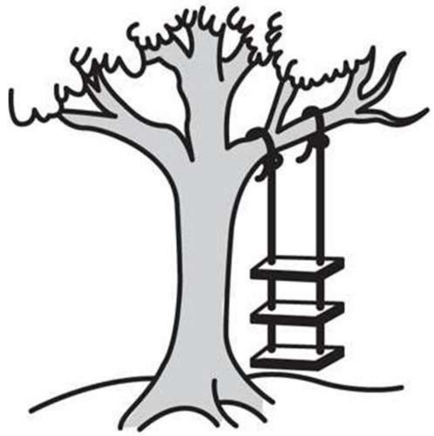
DESIGN METHODOLOGY PROBLEMS AND SOLUTIONS

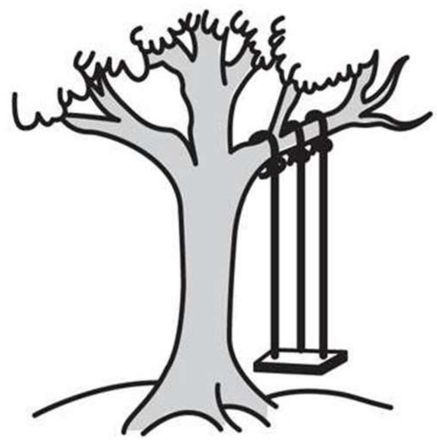
FROM UNDERSTANDING THE PROBLEM TO SELECTING THE BEST CONCEPT

Ernő Baka GT3

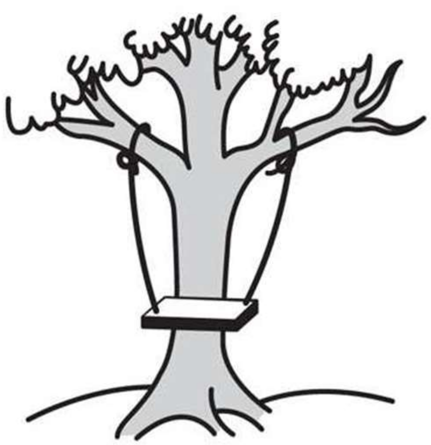
BME GÉP- ÉS TERMÉKTERVEZÉS TANSZÉK
BME DEPARTMENT OF MACHINE AND PRODUCT DESIGN

„DIFFERENT THINKING”

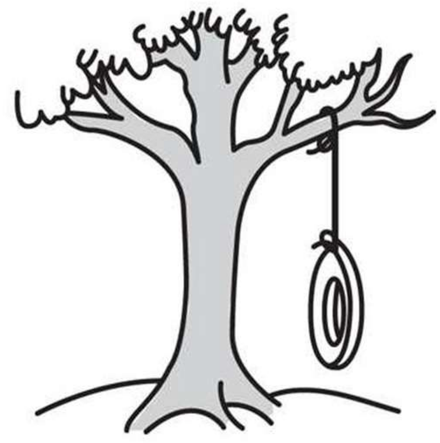

As described by sales


As designed by engineering

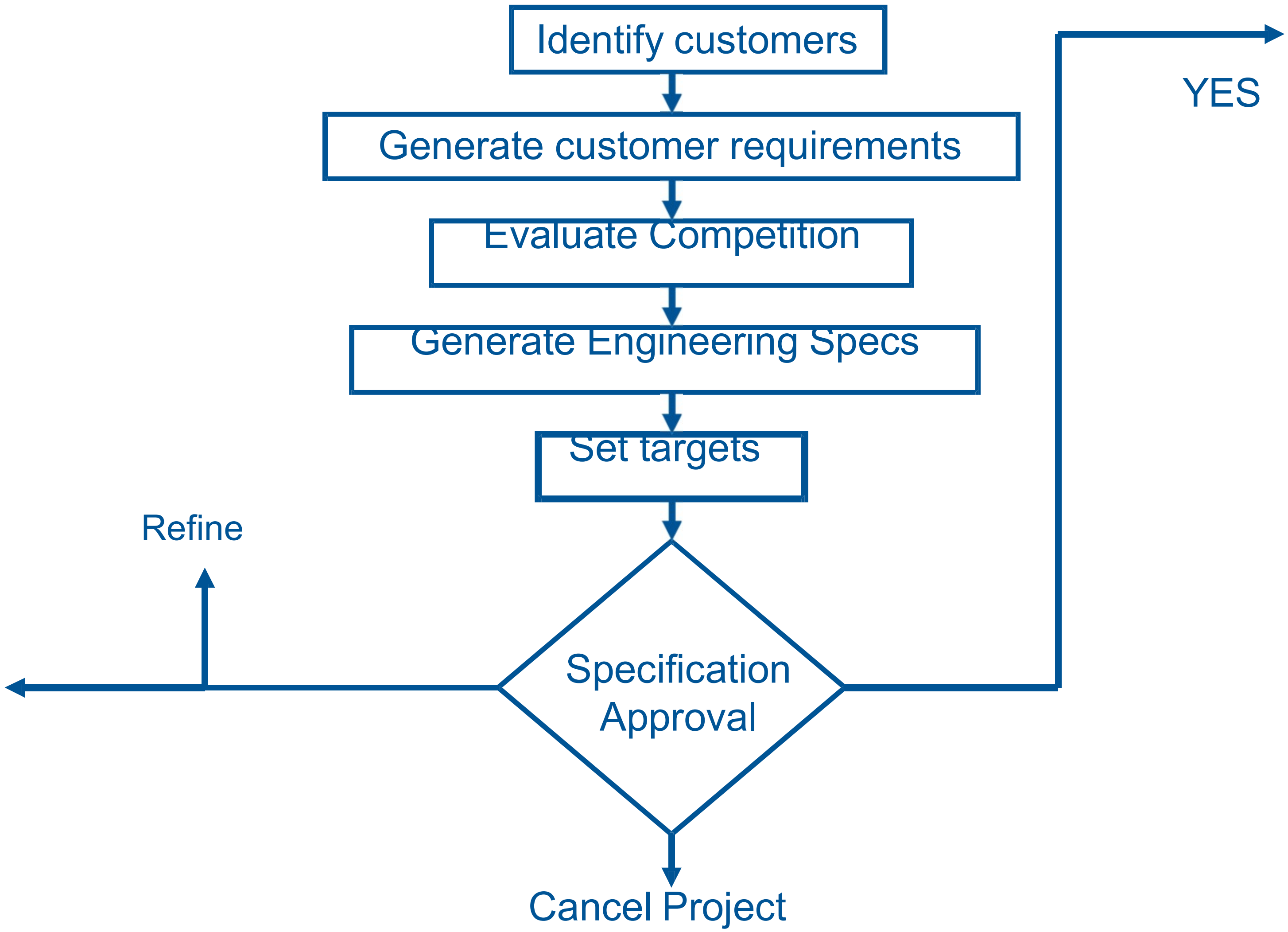

What manufacturing thought was wanted


As manufactured and shipped


As installed at the user’s site.


What the user wanted.

I just wanted a tree swing


Identify customers
Generate customer requirements
Evaluate Competition
Generate Engineering Specs
Set targets
Specification Approval
YES
Refine
Cancel Project

DEVELOPMENT OF ENGINEERING SPECIFICATIONS

- **Translate** customer requirements to *quantitative* specifications of performance, size, weight, cost, etc.

Quantitative & qualitative always influence each other

- Some requirements may only translate into *qualitative* specifications, or *features*, such as appearance, adaptability, serviceability, etc.

QUALITY FUNCTION DEPLOYMENT (QFD)

- Proven to reduce **time** and **cost** of product development
- 1995 survey shows that **69**% of 150 US companies use **QFD**
- Separates the *what* needs to be designed from the *how* the design will work and look
- House of Quality

QFD HOUSE OF QUALITY IN GENERAL

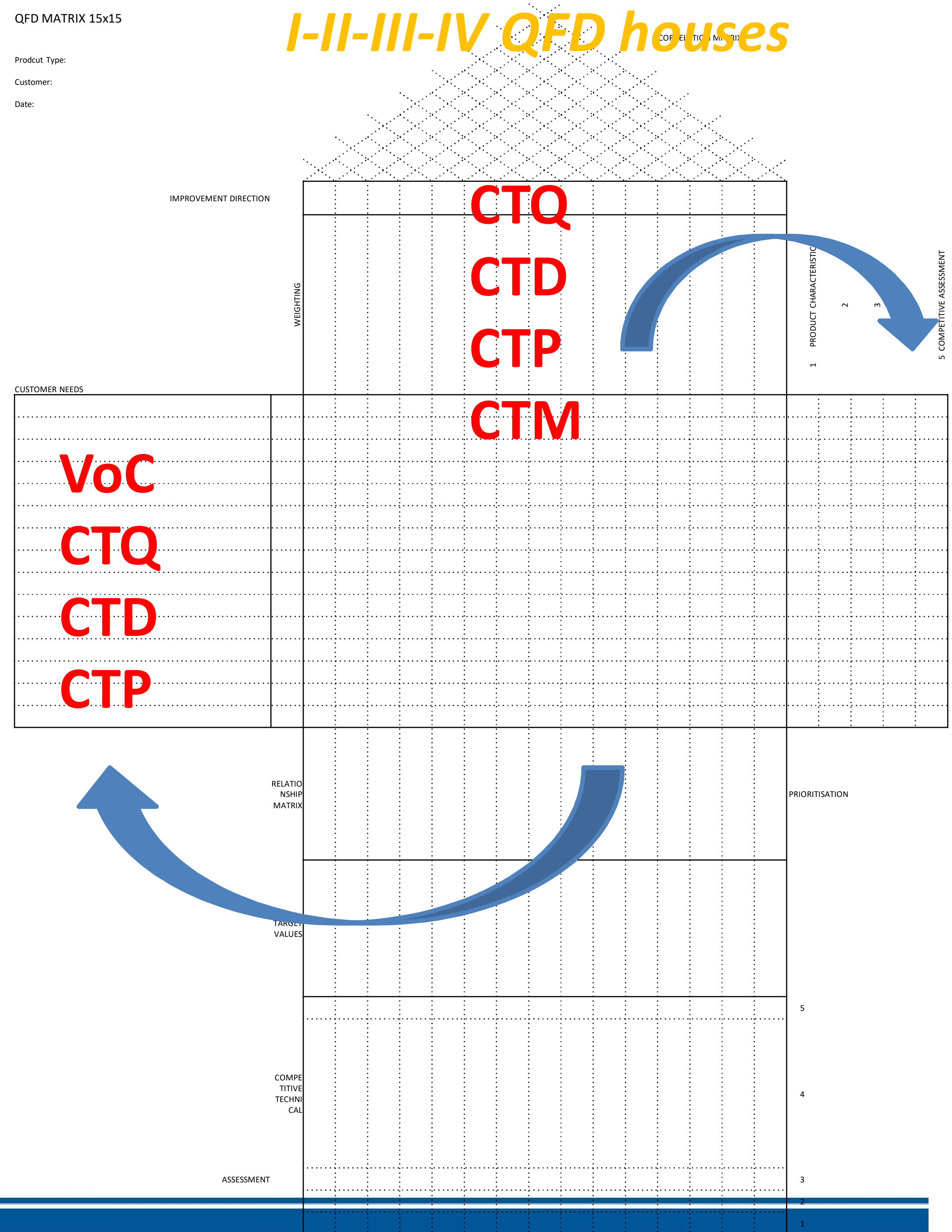
QFD quality function deployment, helps to describe the product fully and clearly. In a proper product description we do **Product Solution Scoping**. We describe NEEDS, FUNCTIONS AND PERFORMANCE.

We gathering the Voice of the Customer then we capture customer needs. (interviews, surveys)

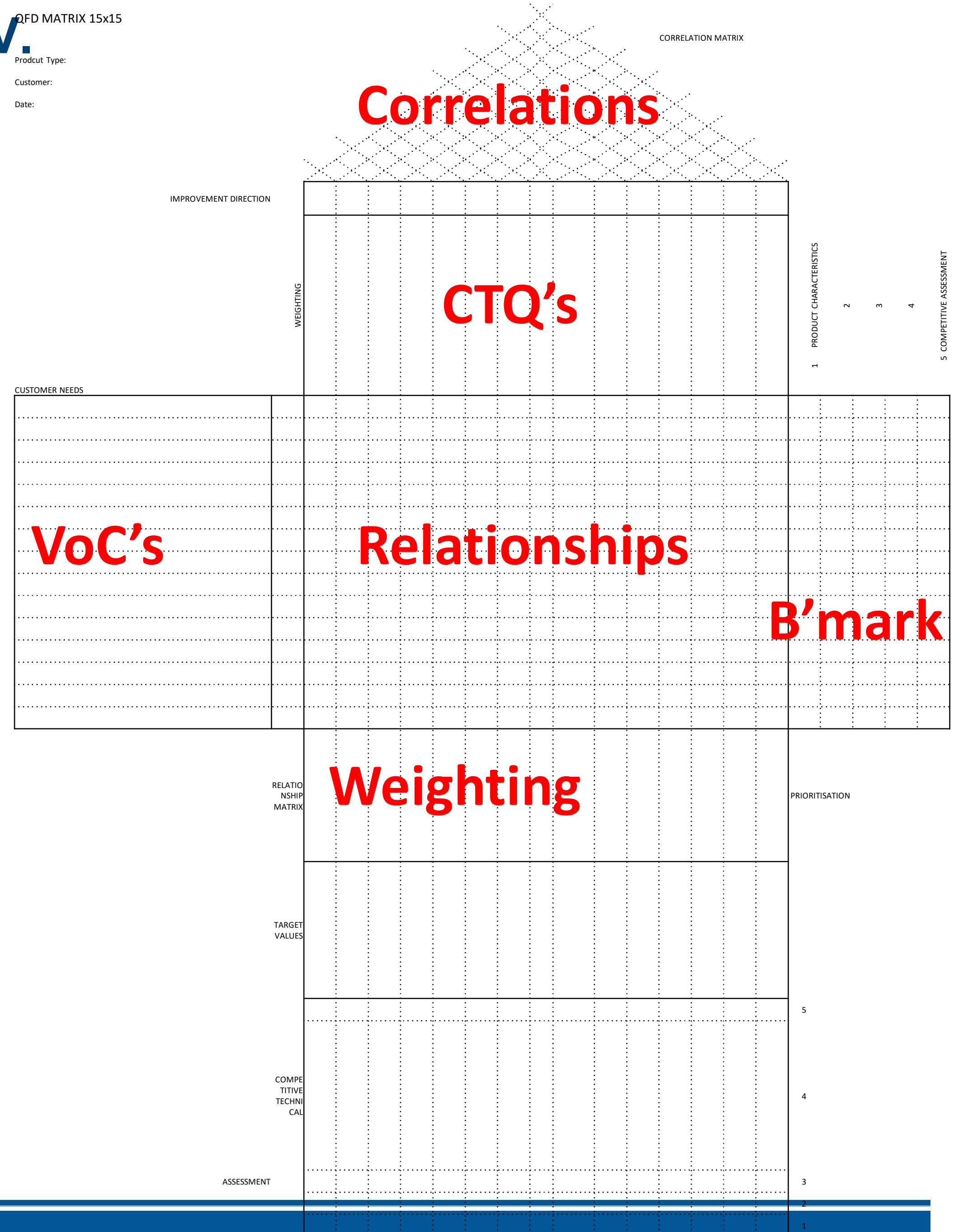
We categorise and proioritise. (kano, affinity, pairwise)

We conduct FAST functional analysis. (funcional family tree)

We translate the Voice of the Customer **VoC** to measurable variables.



QFD HOUSE OF QUALITY I. II. III. IV.



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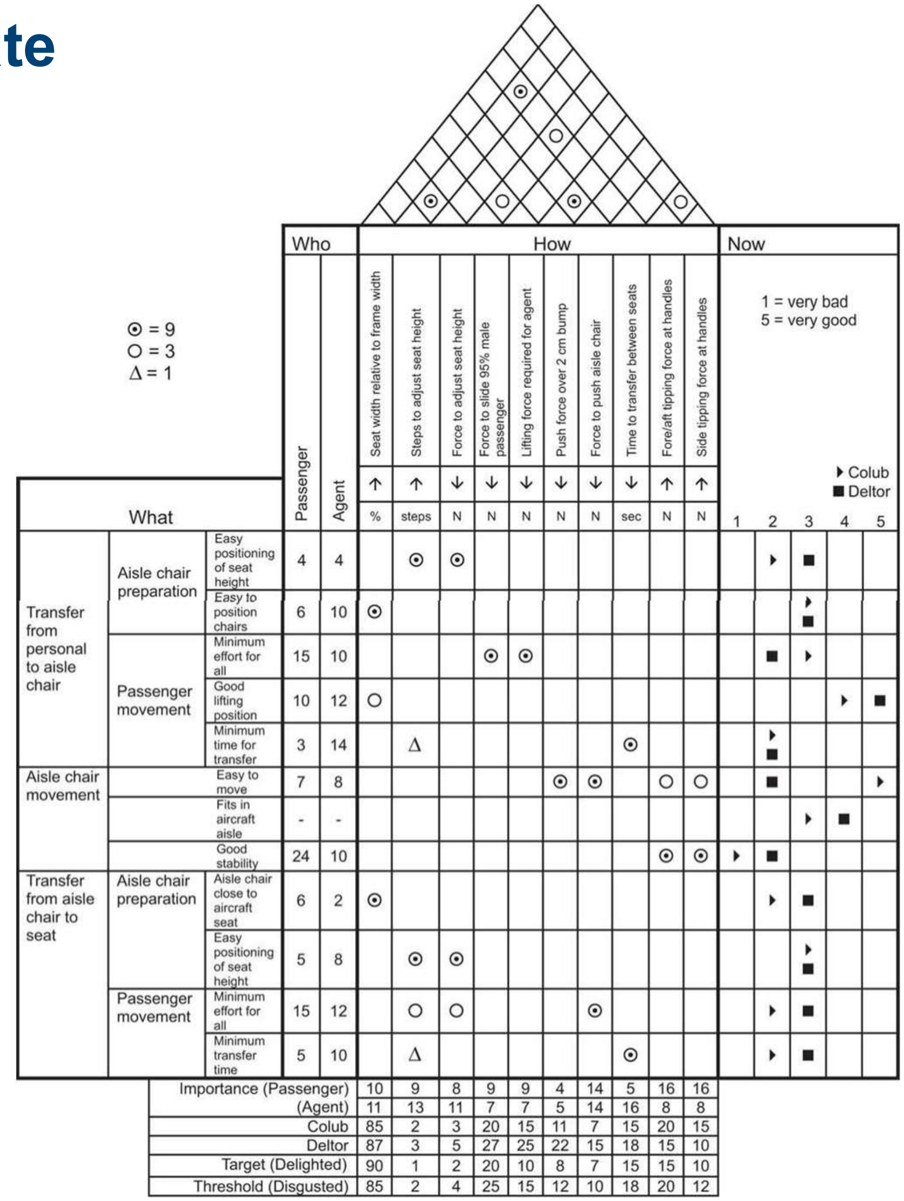
CTQ's
↓
CTD's
↓
CTP's
↓
CTM's

QFD general template



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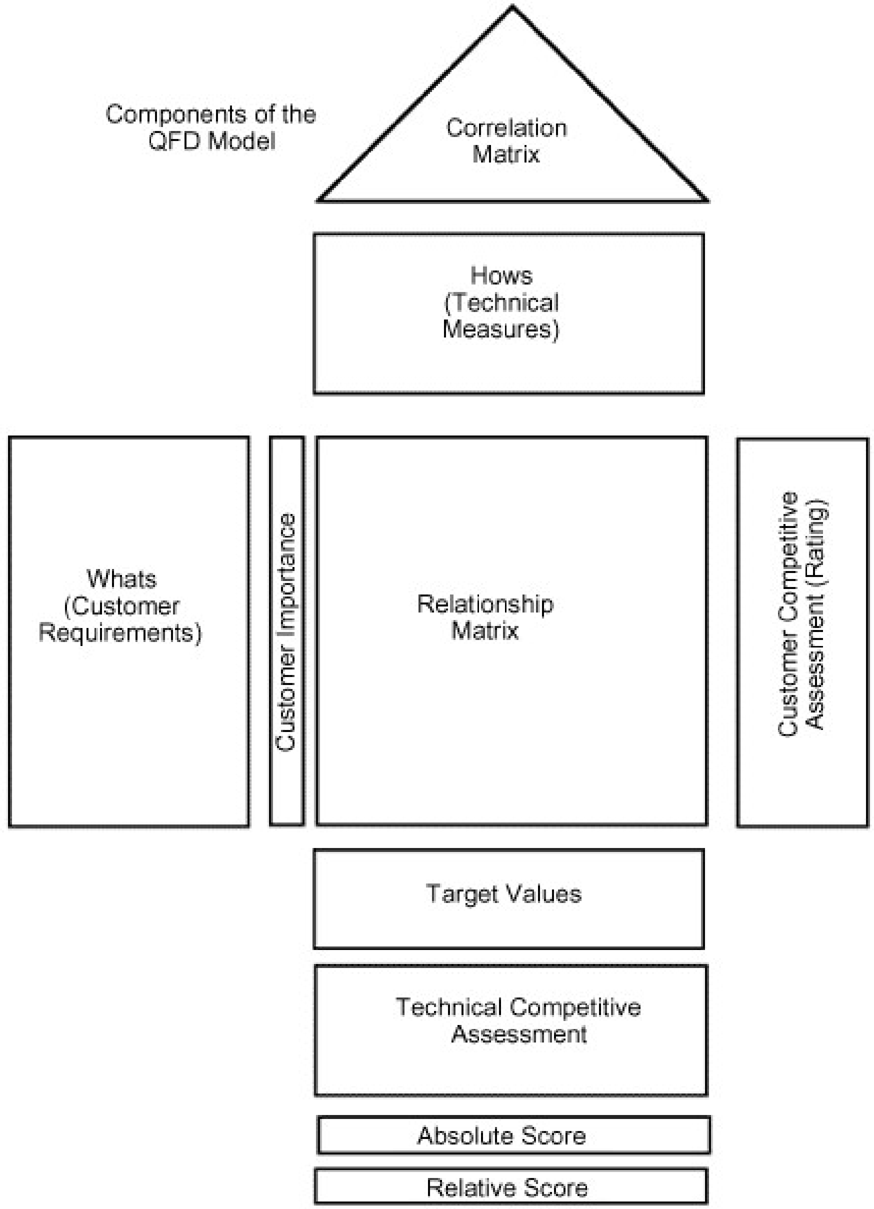
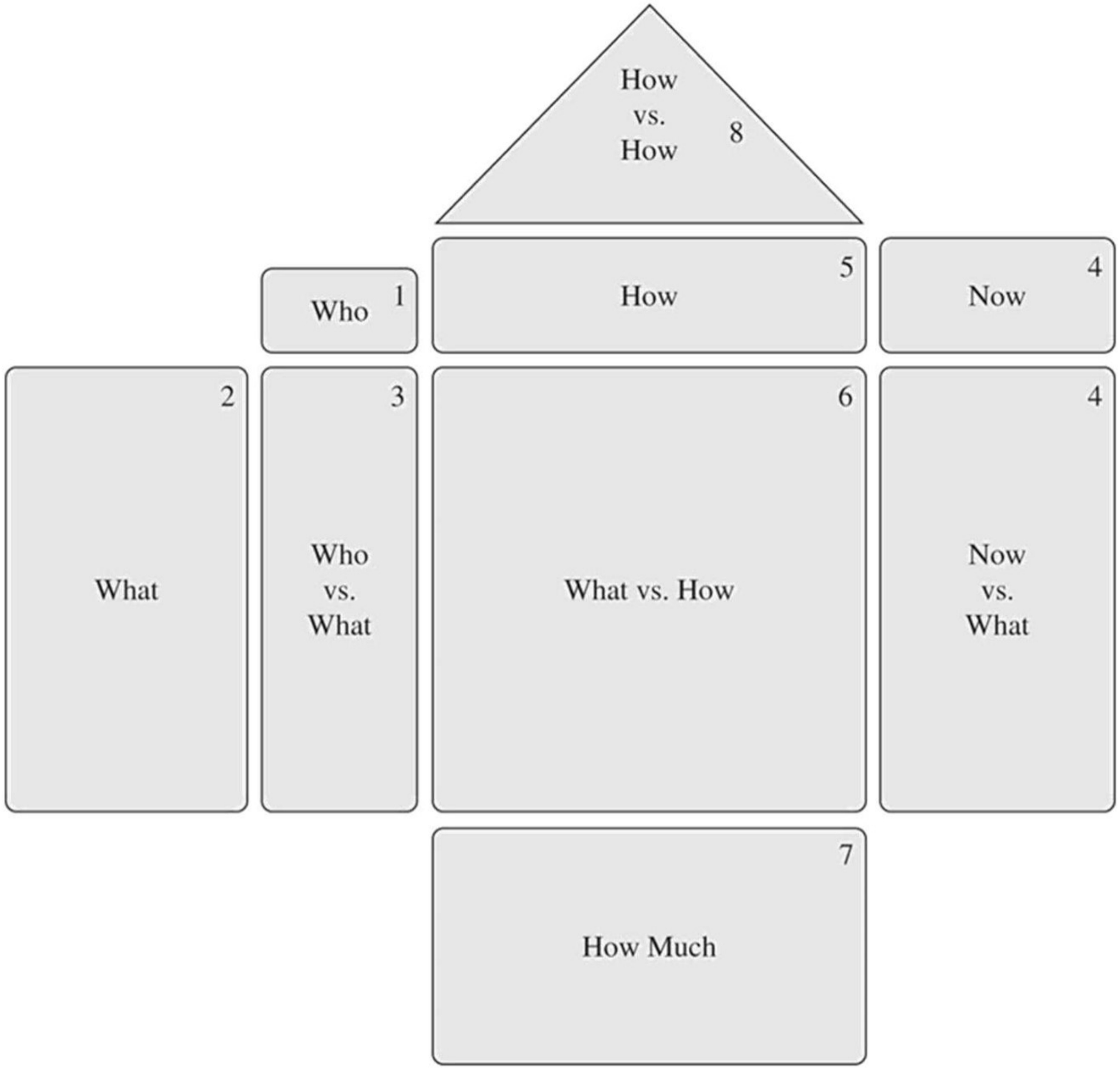
QFD


Components of the QFD Model
Correlation Matrix
Hows (Technical Measures)
Whats (Customer Requirements)
Customer Importance
Relationship Matrix
Customer Competitive Assessment (Rating)
Target Values
Technical Competitive Assessment
Absolute Score
Relative Score

QFD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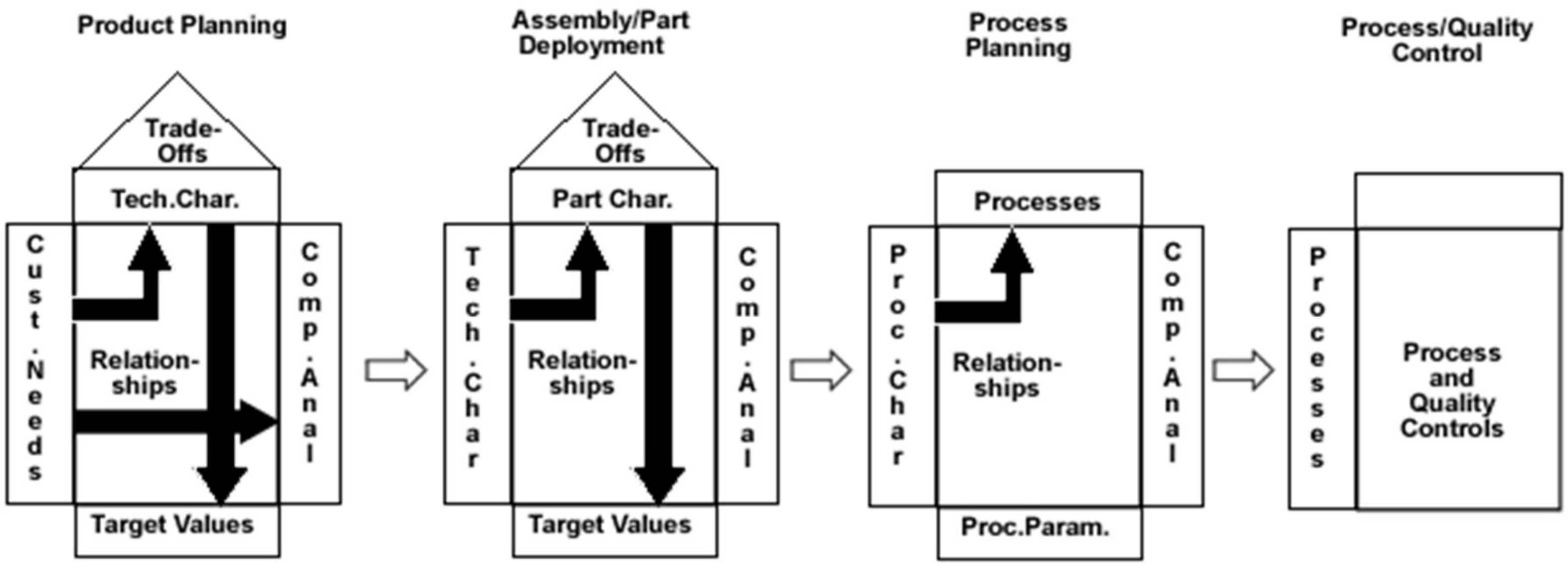
QFD (the 4 quality house)



- Define & prioritize customer needs
- Analyze competitive opportunities
- Plan a product to respond to needs & opportunities
- Establish critical characteristic target values

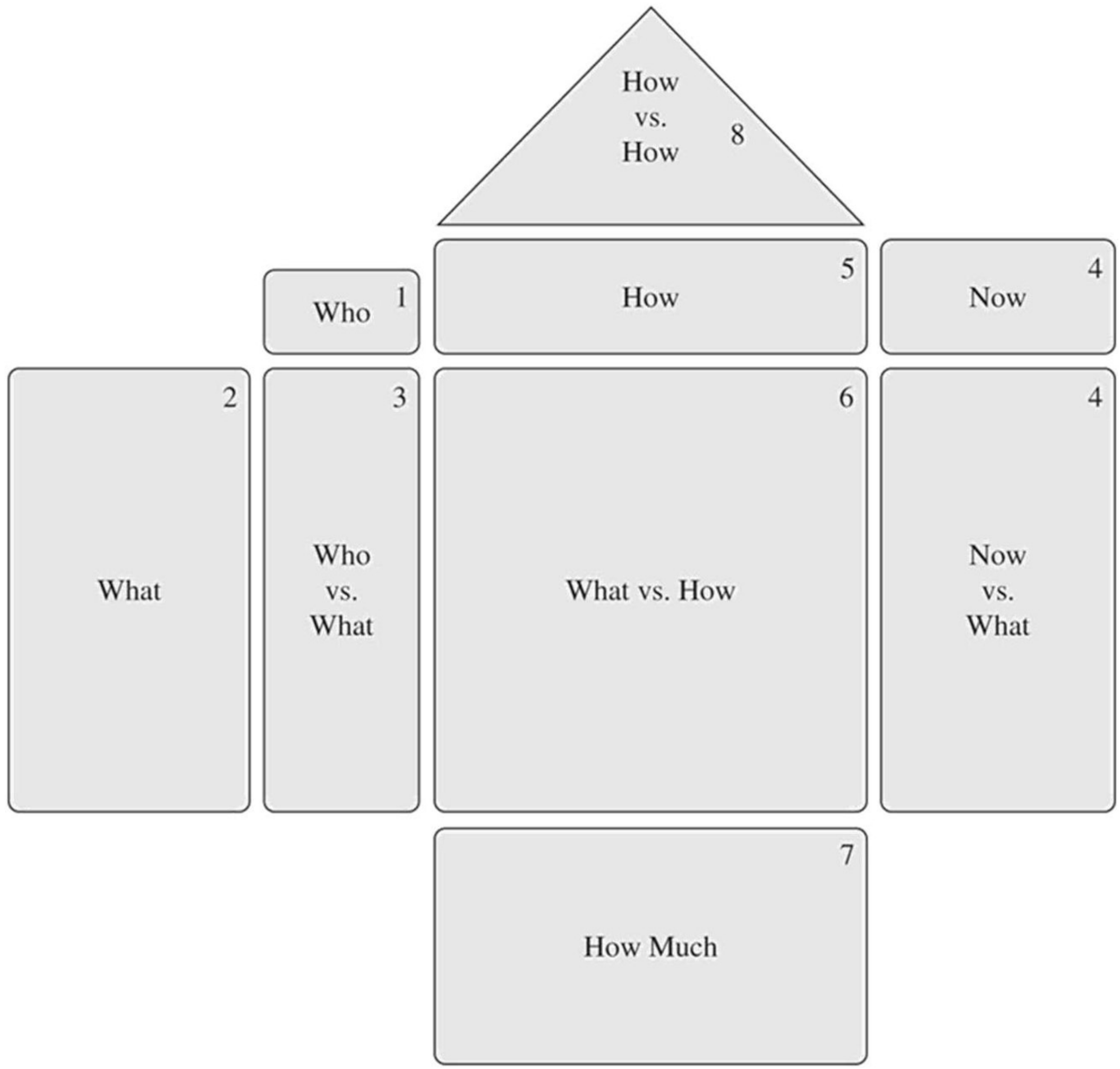
- Identify critical parts & assemblies
- Flowdown critical product characteristics
- Translate into criticalpart/assy characteristics & target values

- Determine critical processes & process flow
- Develop production equipment requirements
- Establish critical process parameters

- Determine critical part and process characteristics
- Establish process control methods & parameters
- Establish inspection & test methods & parameters

CTQ's **CTD's** **CTP's** **CTM's**

QFD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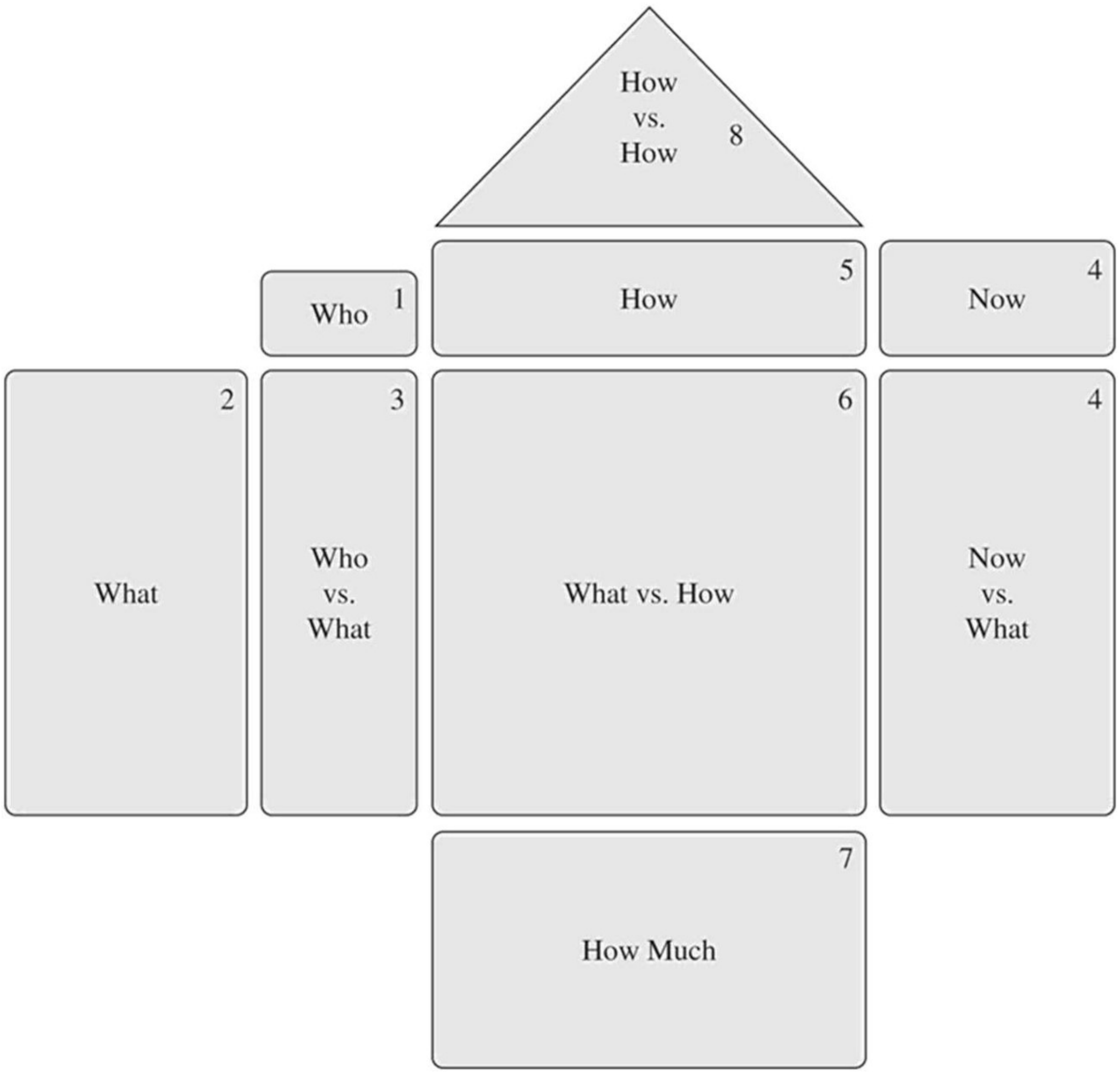
QFD, STEP 1: IDENTIFY CUSTOMERS ("WHO")

- Consumer
- Management
- Manufacturing personnel
- Marketing/Sales staff
- Service personnel
- Standards organizations (e.g., ANSI, UL, ASTM, etc.)

QFD



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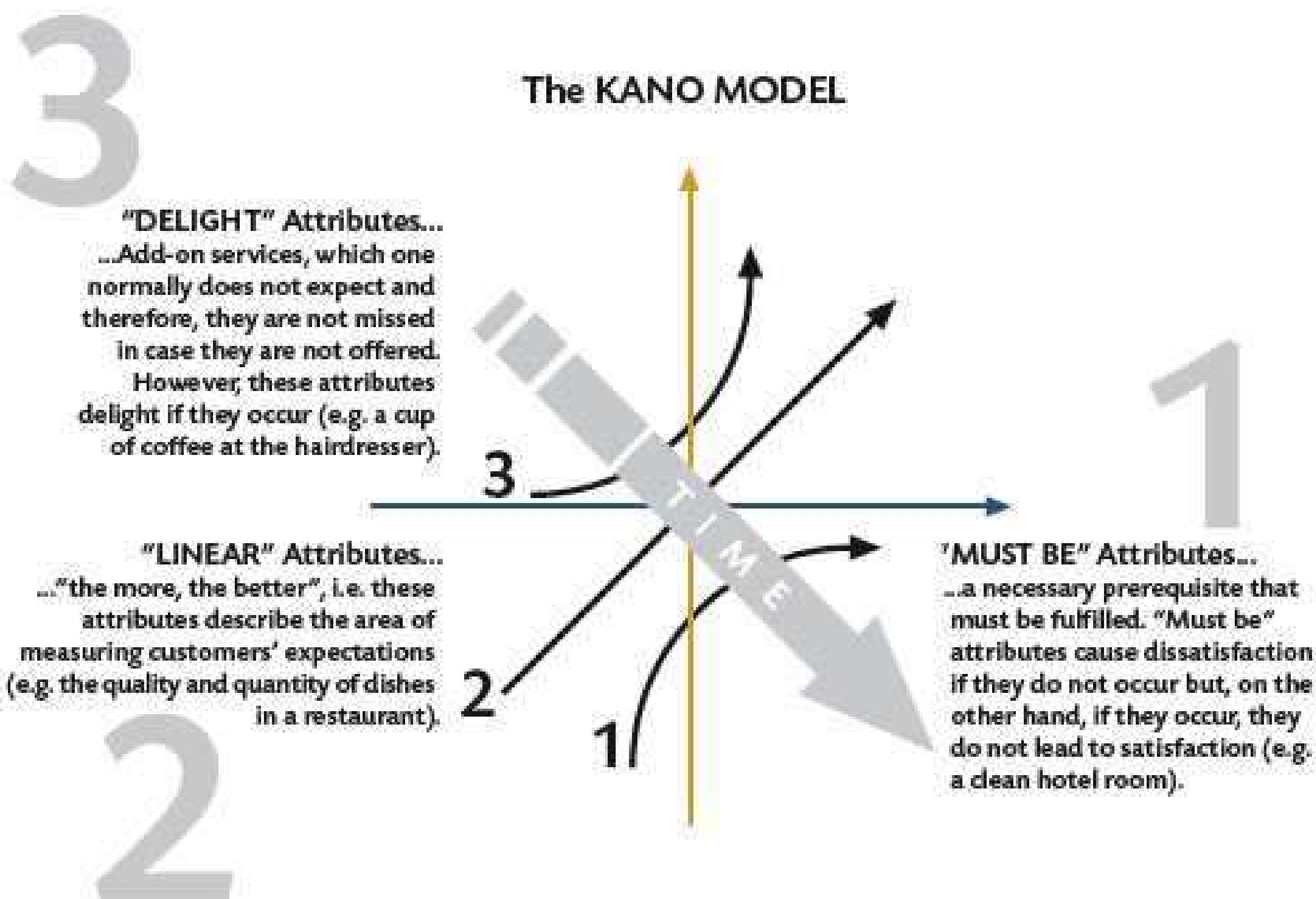
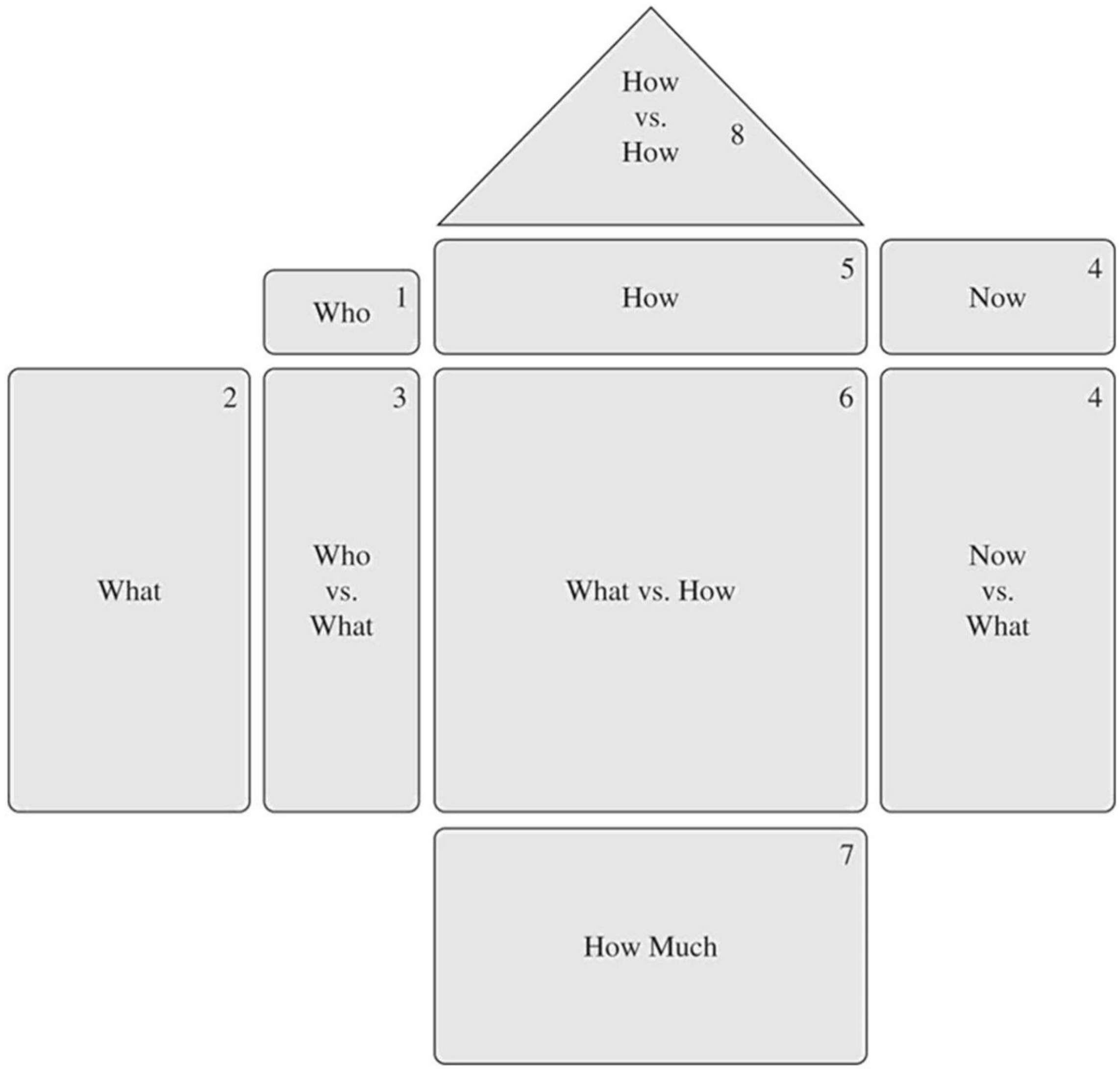
QFD, STEP 2: DETERMINE CUSTOMER REQUIREMENTS (“WHAT”)

- Customer satisfaction
  - *Basic*, *performance*, & *excitement* qualities
- Collection methods
  - Written surveys
  - Focus groups
- Types of requirements

QFD, STEP 2: DETERMINE CUSTOMER REQUIREMENTS (“WHAT”)



QFD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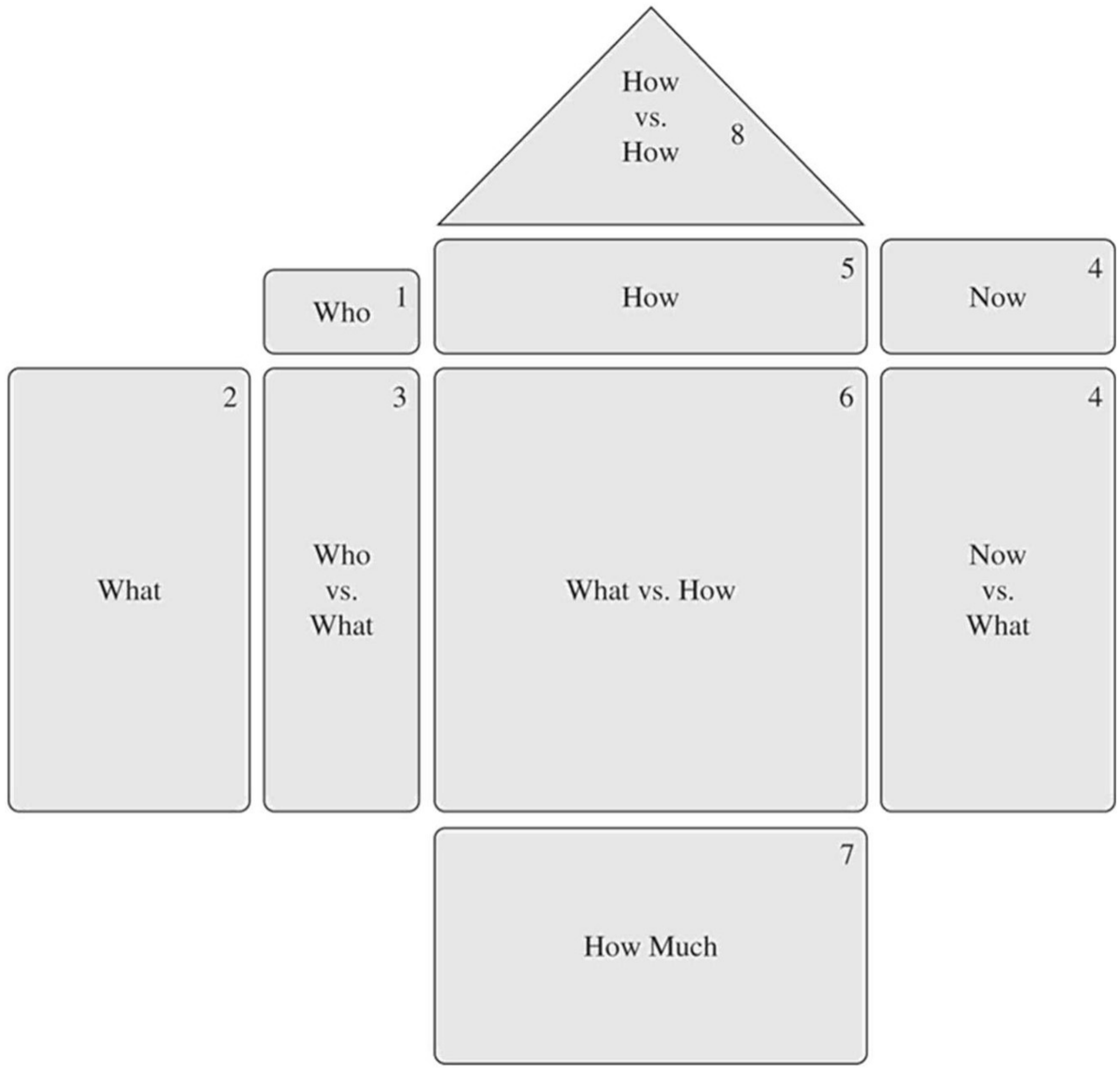
QFD, STEP 3: DETERMINE RELATIVE IMPORTANCE OF REQUIREMENTS ("WHO VS. WHAT")

- Survey several representatives from each customer group
- Requirements are either "ranked" or "weighted" within each customer group
  - fixed sum weighting method is suggested, where a sum (e.g., 100 points) is distributed among the requirements

QFD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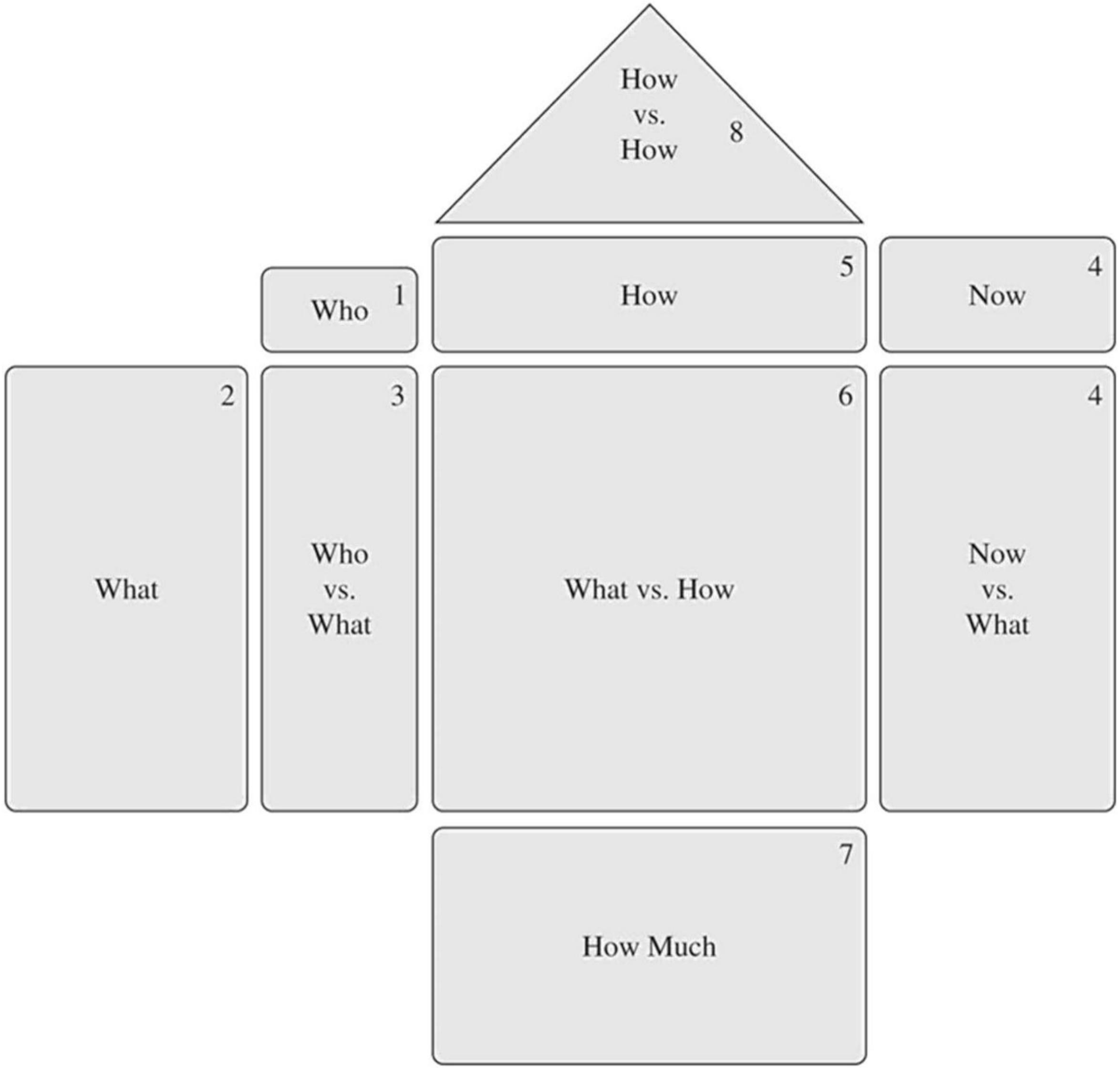
QFD, STEP 4: IDENTIFY AND EVALUATE THE COMPETITION ("NOW VS. WHAT")

- Competition benchmarking
- Compare each competing product with customer requirements
- Subjective comparison – use 1 to 5 scale

  1 = design does not meet requirement at all

  5 = design fulfills requirement completely

QFD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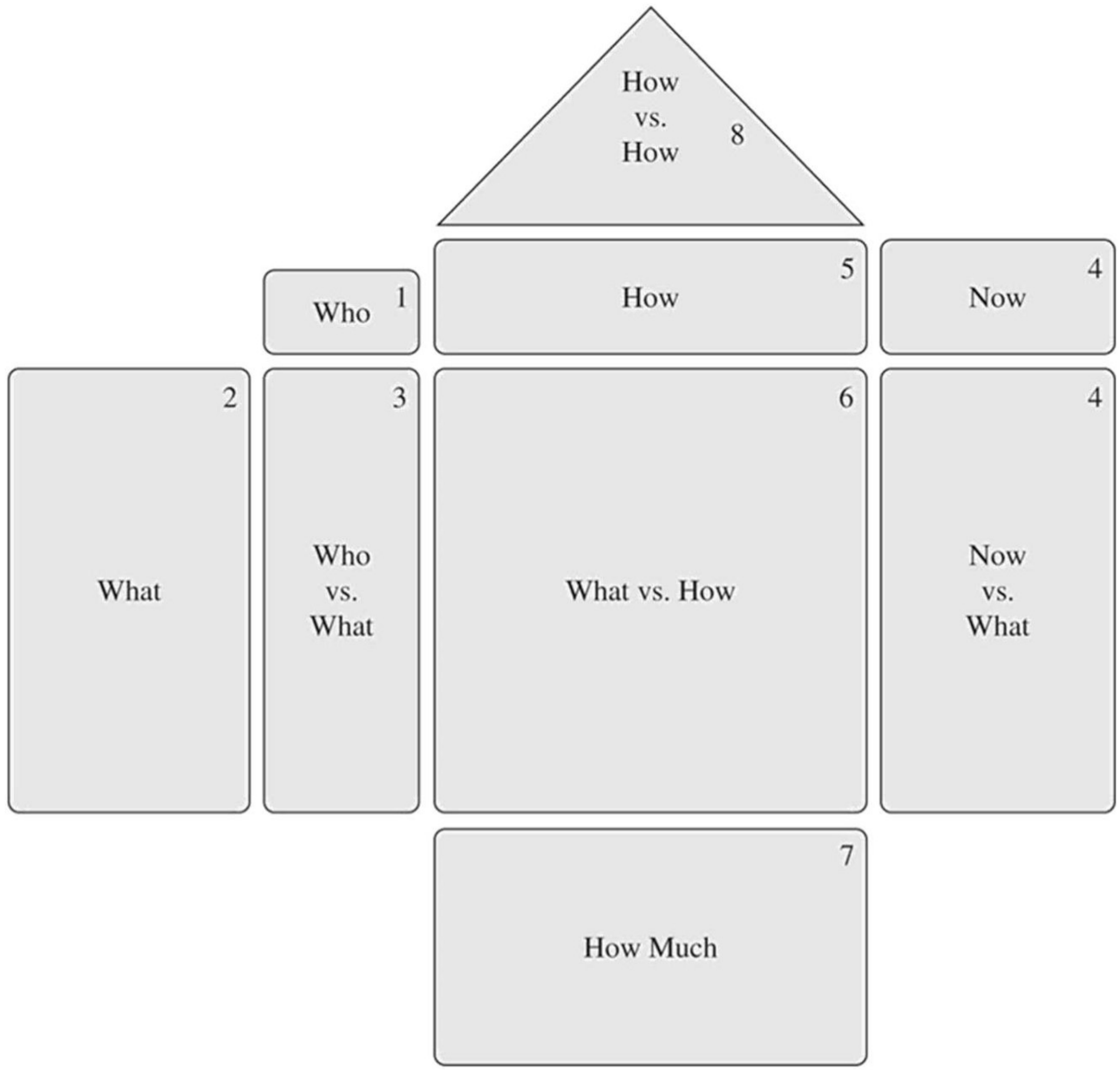
QFD, STEP 5: GENERATE ENGINEERING SPECIFICATIONS ("HOW")

- Develop parameters that tell *how* each customer requirement has been met
- Find all possible ways to measure each customer requirement
- Abstract requirements need refinement

QFD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QFD, STEP 6: RELATE CUSTOMERS' REQUIREMENTS TO SPECIFICATIONS ("WHAT VS. HOW") (Relationship Matrix)

- Rate strength of relationship between engineering specification to each customer requirement

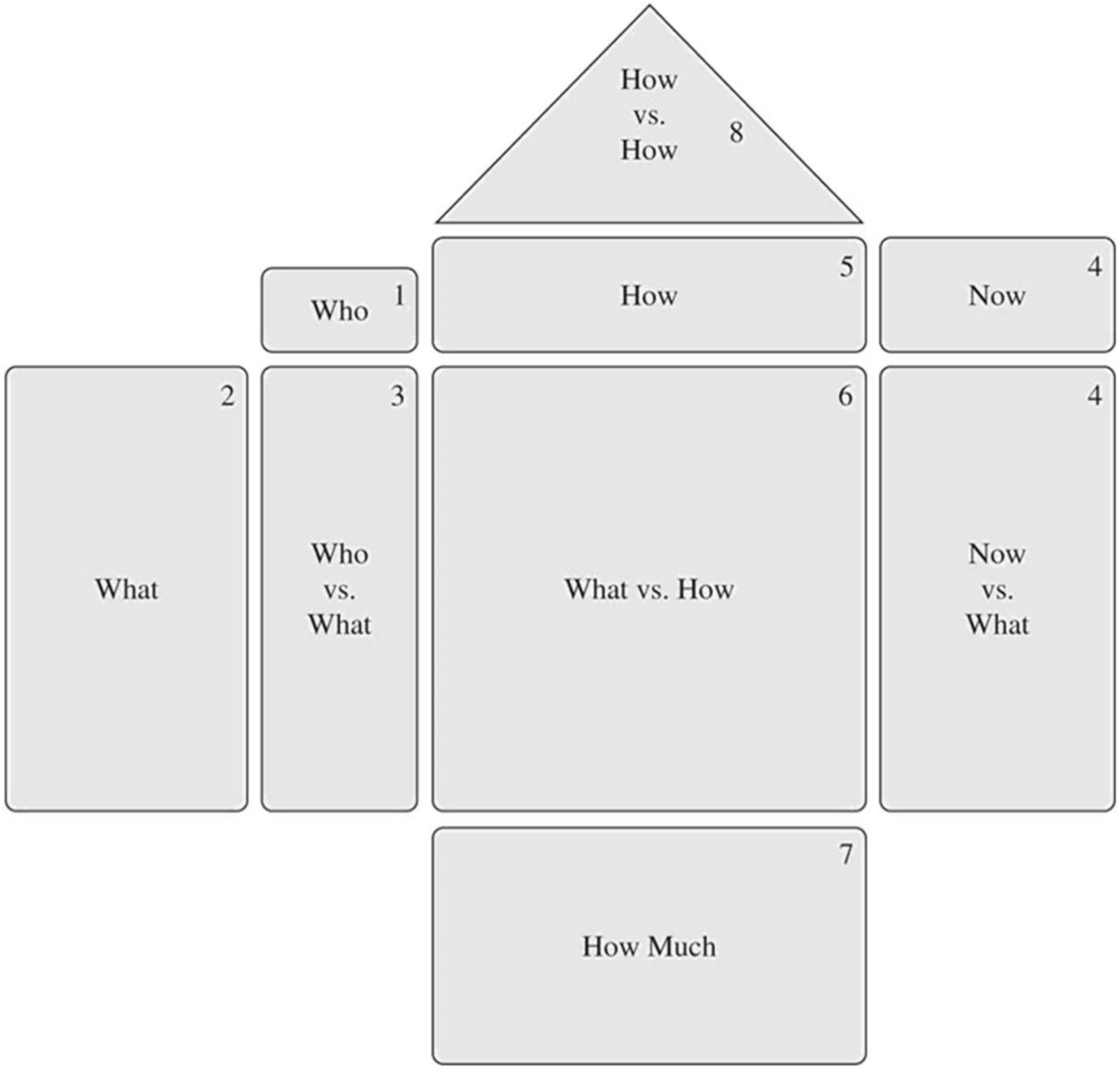
● = strong relationship

□= medium relationship

= weak relationship

Blank = no relationship

QFD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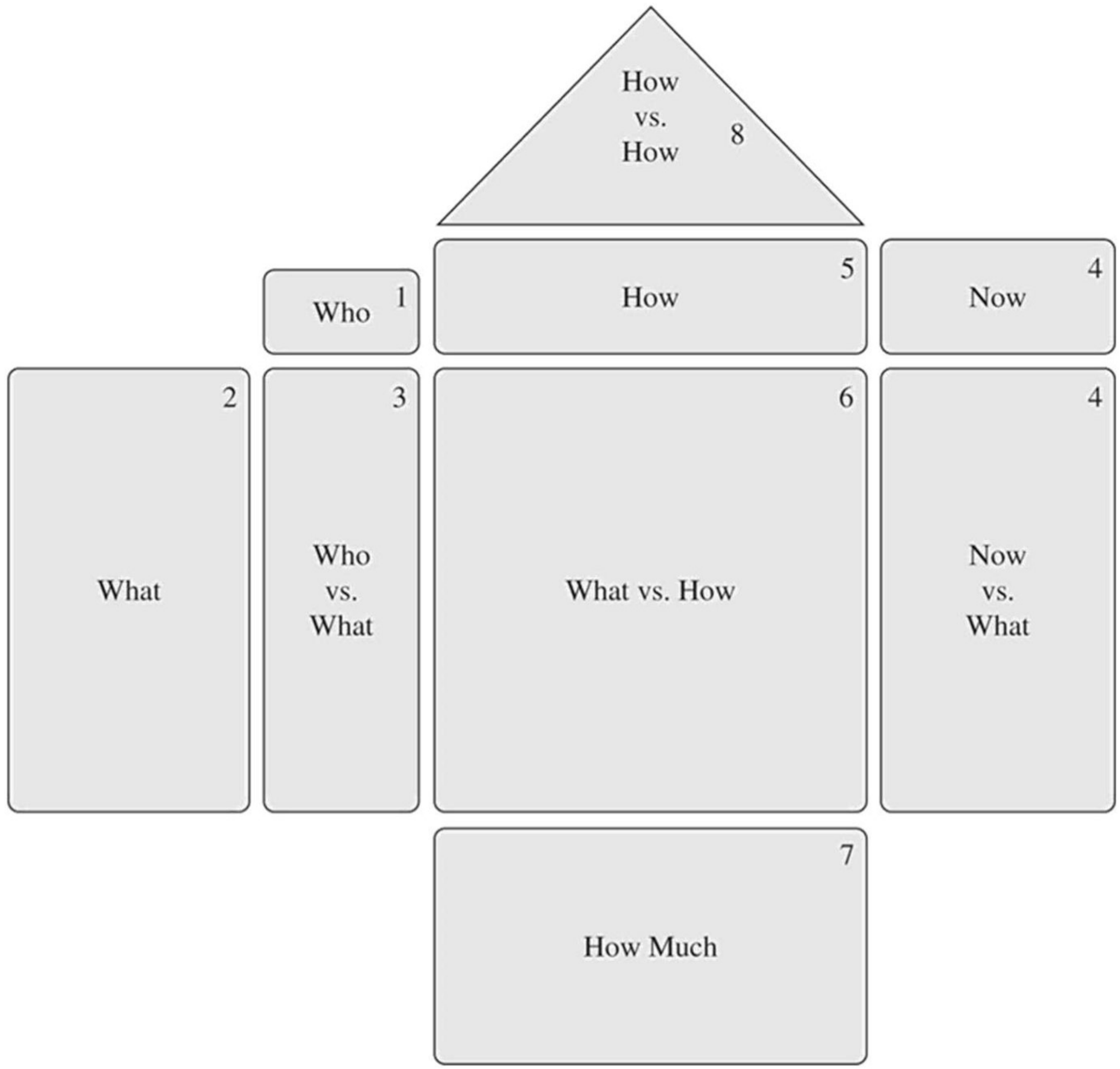
QFD, STEP 7: SET ENGINEERING TARGETS (“HOW VS. HOW MUCH”)

- Quantify competition’s specifications
- Determine numerical target value for each engineering specification
- Usually meets or exceeds competition
- Large improvements need justification (new technology, better concepts ??)

QFD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QFD, STEP 8: IDENTIFY RELATIONSHIPS BETWEEN SPECIFICATIONS (“HOW VS. HOW”) (Correlation Matrix)

- Identify relationships among engineering specifications
- Use -3, -1, 3, 9 system (see section 6.9)
- Meeting one specification may have a positive or negative effect on another TRIZ (inventive problem solving)

QFD: COMMENTS

QFD *process* is as important as its *results*

QFD is a working document

- is often revised & updated during design process
- serves as a design record and communication tool

QFD IN PRACTICE
(Automotive example)

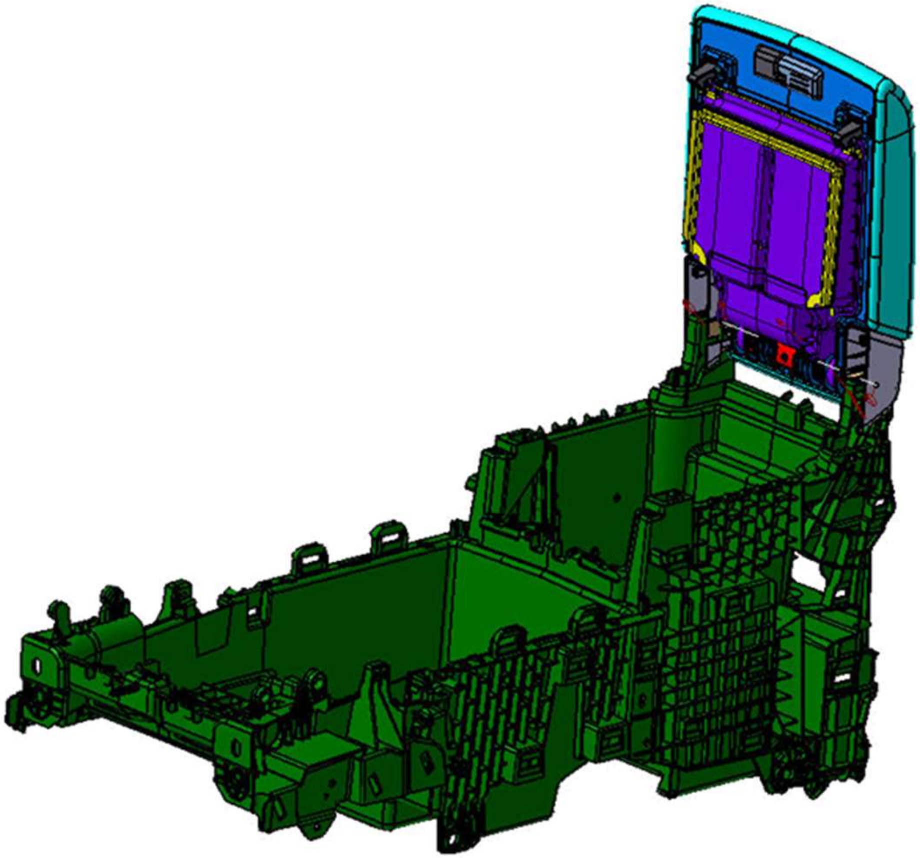
LIST OF REQUIREMENTS

We always do it in effective teams „teamwork” and we need to write down „everything” which comes to our mind, then select them…

	List of requirements				# / # page	
	Product / Project:				Date / Version	
Nr.	Requirement	Value	Weight	Source	Responsible	Comments
I.						
I/1.						
…						

CHARTER (armrest in a SUV)

Customer needs VoC	Rating
Designed look (optic)	6,4
Good feel (haptic)	5
Big storage space	7
Easy acces (big angle)	6,4
Multiple functions	3
Strong against (robust)	7
Multimedia possibilities	1
Quiet operation (no noise)	10
All functions in a logistic way	3
Lightweight	1,9
Smooth operation	10
Durable design	10
Multiple positions of lid	9,1



CTQ's DEFINE

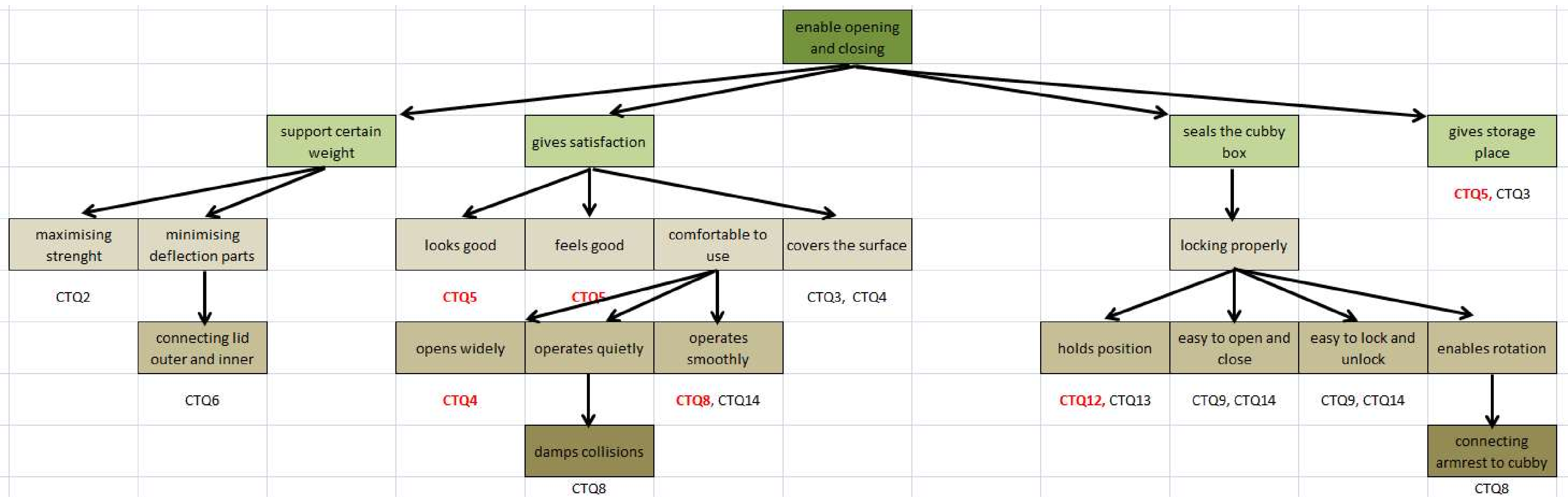
3 most weighted CTQ's are: (measureables)

NO Rattle&Squeak

Easy Opening Angles

Robust and Solid elements

FAST DIAGRAM



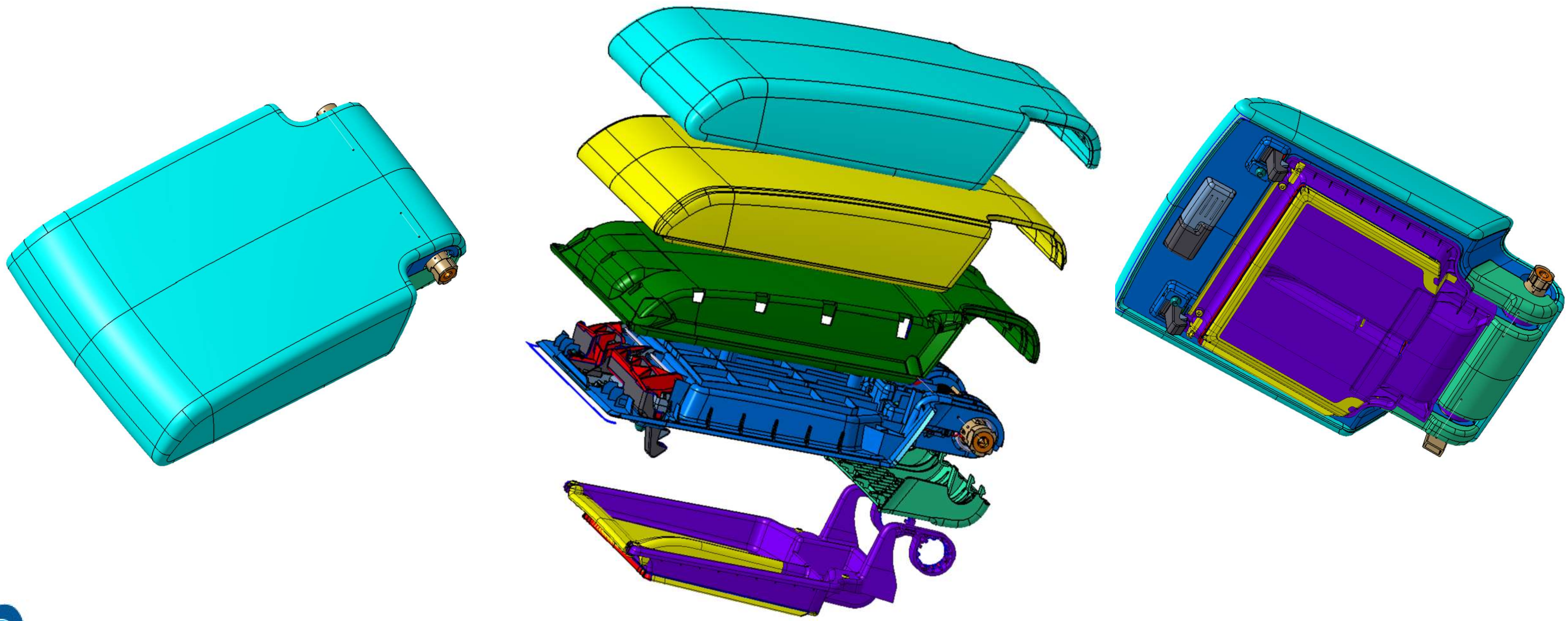
CTD’s CHARACTERISE

3 most weighted CTD’s are:

Angle position holding (brake effect)

Shaft design

Wedge design



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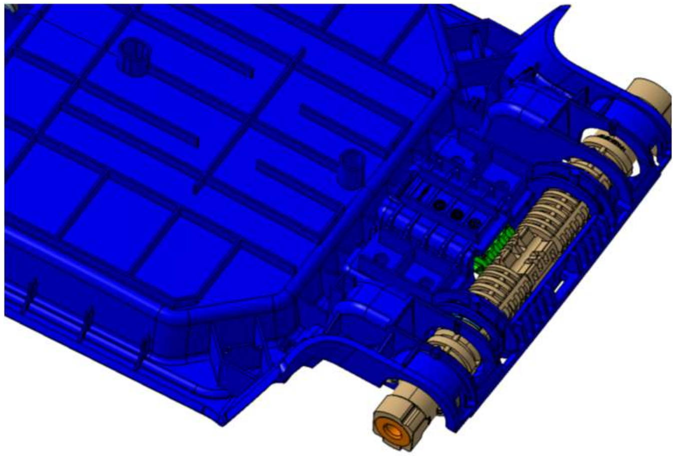
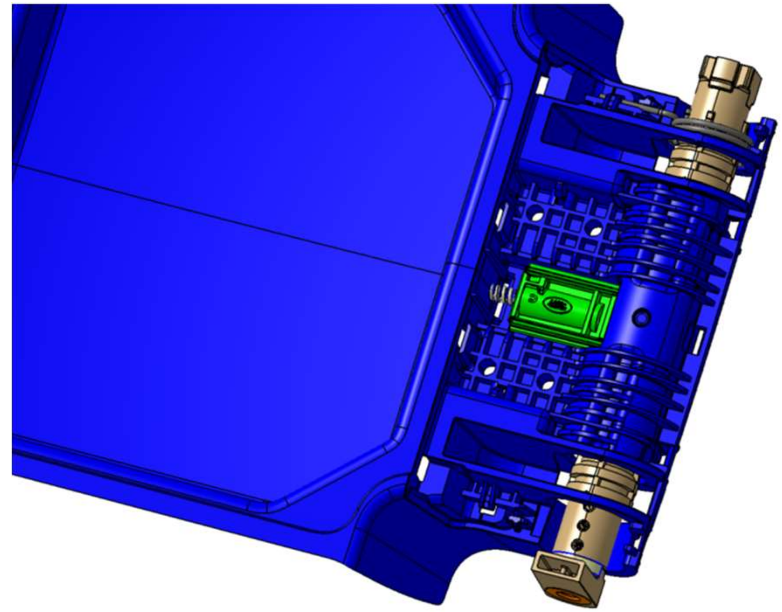
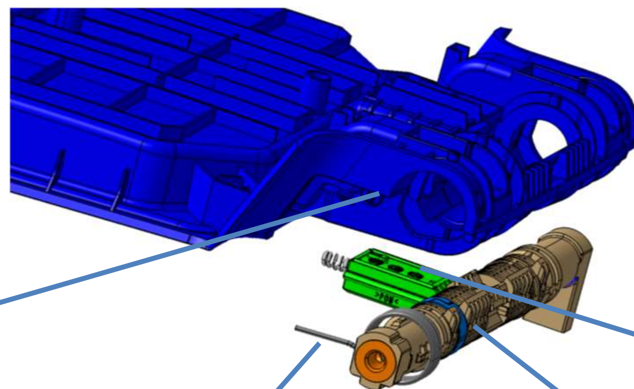
CTP's OPTIMISE

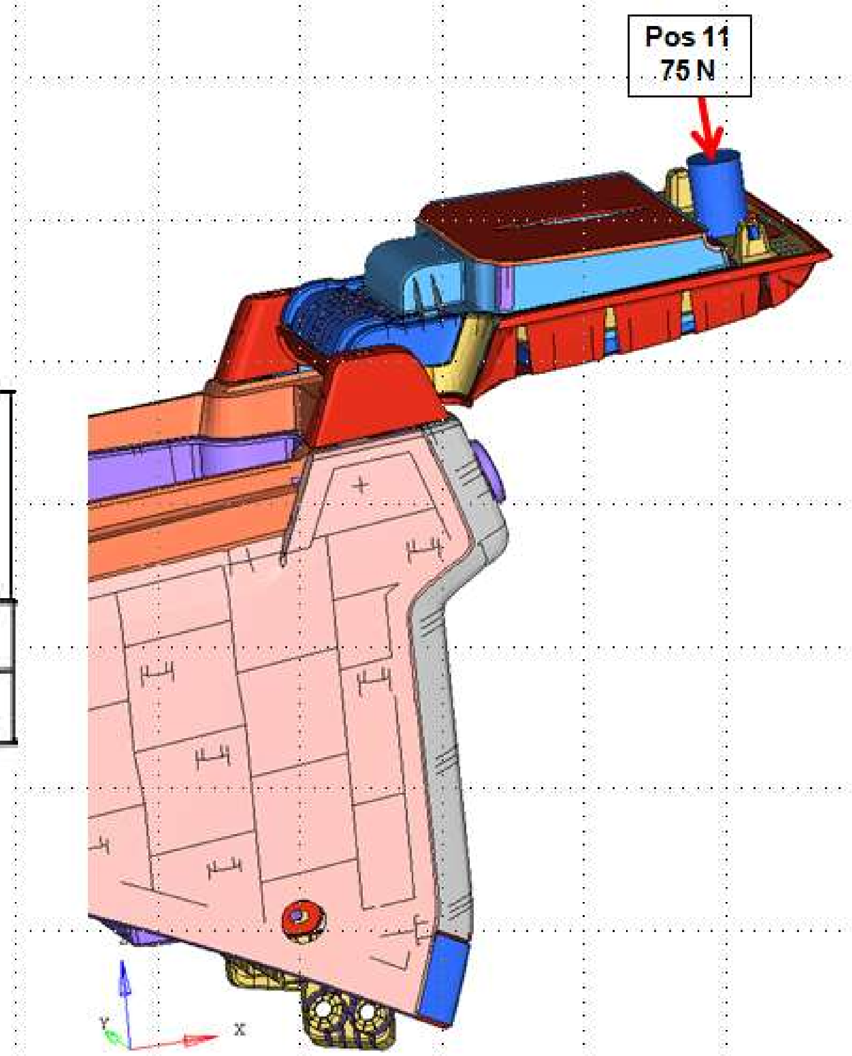






CTP's OPTIMISE (CAE Investigations)

Functional Position	Functional Representation	Force Range (N)	Force Direction (axis)	Maximum Deflection (mm)	Minimum Stiffness (N/m)
11	Leaning on open armrest.	<75	Z	30	2.5
		150	Z	Max. static load test.	



I. calculation tolerances: (location, tolerance chains)

Calculation of tolerance chains, with Gauss square method. We calculate the numbers using DIN and experience. Create drawings and give them to measuring department. Then we have results of points.

We need to measure the parts through the locator points!

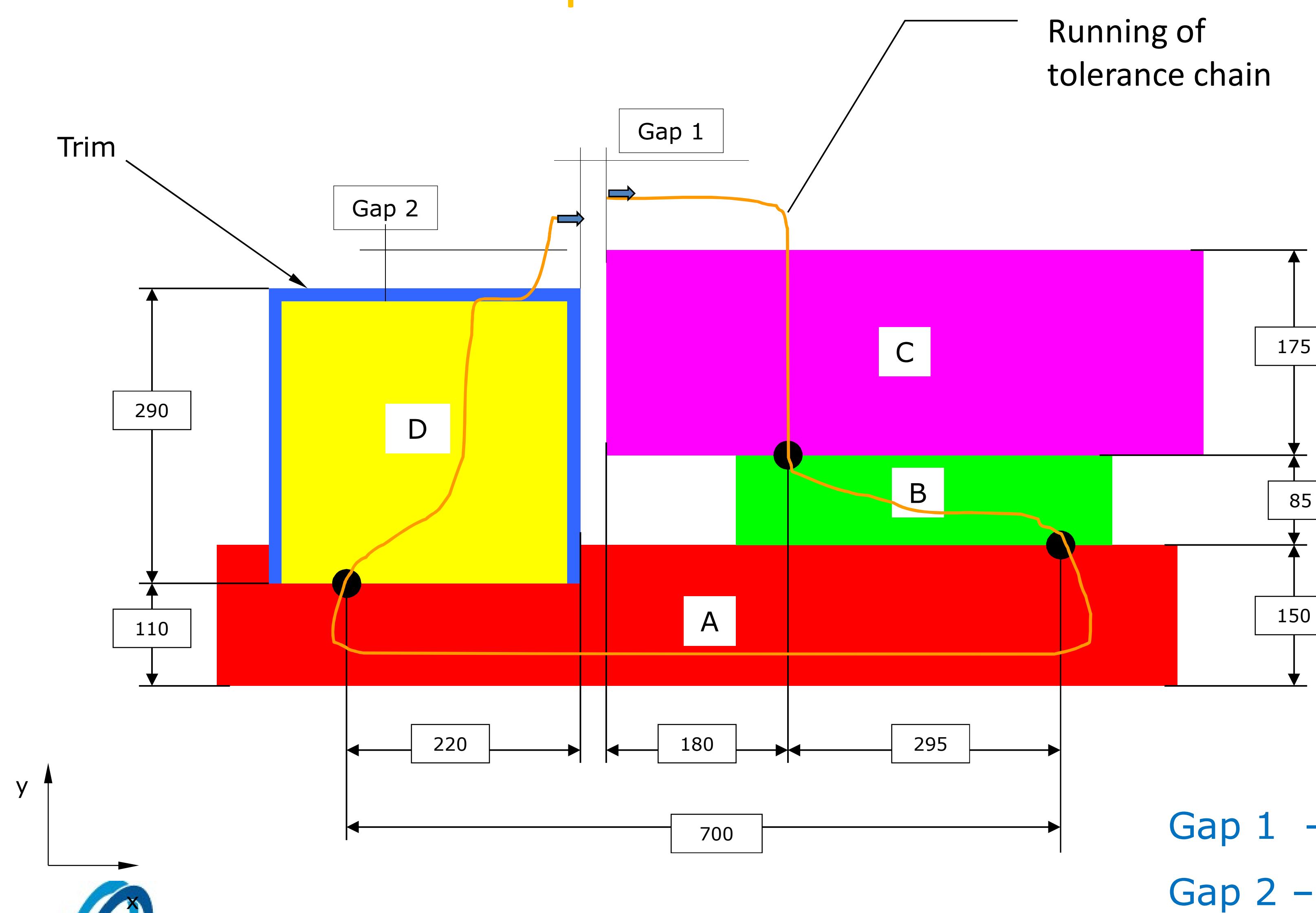
II. evaluation of tolerances: (measurement points)

Evaluation of measurement points on parts. We try to syncronise the theory with practice. (our calculated values measured values) Then assembly measurements.

III. approval of tolerances: (Cpk, Ppk, PSW, releases)

For process (manufacturing) we determine factors (**Sc's**), by means of we can monitor & decide whether process is "perform & capable" or not.

Possible tolerance map



Gap 1 - margin

Gap 2 – flushness

Deviation calculation

1.Arithmetic: (based on discussion)

simple addition of the numbers

application: -in case of 2 mating parts

-at such areas where tolerances have influence of functionality

2. Statistic: (Gauss square method)

square root of the addition of square elements

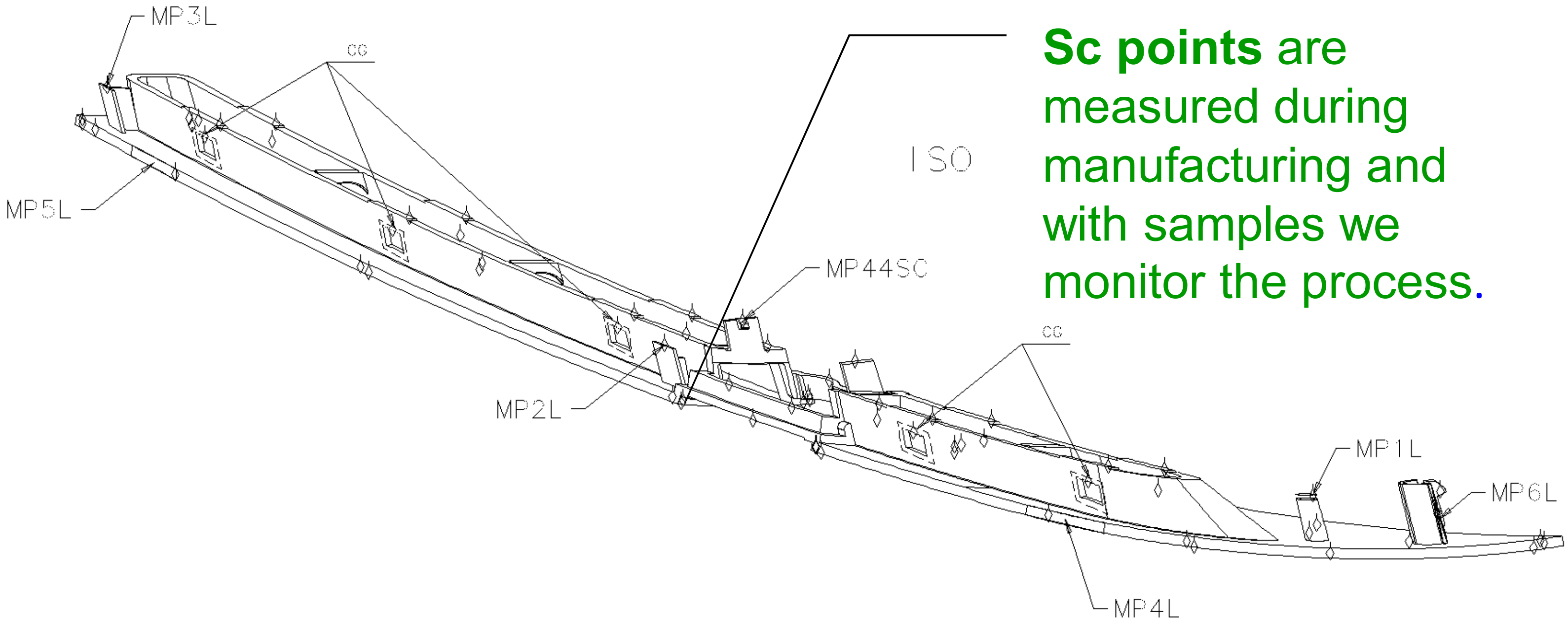
Approval of tolerances:

From process side we need to keep the manufacturing in hand!!! For these we need to monitor, that means we take SAMPLES from the population and create various formulas by means of we can tell: WHETHER the process:

capable and perform

or NOT

Potential Process capability: Cp
Process Capability Index: Cpk

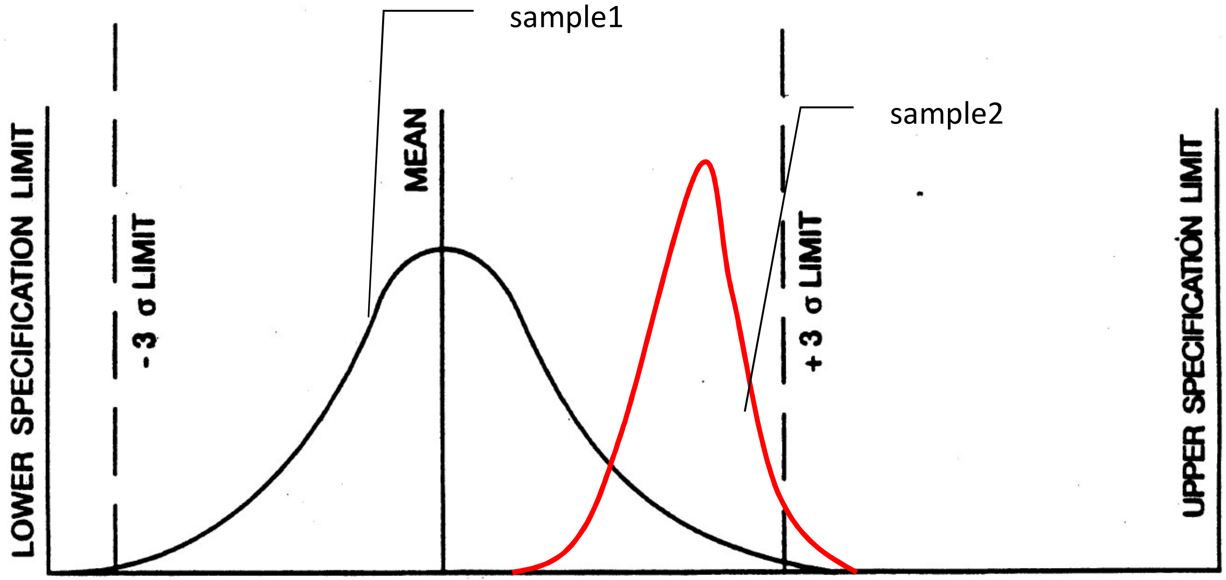


Sc points are measured during manufacturing and with samples we monitor the process.

„Simple” Factors for Judgement

Potential Process Capability (**Cp**) and Capability Index (**Cpk**) are statistical measurements of manufacturing process quality. Cp expresses measured process
variation (±3σ) as a percentage of the allowable dimensional range.

A Cp value of 1.00 means a process uses the full tolerance range of produced parts.
Cpk expresses variation relative to its position within the specification range. (mean shift)

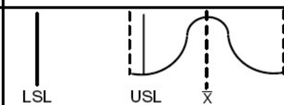
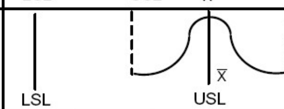
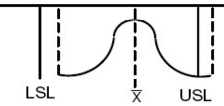
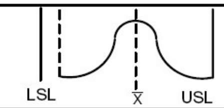
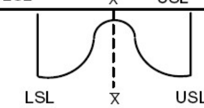
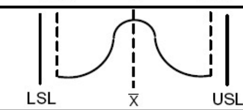


Cp=RANGE/6s **Cpk**=(USL-MEAN)/3s or (MEAN-LSL)/3s

USL: Upper Specification Limit LSL: Lower Specification Limit

MEAN: Average of Sample s: Deviation of Sample

Table 4-1. C_p/C_{pk} Evaluation

C_{pk} Value	Process Performance	
Negative Value	Mean is outside specification limits	
0	Mean is equal to one of the specification limits	
Between 0 - 1.0	Part of 6σ spread falls outside of specification limits	
1.0	One end of 6σ spread falls on specification limits	
Greater than 1.0	6σ spread falls completely within specification limits but with little allowance for deviation	
1.33 and greater	6σ spread falls completely within specification limits and a safety factor exists.	

When Cpk is greater than 1,33 then the process is „perform&capable” ...

The example below illustrates the use of Potential Process Capability, C_p, and Process Capability, C_{pk}.

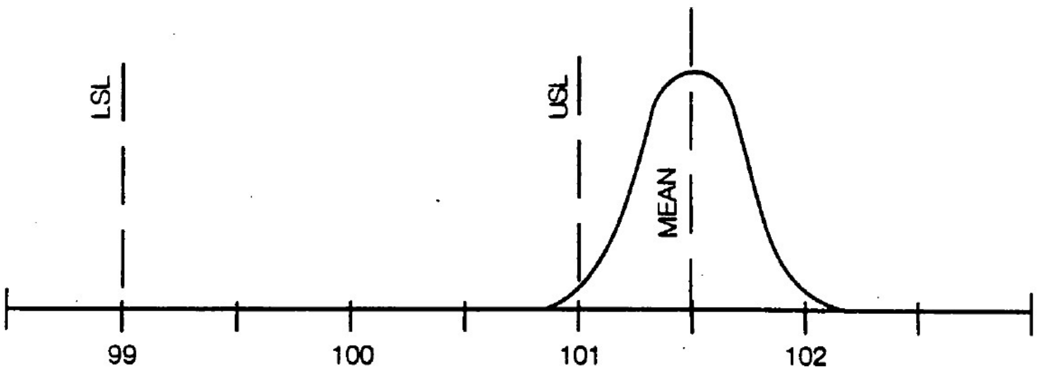
Injection Molded Part Design Tolerance: 100.0 ±1.0 mm
Actual Process Measurement: 101.5 ±0.4 mm (±3σ)

$$C_p = \frac{\text{SPECIFICATION RANGE}}{6\sigma}$$

$$C_p = \frac{2.0\text{ mm}}{0.8\text{ mm}} = 2.5 \quad \textbf{\textit{Acceptable}}$$

$$C_p = \frac{\text{UPPER SPECIFICATION} - \text{MEAN}}{3\sigma}$$

$$C_{pk} = \frac{101.0\text{ mm} - 101.5\text{ mm}}{0.4\text{ mm}} = 1.25 \quad \textbf{\textit{Unacceptable}}$$



The C_p value of 2.5 indicates that this process is capable, but the negative C_{pk} value of -1.25 reveals it does not meet customer specification. The C_p of 2.5 shows process improvement will not help because the root cause is an oversized mold. Solutions include:

CTM's VERIFY (Production Investigations)

Possible changes for a better performance

Rework the mold to reduce the part size (Tooling)

Change the part size specification to match the process (OEM)

Change the tolerance specification to allow for the oversized mold (Engineering)

Re-source to a capable supplier (Sales)

Falsify the results (Management)

In general...

Control of tool, temperature, machine pressure, melt temperature, fill time, etc., reduces process variation for molded plastic parts.

and many other factors which to be determined by the quality team!!!

THANK YOU FOR YOUR ATTENTION!