 1 | 1 | 2 | 1 | 0.40 | 0.57 | 0.25 | 1.22 | 41% | 2.46 | 1.33 | 41% | 0.69 | 1 |
| y2 Target 2 | 1/2 | 1 | 2 | 0.20 | 0.29 | 0.50 | 0.99 | 33% | 3.04 | 1.06 | 33% | 0.56 | 2 |
| y3 Target 3 | 1 | 1/2 | 1 | 0.40 | 0.14 | 0.25 | 0.79 | 26% | 3.78 | 0.84 | 26% | 0.45 | 3 |
| | 2.5 | 3.5 | 4.0 | 0.11 | 0.12 | 0.13 | 3 | 0.59 | | 3.23 | | | |

- Calculates weights (sum = 100%)
- Calculates profile (sum of squares = 1)
- Calculates ranking (for both the same)
  - ➔ The profile is used for the hierarchy because you can compare, add and linearly combine vectors
  - ➔ For weights, this remains forbidden!


- The profile is calculated as an Eigenvector, similar to Google Search
- The method is shown above
  - ➔ The Annihilator method
  - ➔ Annihilates the matrix $\boldsymbol{A}$ by its transform $\boldsymbol{A}^{\mathsf{T}}$
  - ➔ Result is $\boldsymbol{\tau_y}$
  - ➔ $\boldsymbol{A}\boldsymbol{A}^{\mathsf{T}}\boldsymbol{\tau_y} = \boldsymbol{\tau_y}$

# A Sample AHP – Which School to Select?



**AHP Priorities**

| Best School | A Education | B Social Aspects | Weight | Profile | Ranking |
|---|---|---|---|---|---|
| A Education | 1 | 4 | 80% | 0.97 | 1 |
| B Social Aspects | 1/4 | 1 | 20% | 0.24 | 2 |

**AHP Priorities**

| A Education | A01 Learning | A02 Professions | A03 University Readiness | A04 Musical Education | Weight | Profile | Ranking |
|---|---|---|---|---|---|---|---|
| A01 Learning | 1 | 1 | 1/2 | 4 | 26% | 0.52 | 2 |
| A02 Professions | 1 | 1 | 1 | 1/3 | 20% | 0.39 | 4 |
| A03 University Readiness | 2 | 1 | 1 | 3 | 34% | 0.66 | 1 |
| A04 Musical Education | 1/4 | 3 | 1/3 | 1 | 20% | 0.39 | 3 |

**AHP Priorities**

| B Social Aspects | B01 Friends | B02 Campus Life | Weight | Profile | Ranking |
|---|---|---|---|---|---|
| B01 Friends | 1 | 2 | 67% | 0.89 | 1 |
| B02 Campus Life | 1/2 | 1 | 33% | 0.45 | 2 |

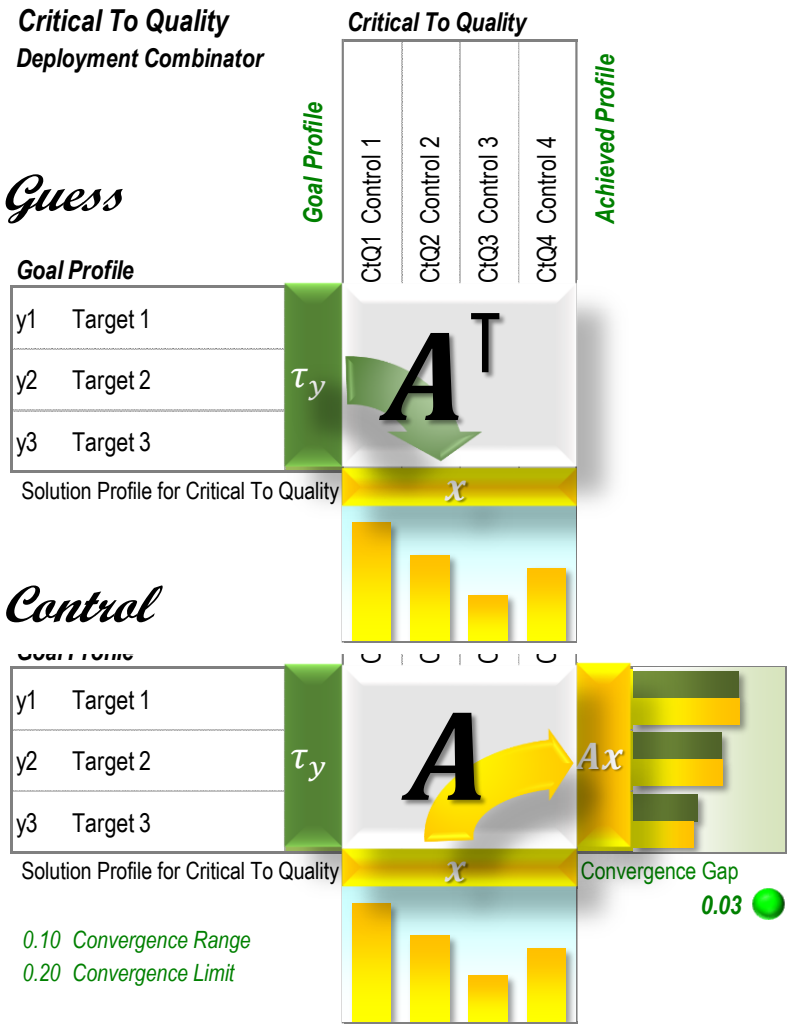
***Top Targets***
***Best School***

| | Top Targets | Attributes | | Profile |
|---|---|---|---|---|
| A Education | A01 Learning | *Ease of learning* | *Trained to learn* | 0.48 |
| | A02 Professions | *Wide range of professions* | *Find an excellent start* | 0.36 |
| | A03 University Readiness | *Will successfully conduct studies* | *Well prepared* | 0.62 |
| | A04 Musical Education | *Learns to perform* | *High precision* | 0.36 |
| B Social Aspects | B01 Friends | *Makes friends for life* | *Good insider relationship* | 0.31 |
| | B02 Campus Life | *Socialize* | *Behavior* | 0.15 |

# Solving a QFD Matrix $y = Ax$



## Theory




## Practice

# The Trick how to Use AHP Calculation in QFD $y = Ax$



$y$ $A$

$x_E = A^T y_E$

Theory

$A_T$

$y_E$ $AA^T$

$y_E$

**Eigenvectors:**

| | | |
|---|---|---|
| **0.71** | -0.69 | -0.17 |
| **0.59** | 0.71 | -0.39 |
| **0.39** | 0.17 | 0.90 |

$y$

| | | | |
|---|---|---|---|
| 9 | 0 | 2 | 0 |
| 0 | 7 | 0 | 5 |
| 1 | 2 | 3 | 3 |

$x_E = A^T y_E$

Theory

| | | |
|---|---|---|
| 9 | 0 | 1 |
| 0 | 7 | 2 |
| 2 | 0 | 3 |
| 0 | 5 | 3 |

$y_E$

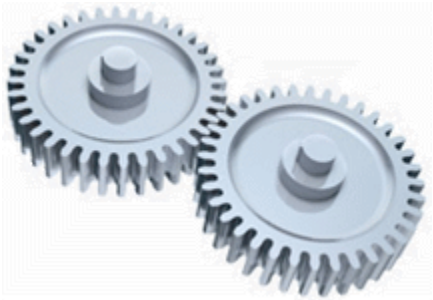
| | | |
|---|---|---|
| 85 | 0 | 15 |
| 0 | 74 | 29 |
| 15 | 29 | 23 |

$y_E$

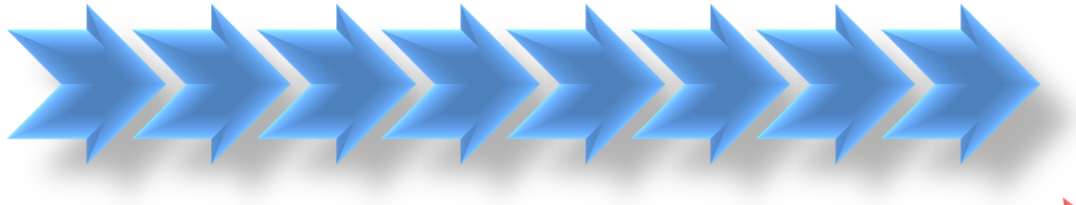
# Advantages of Eigensolution Method

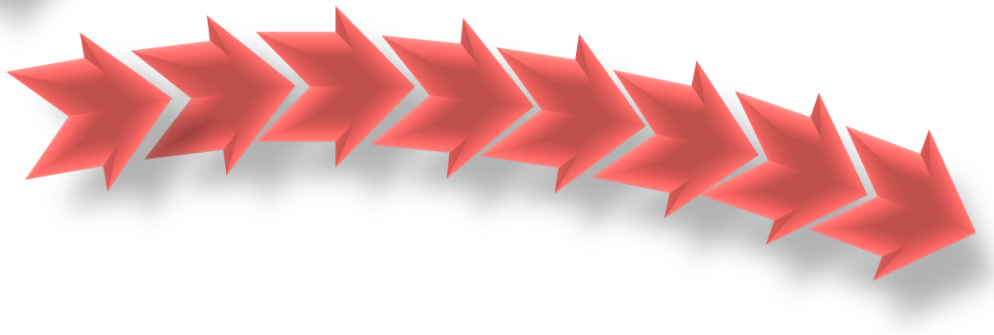


- Eigensolutions are stable
  - ➔ When repeatedly applying the process represented by the transfer function $\boldsymbol{A}$, the response $\boldsymbol{y}$ remains always the same
  - ➔ $\boldsymbol{y} = \boldsymbol{A}\boldsymbol{A}^{\mathrm{T}}\boldsymbol{y} = \boldsymbol{A}\boldsymbol{A}^{\mathrm{T}}(\boldsymbol{A}\boldsymbol{A}^{\mathrm{T}}\boldsymbol{y}) = \boldsymbol{A}\boldsymbol{A}^{\mathrm{T}}\big(\boldsymbol{A}\boldsymbol{A}^{\mathrm{T}}(\boldsymbol{A}\boldsymbol{A}^{\mathrm{T}}\boldsymbol{y})\big) = \cdots$



- Other solutions might also yield good – even better – convergence gaps but when repeated the process diverges





- Eigensolutions level out inconsistencies

# A Measure for Quality – the Convergence Gap

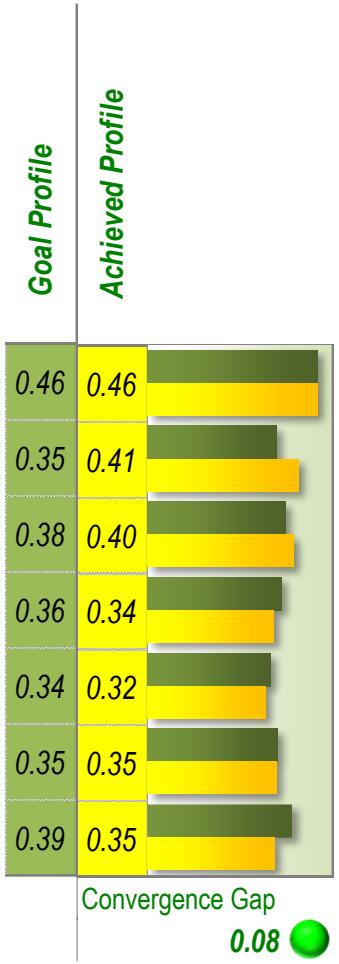


- The **Convergence Gap**

$$\|y - \tau_y\| = \sqrt{\sum_{i=1}^{m} (y - \tau_y)_i^{\,2}}$$

reveals the quality of the goal profile's approximation by the achieved solution profile

- This is the Euclidean Norm
  - ➔ Distance between vectors $y$ and $\tau_y$

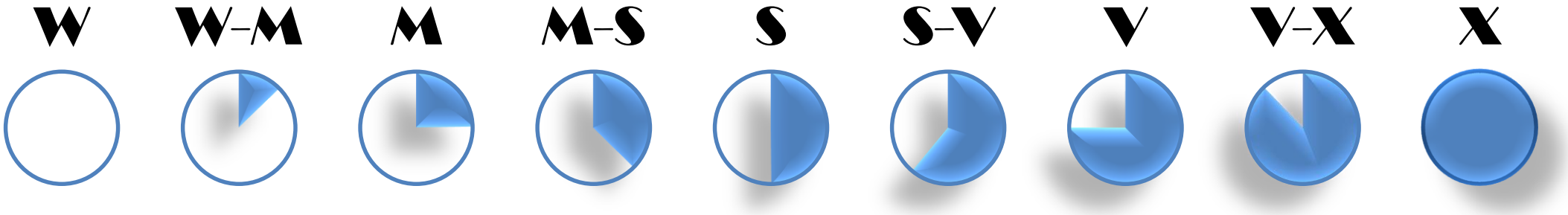


# Displaying QFD Relationship Weights with AHP Judgments



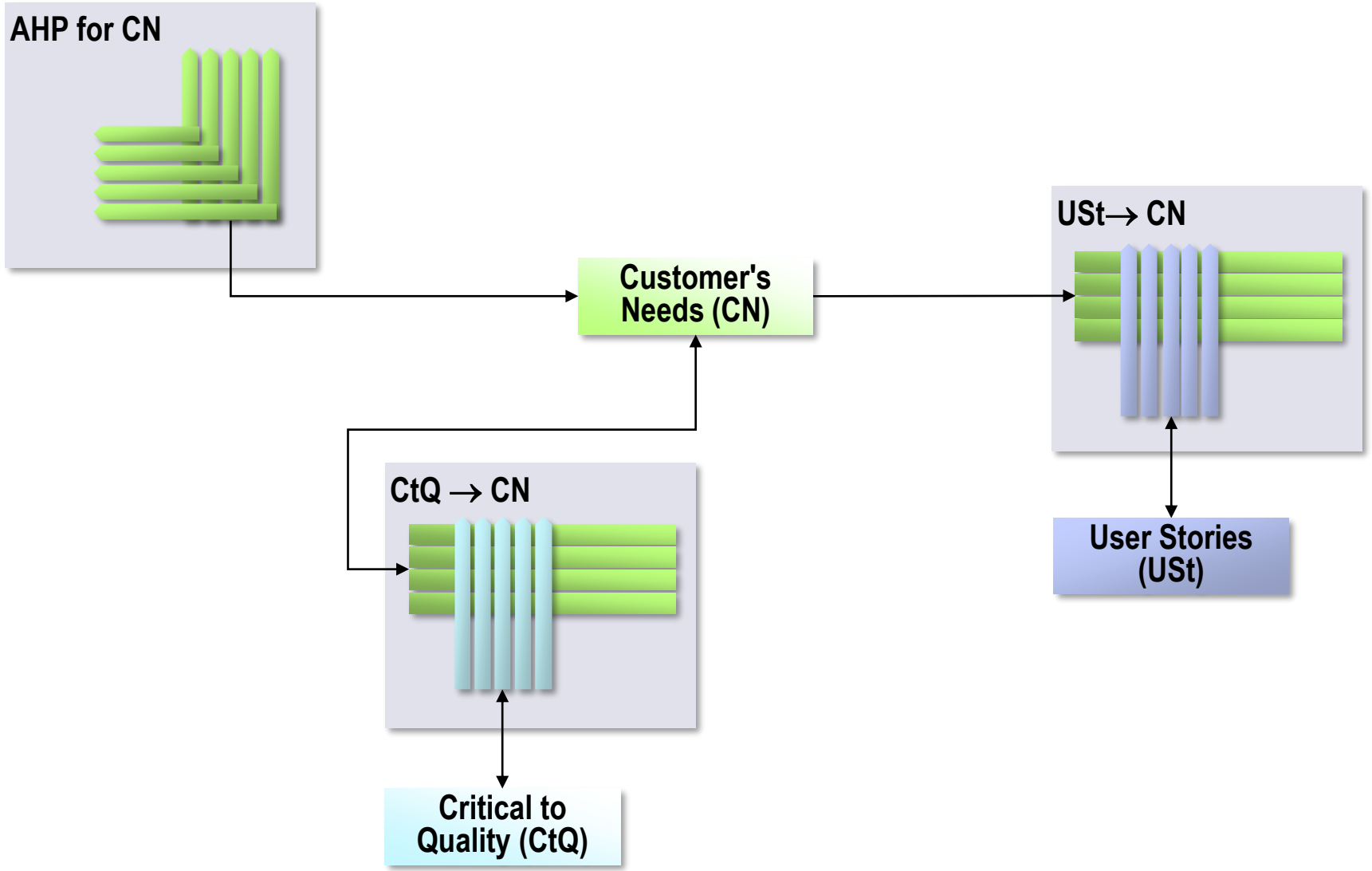
- When using symbols, ISO 16355 proposes cloud symbols
  - → W Weak (1)
  - → M Medium (3)
  - → S Strong (5)
  - → V Very Strong (7)
  - → X eXtremely strong (9)

| | |
|---|---|
| 9 | Overruling importance |
| 8 | |
| 7 | Much higher importance |
| 6 | |
| 5 | Clearly higher importance |
| 4 | |
| 3 | Somewhat higher importance |
| 2 | |
| 1 | Equal importance |
| 1/2 | |
| 1/3 | Somewhat smaller importance |
| 1/4 | |
| 1/5 | Clearly smaller importance |
| 1/6 | |
| 1/7 | Much smaller importance |
| 1/8 | |
| 1/9 | No importance at all |



# Comprehensive QFD with AHP





# Conclusion



- The ISO 16355 standard projects QFD into the 21st century
- QFD is thanks to good mathematics implementable in quality processes
  - ➔ Implement New Lanchester Theory into the New Feature Prioritization concept
  - ➔ Use QFD in agile software development for testing and safety deployment
- QFD will always depend on the teams using it
  - ➔ Because it record and documents the reasons for taking decisions
- QFD will go mainstream

QFD-Institut
QFD Institut Deutschland e.V. (QFD-ID)

euro project office
Master your project.

# Questions?

Customer Orientation

Lean Six Sigma

Agile Processes

Project Estimations

Transfer Functions

# Traditional Solution Profile and Modern Solution Profile

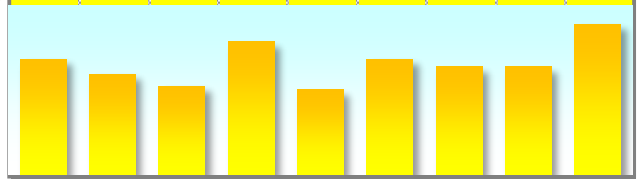


- Eigensolution level
  Inconsistencies out
  - ➔ Similar to Saaty's AHP Calculation

***Critical To Quality***
***Deployment Combinator***

***Critical To Quality***

| ***Customer's Needs*** | | ***Goal Profile*** | x1 Browser Style GUI | x2 Keep to XSQL Standard | x3 Open Interfaces | x4 Agile Programming | x5 Reusable classes | x6 Custom Extensions | x7 Portfolio Management | x8 Reliable Functionality | x9 Moderated Forum | ***Achieved Profile*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| y1 | Competency to answer inquiries | *0.46* | 9 | 9 | 9 | 3 | | 3 | 3 | 9 | 3 | *0.46* |
| y2 | Confidentiality | *0.35* | | 9 | 3 | | 9 | 9 | 3 | | 9 | *0.41* |
| y3 | Suitability for business needs | *0.38* | 3 | | 3 | 9 | 3 | 3 | 9 | 9 | 1 | *0.40* |
| y4 | Short Development Cycles | *0.36* | | 3 | 3 | 3 | 3 | 3 | 9 | | 9 | *0.34* |
| y5 | Functionality where you need it | *0.34* | 9 | | | 9 | 1 | 3 | | 9 | | *0.32* |
| y6 | Social competency | *0.35* | | | | 9 | 3 | 9 | 1 | | 9 | *0.35* |
| y7 | Communication | *0.39* | 9 | 3 | 3 | 3 | 3 | | 3 | | 9 | *0.35* |
| | Solution Profile for Critical To Quality | | *0.34* | *0.30* | *0.26* | *0.39* | *0.25* | *0.34* | *0.32* | *0.32* | *0.44* | Convergence Gap |
| | | | | | | | | | | | | *0.08* |



*0.10* *Convergence Range*
*0.20* *Convergence Limit*

# Profiles and Weights



- In the columns, two priority profiles are summed up yielding the sum of profiles in the third row, and normalized again in the fourth row
- Left are the corresponding weight vectors
- Summing up the weight vectors and transform them back to profiles yields different results than the sum of profiles
- Summing up the corresponding weight vectors is bad mathematics
  - Good mathematics is with profiles only
  - When calculating with weights, large vector components leave a bias

| | Weights | → | Profiles | → | Weights | |
|---|---|---|---|---|---|---|
| Topic 1 | 5% | 0.00 | 0.06 | 0.06 | 5% | |
| Topic 2 | 85% | 0.72 | 0.99 | 0.99 | 85% | |
| Topic 3 | 10% | 0.01 | 0.12 | 0.12 | 10% | |
| | 100% | 0.86 | 1.00 | 1.17 | 100% | *Weight & Profile 1* |
| | plus ↓ | → | plus ↓ | → | Weights | |
| Topic 1 | 33% | 0.11 | 0.57 | 0.57 | 33% | |
| Topic 2 | 34% | 0.12 | 0.59 | 0.59 | 34% | |
| Topic 3 | 33% | 0.11 | 0.57 | 0.57 | 33% | |
| | 100% | 0.58 | 1.00 | 1.73 | 100% | *Weight & Profile 2* |
| | sum ↓ | | sum ↓ | → | Weights | |
| Topic 1 | 0.38 | | 0.63 | 0.34 | 21.7% | |
| Topic 2 | 1.19 | | 1.58 | 0.86 | 54.5% | |
| Topic 3 | 0.43 | | 0.69 | 0.37 | 23.7% | |
| | 2.00 | | 1.84 | 1.58 | 100% | *Sum of Profiles 1+2* |
| | norm ↓ | → | Profiles | → | Weights | ≠ |
| Topic 1 | 19% | 0.04 | 0.22 | 0.22 | 19.0% | |
| Topic 2 | 60% | 0.35 | 0.69 | 0.69 | 59.5% | |
| Topic 3 | 22% | 0.05 | 0.25 | 0.25 | 21.5% | |
| | 100% | 0.66 | 0.77 | 1.17 | 100% | *Sum of Weights 1+2* |
| | | | | 0.24 | | ***Convergence Gap*** |