**IWSM2000- 10th International Workshop on Software Measurement**

Berlin, October 4-6, 2000

**GERMANY**

# QF²D: A different way to measure Software Quality

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# Agenda

- Introduction
- Quality Function Deployment (QFD)
- Quality Models and the Quality Factor (QF)
- $QF^2D$: description and advantages
  - the procedure flow
  - the new calculation
- Conclusions and Prospects

# Introduction

Product Quality is definable as "***the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs***" (ISO 8402)

# Introduction

Trend:

Growing attention towards project measurement (both of process and product) in the Software Engineering community in order to reach optimal qualitative levels

Practice: many companies consider only the Economic and /or Technical viewpoints in evaluations and in a quantitative manner

- Reasons: cultural and economic motivations
- Results: an incomplete product evaluation

# Introduction

**A comprehensive Software Quality Assessment should take into account multiple and distinct viewpoints:**

| Actors | Viewpoint | Objectives |
|---|---|---|
| Managers | Economic (E) | Overall quality |
| Users | Social (S) | Usability |
| Developers | Technical (T) | Conformance to requirements |

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# Quality Function Deployment (QFD)

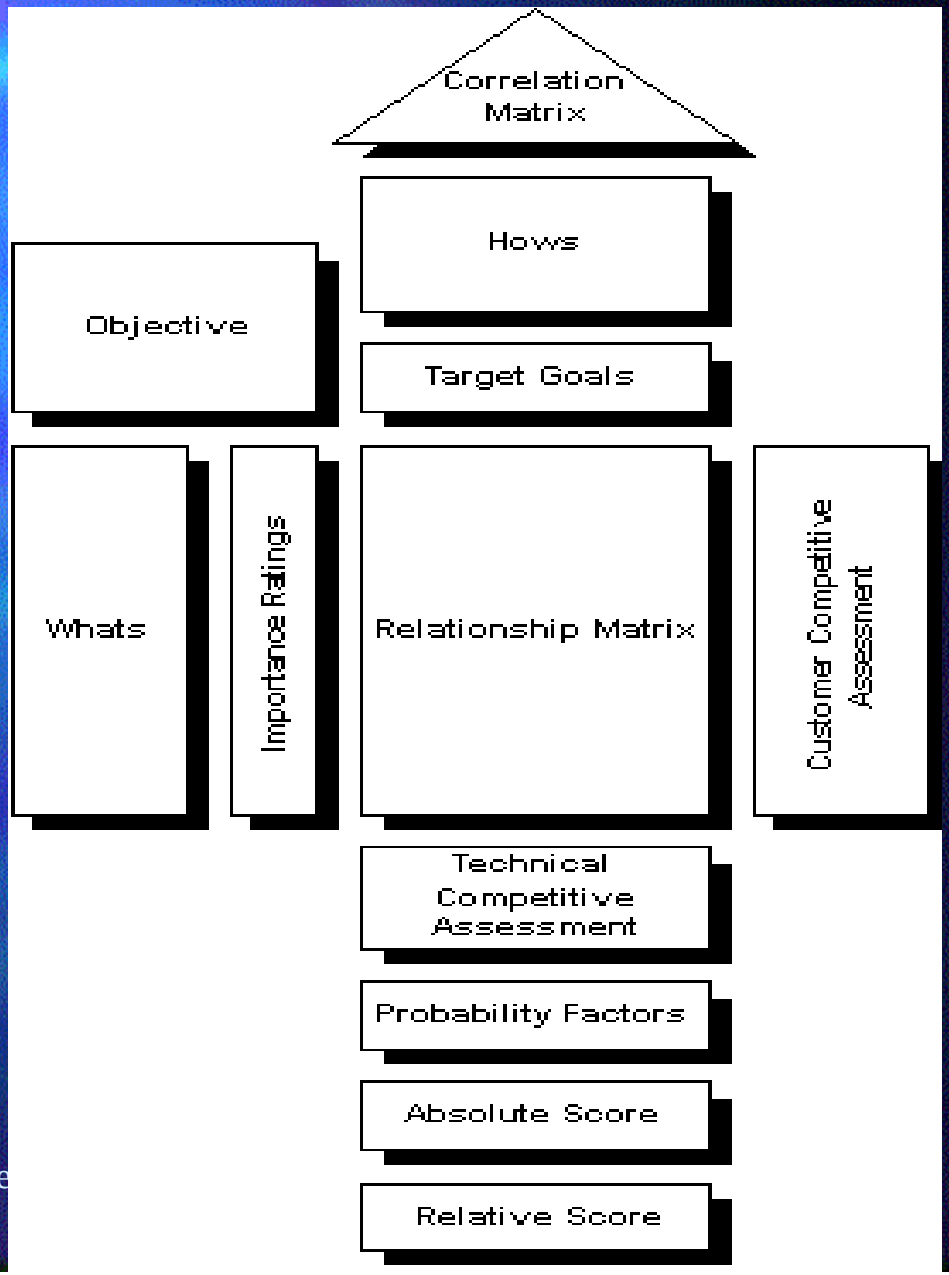
**TQM (Total Quality Management) studies in Japan have focused on the customers: a widely applied technique is, for instance, QFD (Quality Function Deployment).**

**QFD** is a method for translating customer requirements (ref. "*Voice of the Customer*") into appropriate technical requirements throughout the development and production of a product.

# House of Quality (HoQ)

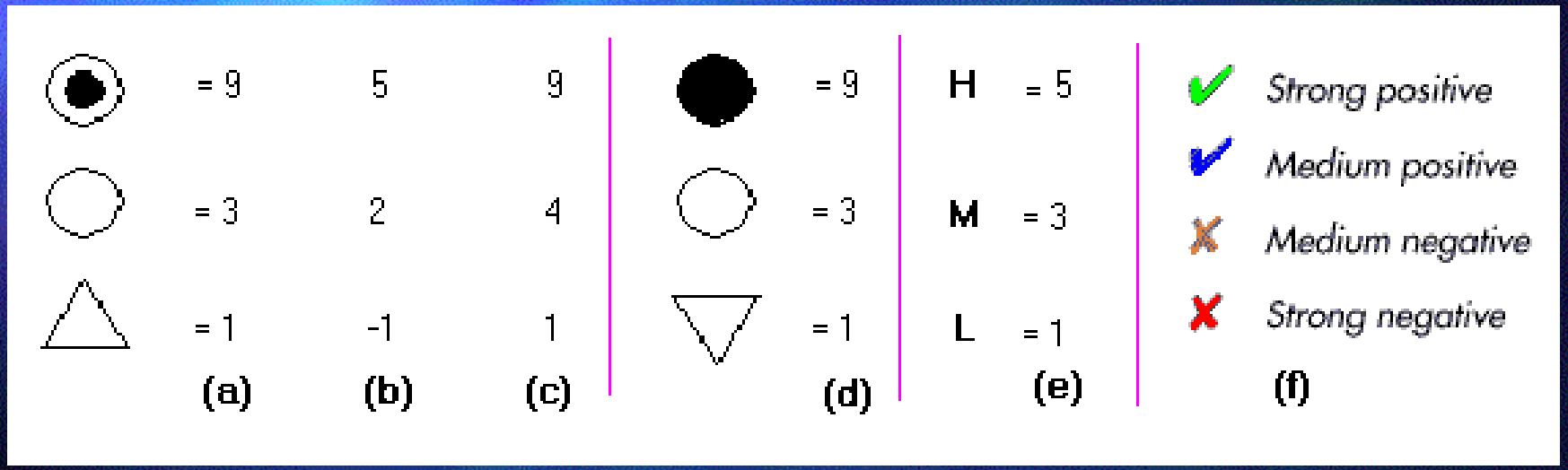
QFD includes a series of matrixes, as tools to represent data.

Most commonly used matrix: the "House of Quality" (**HoQ**)



# HoQ symbols

Every point discussed in the HoQ must be rated. In the figure, some of the most common rating and weights used in QFD studies and applications:



# QFD in Software Engineering

- Distributed QFD (**DQFD**) by *DEC*
- **Project QFD** by *Richard Zultner*
- Study by *Eriksson, McFadden and Tittanen* : focus on the need to join process and product analysis to check whether the user requirements concerning both the product and the project issues were correctly determined and to get the customers' acceptance of these points;
- **SPI/HoQ** model by *Ita Richardson*: a tool to help the implementation of SPI action plan for SMEs (using Bootstrap as the reference SPI model).
- Matrix of Change (**MoC**) project by the *Massachusetts Institute of Technology*: as useful guidelines for Change Management.

# QFD and Software Engineering

- **Conclusion**: QFD could be a useful tool for other Software Engineering applications

- **To be investigated**: can QFD be applied to improve the software Quality Models (QM) actually in use, and our QF technique?

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# Quality Models

A Quality Model (**QM**) is defined as:

- *the set of characteristics and relationships between them which provide the basis for specifying quality requirements and evaluating quality*
- *a structured set of properties required for an object of a class to meet the defined purposes*

# Quality Models

So a QM is given by the decomposition of a valuable object (process / product / organisation) in a list of:

- *characteristics*
- *sub-characteristics*
- *measures*

**Scope**: predict / assure / verify the achievement of a defined goal about the object before (+ during + after) producing it.

# Quality Models

The best known QMs for software are those by:

- McCall et al. (1977) [called **FCM - Factor/Criteria Model**]
- Boehm et al. (1978)
- ISO/IEC 9126 (1991 and 2000 updates)
- IEEE 1061 (1992)
- Dromey (1995)

# Quality Models

It is possible to classify them depending on the:

- **number of layers** (2, 3)

| *Layer* | **Boehm** | **McCall** | **ISO** | **IEEE** | **Dromey** |
|---|---|---|---|---|---|
| 1 | H-Level Charact. | Factor | Characteristic | Factor | H-Level Attribute |
| 2 | Primitive Charact. | Criteria | Subcharacteristic | Subfactor | Subordinate Attribute |
| 3 | (Metric) | (Metric) | (Metric) | Metric | |

- **number of relationships between first two layers** (1:n, n:m)

*p.e. McCall's model (**FCM**) -> every sub-characteristic is linked to one or more characteristics while in **ISO/IEC 9126** every characteristic has its own set of sub-characteristics*

# Quality Models

**General Problems in QMs**:

- insufficient list mapping with an everyday reality more and more complex
- little assistance in building quality into software
- individual interpretations of models and of its variables

# Quality Models

**But**: there is strength and usefulness in shared common interpretations, rather than individual interpretations of quality

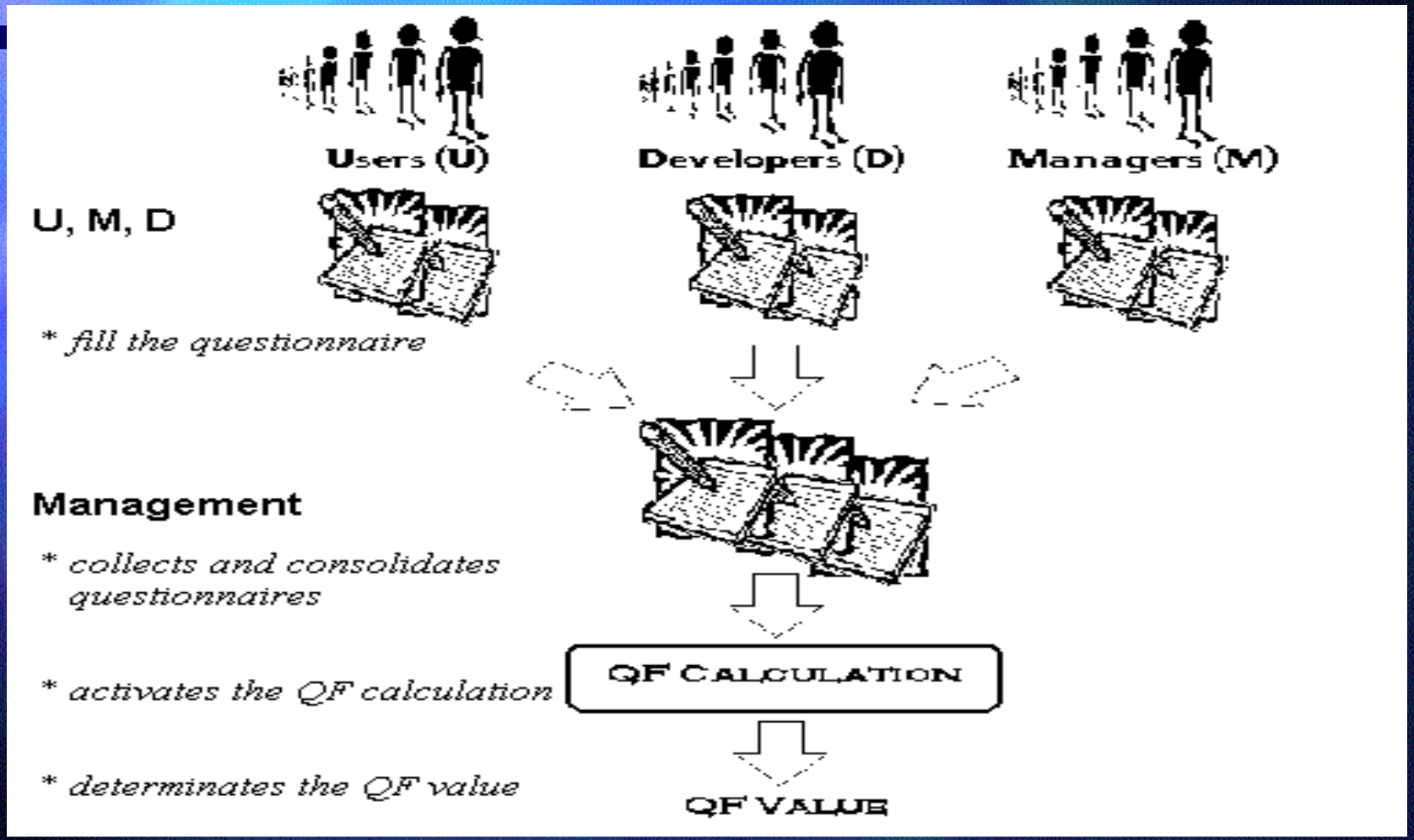
**Solution**: use of ISO standard because they represents the largest international consensus on a software quality model

# Quality Factor (QF) - *Buglione & Abran (1999)*

The Quality Factor (**QF**) technique consolidates into a single numerical value (based on ISO/IEC 9126 standard) integrating Users' (**U**), Developers' (**D**) and Managers' (**M**) opinions about the quality of the software being measured.

QF uses an *open* weight scale methodology (*does not force a single set of weights*).

# QF - the procedure flow



# QF: Improvements required

- QF applied for ex-post evaluation purposes
- QF with ISO 9126:1991 version only
- QF has a specific approach to match stakeholders' viewpoints: any other one?
- QF calculation use several tables: is it possible to simplify the procedure?

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# QF²D: a new approach

- **Challenge**: merging the QF technique into the QFD approach
- **Result**: an improved technique to be referred to as: Quality Factor through QFD (QF²D)

# Basic improvements to QF

- Multi-perspective evaluation (E, S, T) of software quality in the development / maintenance phases
  (*not only in the assessment phase*)
- Evaluation of QF on a percentage scale
  (*to obtain an easier intuitive understanding of results*)
- Use of ISO 9126 and 14598 series
  (*for software quality attributes and evaluation*)

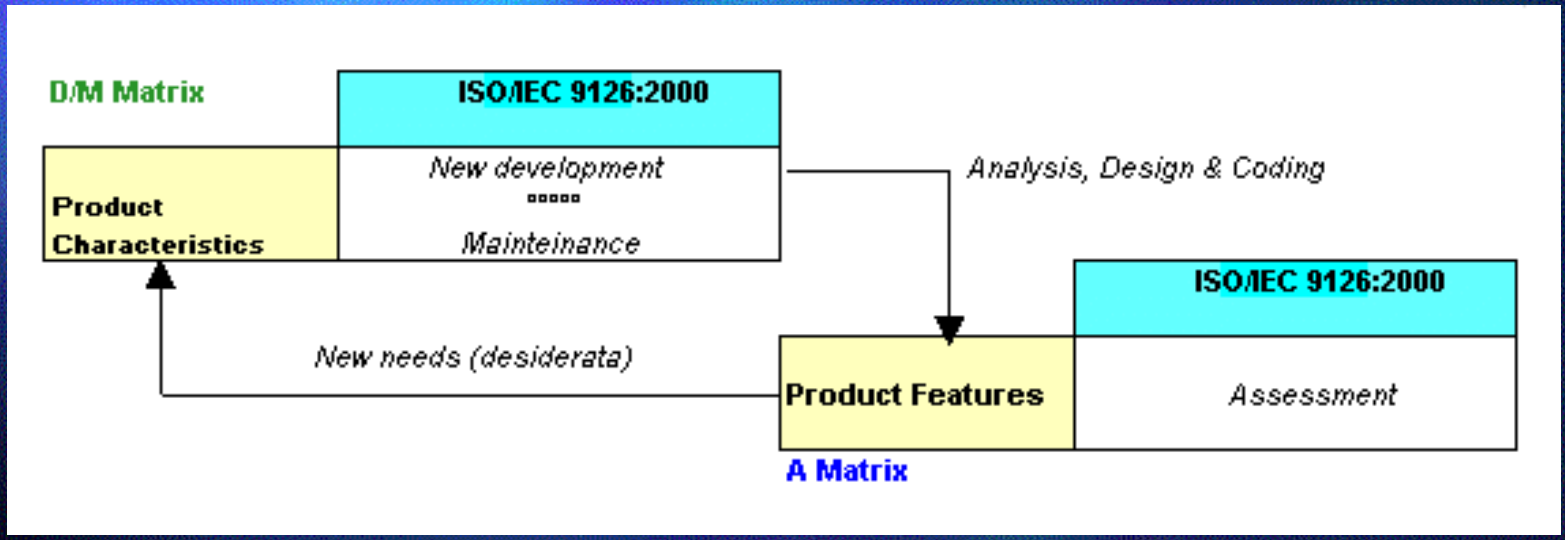
# Advantages from HoQ usage

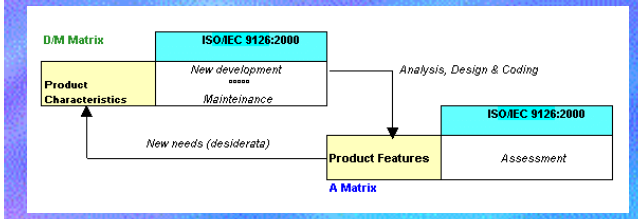
- Simplification and rationalisation of the QF method;
- Summarisation of all data in one table;
- Use of histograms to prioritise in a visual way the most relevant sub-characteristics and *target goals* of products to be evaluated

# QF²D lifecycle

**2 Matrices**:

- **D / M** (***D***evelopment / ***M***ainteinance)
- **A** (***A***ssessment)






# QF²D lifecycle - D/M matrix

**WHAT (rows)**:

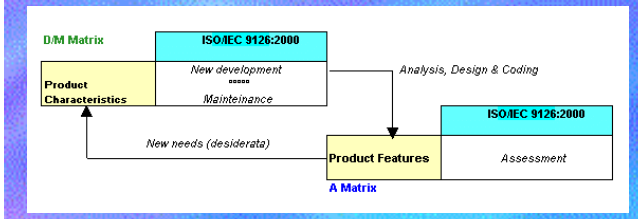
- expresses the *targets* by the three interest groups (E, S, T)
- priority fixed on a Likert scale (from 1 to 5)
- considers the three groups of stakeholders (well-known quality models like EFQM and Malcolm Baldrige also use their distinct viewpoints)

**HOW (columns)**:

- represents the list of the new upcoming ISO/IEC 9126 standard sub-characteristics (parts 2, 3 and 4)

In the Matrix:

- relationship between *user requirements* to be translated into product features and quality sub-characteristics expressed on the ISO/IEC 14598-1 scale (from 0 to 3), in place of the common QFD graphic symbols used in the HoQ




# QF²D lifecycle - A matrix

**WHAT (rows)**:

- represents the list of the new upcoming ISO/IEC 9126 standard sub-characteristics (parts 2, 3 and 4)
- priority fixed on a Likert scale (from 1 to 5)

**HOW (columns)**:

- expresses the *product features* of the assessed product
- consider the three groups of stakeholders, as in well-known quality models like EFQM and Malcolm Baldrige

In the Matrix:

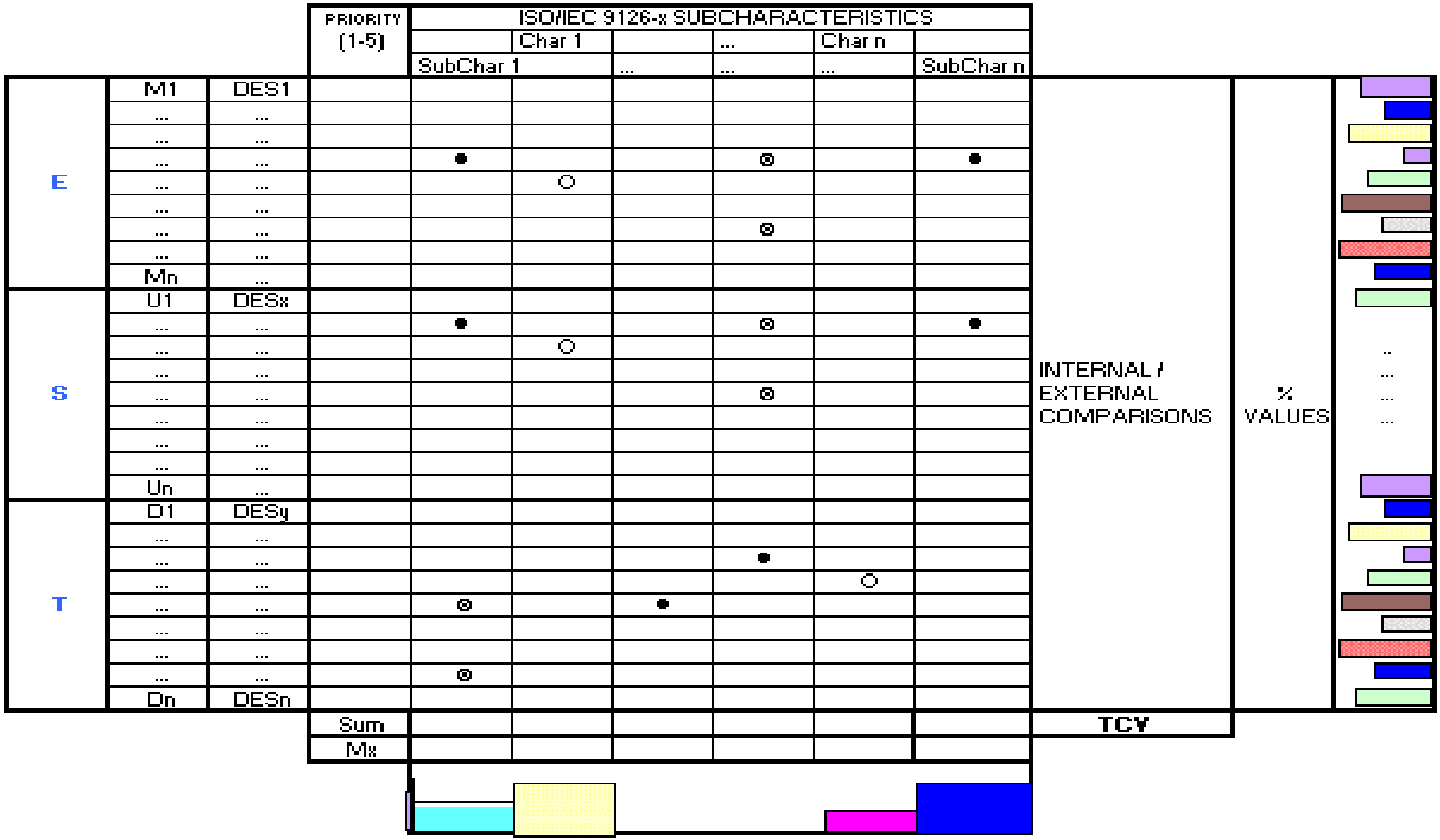
- relationship between *product features* and quality sub-characteristics expressed on the ISO/IEC 14598-1 scale (from 0 to 3), in place of the common QFD graphic symbols used in the HoQ

# QF$^2$D symbols

- **Foundation**: use of the ISO standards for SwEng
- **Application**: ISO/IEC 14598-1 rating scale applied to QFD-like symbols

| Mark | QF$^2$D Symbol | Rating | Global Rating |
|---|---|---|---|
| 3 | ● | Excellent | Satisfactory |
| 2 | ◎ | Good | |
| 1 | ❍ | Fair | |
| 0 | Blank | Poor / Absent | Unsatisfactory |

# QF²D matrices structure - D/M matrix example



# QF²D - the calculation

The instrument needed for the QF²D calculation is:

- HoQ-like table: **D/M** (Development / Mainteinance) or **A** (assessment) matrix

Template Excel available at:
**http://www.geocities.com/lbu_measure/qf/qf2d.htm**

# QF²D - the calculation (D/M matrix)

**6 Steps**:

① *Listing of the most relevant desiderata on the matrix*

② *Determination for each desiderata of:*

- *level of priority (1-5)*
- *which sub-characteristic(s) is (are) correlated it to the target*
- *which rating (0-3) of the sub-char is linked to the target (circle symbols)*

③ *Calculation of the sub-characteristics values (**SSV**)*

④ *Calculation of the whole characteristics values (**CV**)*

⑤ *Calculation of the Total Characteristics Value (**TCV**)*

⑥ *Determination of the final **QF2D** value (TCV / TCVmax)*

**Note**: using a spreadsheet solution, you can automatically calculate priorities (*histograms*) and delta values in the "Internal-external comparisons" zone of the matrix

# QF$^2$D: main advantages

- Use of new ISO 9126:2000 standard series;
- Not only an assessment of product but also of development/maintenance (*with feedback loop*);
- Use of ISO 14589-1 evaluation scale to express relationships in the HoQ table;
- Greater granularity in the whole product evaluation (*at the sub-characteristic level*);
- Use of a single table to collect data and visualise results (*for all participants from the three interest groups: E, S, T*)

# Example

**Assumptions**:

- 5 respondents to the questionnaire (1 manager, 2 users, 2 developers)
- 31 quality sub-characteristics used

# Example

Thus, it derives the following formulas for:

- **SCV**
- **CV**
- **TCV** (value, min, max)
- **QF²D**

| | | |
|---|---|---|
| **SCV** | $\sum_{j=1}^{x} PR_j * SCV_{j,z}$ | *Where*<br>**X**= no. Of desired features (D/M matrix) or the no. Of people choosing certain product features (A matrix)<br>**Z**= the sub-characteristic to evaluate |
| **CV** | $\sum_{i=f}^{l} \sum_{j=1}^{x} PR_j * SCV_{j,i}$ | *Where*<br>**X**= no. Of desired features (D/M matrix) or the no. Of people choosing certain product features (A matrix)<br>**F**= ordinal number of the first sub-char for that characteristic<br>**L**= ordinal number of the last sub-char for that characteristic |
| **TCV** | $\sum_{i=1}^{31} \sum_{j=1}^{x} PR_j * SCV_{j,i}$ | *Where*<br>**X**= no. Of desired features (D/M matrix) or the no. Of people choosing certain product features (A matrix) |
| **TCVmin** | X*0 | *Where*<br>**X**= no. Of desired features (D/M matrix) or the no. Of people choosing certain product features (A matrix) |
| **TCVmax** | X*465 | *Where*<br>**X**= no. Of desired features (D/M matrix) or the no. Of people choosing certain product features (A matrix)<br>465 = 31 (no of sub-char) * 3 (max rating) * 5 (max priority) |
| **Final Quality Value** | $QF^2D = \frac{TCV}{TCV_{max}}$ | |

# Example

After filling the QF²D table, this is the result:

| | | | PRIORITY (1-5) | SubChar 1 | | SubChar 30 | SubChar 31 | | |
|---|---|---|---|---|---|---|---|---|---|
| E | M1 | REQ1 | 1 | 3 | | 3 | 2 | | |
| S | U1 | REQ2 | 5 | 2 | | 3 | 2 | | |
| | U2 | REQ3 | 4 | 1 | ••• | 3 | 2 | | |
| T | D1 | REQ4 | 3 | 2 | | | 2 | | |
| | D2 | REQ5 | 2 | 0 | | 1 | 2 | | |
| | | Sum | | 23 | | 32 | 30 | **TCV =** | 787 |
| | | Mx | | 4,600 | | 6,400 | 6,000 | $TCV_{max}$ = | 2325 |

**QF2D =** 0,3385

| Symb | ISO Rating |
|---|---|
| ● | 3 |
| ◉ | 2 |
| ○ | 1 |
| | 0 |

# Example

And this is the analytic result, in order to evaluate it with more attention:

| | | Tot value | % | | % | Tot % |
|---|---|---|---|---|---|---|
| CV1 | ***Functionality*** | 117 | 14,87 | 1 Suitability | 2,92 | 14,87 |
| | | | | 2 Accuracy | 3,56 | |
| | | | | 3 Interoperability | 2,92 | |
| | | | | 4 Compliance | 2,16 | |
| | | | | 5 Security | 3,30 | |
| CV2 | ***Reliability*** | 122 | 15,50 | 6 Maturity | 4,07 | 15,50 |
| | | | | 7 Fault tolerance | 1,52 | |
| | | | | 8 Recoverability | 4,83 | |
| | | | | 9 Compliance | 5,08 | |
| CV3 | ***Usability*** | 112 | 14,23 | 10 Understandability | 2,29 | 14,23 |
| | | | | 11 Learnability | 2,41 | |
| | | | | 12 Operability | 2,29 | |
| | | | | 13 Attractiveness | 4,45 | |
| | | | | 14 Compliance | 2,80 | |
| CV4 | ***Efficiency*** | 78 | 9,91 | 15 Time behaviour | 2,92 | 9,91 |
| | | | | 16 Resource utilization | 1,91 | |
| | | | | 17 Compliance | 5,08 | |
| CV5 | ***Maintainability*** | 123 | 15,63 | 18 Analyzability | 3,56 | 15,63 |
| | | | | 19 Changeability | 3,18 | |
| | | | | 20 Stability | 3,56 | |
| | | | | 21 Testability | 2,80 | |
| | | | | 22 Compliance | 2,54 | |
| CV6 | ***Portability*** | 116 | 14,74 | 23 Adaptability | 3,05 | 14,74 |
| | | | | 24 Installability | 4,45 | |
| | | | | 25 Replaceability | 1,02 | |
| | | | | 26 Co-existence | 3,30 | |
| | | | | 27 Compliance | 2,92 | |
| CV7 | ***Quality in Use*** | 119 | 15,12 | | 3,05 | 15,12 |
| | | | | | 4,19 | |
| | | | | | 4,07 | |
| | | | | | 3,81 | |
| | ***TCV*** | 787 | 100,00 | | | |

# Example

Two levels of comparison are possible after filling the A matrix:

- **higher level**: between the 2 QF$^2$D values
- **lower level**: among the sub-char evaluation from the D/M to the A matrix

The results from this analysis will represent the input for the next D/M step.

# Conclusions & Prospects

- QF$^2$D calculation: for a more objective software quality measurement including a multi-perspective viewpoint (E, S, T) and it leverages the QFD (Quality Function Deployment) technique
- QF$^2$D procedural flow is much simpler
- This technique is aligned with the upcoming version of ISO/IEC 9126:2000

# Conclusions & Prospects

- QF$^2$D is very flexible: it can incorporate a variable number of target/product characteristics (*to derive the final quality value*)
- QF$^2$D can be used separately or jointly with the QEST/LIME models
  - *focussing either on a qualitative assessment only or as the qualitative assessment within a full multidimensional performance assessment*

# Question Time

Thank you for your attention!

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