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Applications of statistical and related methods to new technology and product development process —

Part 6:
Guidance for QFD-related approaches to optimization

Application des méthodes statistiques et des méthodes liées aux nouvelles technologies et de développement de produit —

Partie 6: Lignes directrices pour QFD et approches reliées pour l'optimisation

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Foreword

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This document was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 8, *Application of statistical and related methodology for new technology and product development*.

A list of all parts in the ISO 16355 series can be found on the ISO website.

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Introduction

Quality function deployment (QFD) is a method to assure customer or stakeholder satisfaction and value with new and existing products by designing in, from different levels and different perspectives, the requirements that are most important to the customer or stakeholder, and ensuring their quality throughout the downstream activities of design, development, supply, building, commercializing, support and retiring from the market. These requirements are well understood through the use of quantitative and non-quantitative tools and methods to improve confidence of the design and development phases that they are working on the right things. In addition to satisfaction with the product, robust parameter design improves the process by which new products are developed and produced.

Reported results of using QFD include improved customer satisfaction with products at time of launch, improved cross-functional communication, systematic and traceable design decisions, efficient use of resources, reduced rework, reduced time-to-market, lower life cycle cost, improved reputation of the organization among its customers or stakeholders.

This document demonstrates the dynamic nature of a customer-driven approach. Since its inception in 1966, QFD has broadened and deepened its methods and tools to respond to the changing business conditions of QFD users, their management, their customers, and their products. Those who have used older QFD models will find these improvements make QFD easier and faster to use. The methods and tools shown and described represent decades of improvements to QFD; the list is neither exhaustive nor exclusive. Users should consider the applicable methods and tools as suggestions.

Robustness assessment is performed as a consideration of overall loss during the product's life cycle. The overall loss is composed of costs and losses at each stage of the product's life. It includes all costs incurred during not only the production stage, but also the disposal stages. When a product is not robust, the product causes many environmental and socioeconomic losses (including losses to the manufacturer and the users) due to poor quality caused by functional variability throughout its usable lifetime from shipping to final disposal. Product suppliers have responsibilities and obligations to supply robust products to the market to avert losses and damages resulting from defects in the products. The role of robust parameter in the QFD process is presented with examples and references to other ISO documents and related materials.

The topics in this document are not exhaustive and vary according to industry, product, and markets. They are considered a guide to encourage users of this document to explore activities needed to accomplish the same goal for their products.

Users of this document include all organization functions necessary to assure customer satisfaction, including business planning, marketing, sales, research and development (R&D), engineering, information technology (IT), manufacturing, procurement, quality, production, service, packaging and logistics, support, testing, regulatory, business process design, and other phases in hardware, software, service, and system organizations.

Applications of statistical and related methods to new technology and product development process —

Part 6:
Guidance for QFD-related approaches to optimization

1 Scope

This document provides guidance for QFD-related approaches to optimization through robust parameter design to ensure customer satisfaction with new products, services, and information systems. It is applicable to identify optimum nominal values of design parameters based on the assessment of robustness of its function at the product design phase.

NOTE Some of the activities described in this document can be used at earlier and later stages. Other approaches to solve optimization problems in new technology and product development processes are listed in Annex B.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16336:2014, *Applications of statistical and related methods to new technology and product development process — Robust parameter design (RPD)*

ISO 16355-1:2015, *Application of statistical and related methods to new technology and product development process — Part 1: General principles and perspectives of Quality Function Deployment (QFD)*

3 Terms and definitions

For the purposes of this document, the terms, definitions and symbols given in ISO 16336 and ISO 16355-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Basic concepts of QFD

The basic concepts of QFD are described in ISO 16355-1:2015, Clause 4.

5 Integration of QFD and robust parameter design

5.1 Quality engineering

5.1.1 General

Dr. Genichi Taguchi, a pioneer in Japanese quality methods, developed a philosophy of quality engineering based more on technology than theory in order to measure loss, maintain quality in production, and improve quality continuously. The goal is to create high quality, low cost goods and services that satisfy customer needs, a goal shared with quality function deployment (QFD)[3].

5.1.2 Loss function

Measuring loss can be explained by the concept of the loss function; any variability from the ideal function of a product creates a loss:

a) to the customer, who is unable to fully enjoy their intended use for the expected life of the product)[8];

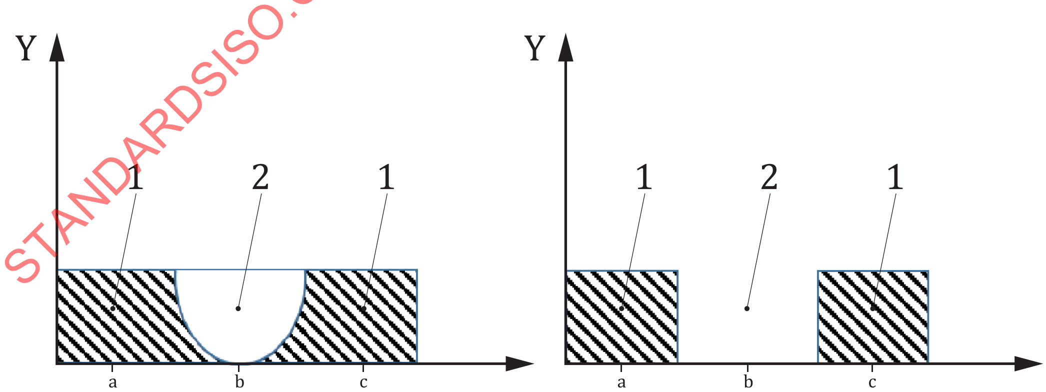
NOTE Robust parameter design focuses on the customer's quality loss due to variability in the function or performance of the product. This has alternatively been called the cost of inferior quality[2].

b) to the organization, which can result from wasted activity, wasted materials, wasted time, rework, scrap, warranty replacement, maintenance[12];

c) to society, which can result from regulation, disposal, recovery, safety, hazards[7].

5.1.2.1 Taguchi's loss function vs. specification loss function

Measuring loss can be performed by calculating the cost to the customer, organization, and society due to variability from the target design specification set to fully satisfy the customer. Defining this target specification level is described in ISO 16355-5:2017, Clause 9, in the maximum value table, and in ISO 16355-5:2017, 10.3.4.1 in both the unweighted and weighted design planning tables. Taguchi's loss function considers any deviation from the target specification to be a loss to the customer, organization, and society, and it can be quantified in terms of cost. Traditional loss function is a step function in that as long as the product or component performance is within the lower and upper specification limits of the nominal target value, there is no loss recognized, as shown in Figure 1.



Key

Y	cost	a	Lower specification limit.
1	loss	b	Target specification.
2	no loss	c	Upper specification limit.

Figure 1 — Taguchi (left) and specification (right) loss function

5.1.2.2 Calculating the loss function

The farther from the nominal target specification the product or component performance varies, the greater the Taguchi loss function is. Monetizing the average loss allows the QFD team to consider different design alternatives with different costs and loss. The average loss can be calculated with a quadratic formula[13]:

$$\bar{L} = k\left[\sigma^2 + (\bar{y} - T)^2\right]$$

where

$\bar{L}$ is the loss to the customer, organization, or society,

k = money/Δ^2,

where Δ is the tolerance, difference between the designed nominal value and the tolerance limit, and "money" is loss when characteristic exceeds the tolerance Δ,

T is the target value of performance,

σ^2 is the variance of performance, and

$\bar{y}$ is the average performance.

The determination of tolerance Δ is described in ISO 16337:—1), 4.3.

NOTE 1 The above Taguchi loss function quadratic equation is commonly used in QFD when the target specification is a nominal-the-best functional or non-functional requirement. Different equations for larger-the-better and smaller-the-better specifications can also be used[11].

NOTE 2 In QFD applications, the value of k can be set to 1 since the monetary loss to customers would be the same for all competitors[13].

NOTE 3 Competitive benchmarking of performance can be done in real-life environments (called gembas in QFD) that represent key applications of key customers that were defined in the customer segments table described in ISO 16355-2:2017, 9.2.2.2, and prioritized in the business goals - customer segments prioritization matrix described in ISO 16355-2:2017, 9.2.3. If not possible, laboratory or computer simulations can be used as a proxy. The results can be recorded in the maximum value table described in ISO 16355-5:2017, Clause 9, and in either the unweighted and weighted design planning tables described in ISO 16355-5:2017, 10.3.4.1.

NOTE 4 The loss function for dynamic characteristic cases is defined as $\bar{L} = k\sigma^2 = k/\eta$, as described in ISO 16337:—1), 4.3.

5.1.3 Types of factors which affect variability

The goal of robust parameter design is to minimize loss due to variation[5]. There are different types of factors to be considered on minimizing loss due to variation, as shown in Figure 2:

a) shifts in mean (B2 has higher mean than B1);

b) changes in variability (C2 has less variability than C1);

c) changes in costs, same mean or variability, but can lower cost by picking cheaper alternative (D1 or D2);

d) trade-off between mean and variability (A1 versus A2).

1) Under preparation. Stage at the time of publication: ISO/DIS 16337:2019.

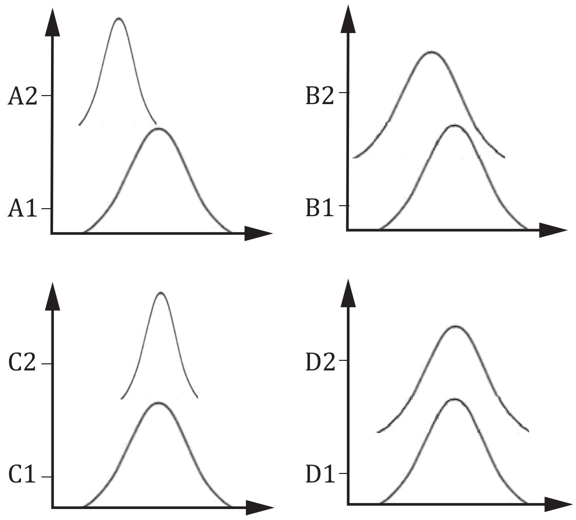


Figure 2 — Types of factors

5.2 When to use quality engineering

Quality engineering can be used throughout the new product development process[9].

a) In the planning and development phase, it can assist technological research and feasibility studies of project concepts as described in ISO 16355-2:2017, 9.1.2.8.2.

b) In the design phase, it can help structure simulation studies, failure mode and effects analysis (FMEA), as described in ISO 16355-5:2017, 10.4.5.8, in testing specifications as described in ISO/TR 16355-8:2017, 11.2, and in making design decisions.

c) In the product planning phase, it can influence process design as described in ISO/TR 16355-8:2017, Clause 10, prototype development as described in ISO/TR 16355-8:2017, 11.5, standardization as described in ISO/TR 16355-8:2017, 13.5, and supply chain decisions as described in ISO/TR 16355-8:2017, 12.4.

d) In the production phase, it can improve process controls as described in ISO/TR 16355-8:2017, 13.2, tolerancing as described ISO/TR 16355-8:2017, 9.2, and inspection as described in ISO/TR 16355-8:2017, 13.5.1.

e) In the sales and service phase, it can improve service procedures and technical bulletins as described in ISO/TR 16355-8:2017, 15.5 and Clause 16, and with customer satisfaction with product functions and performance as described in ISO 16355-3:2019 and ISO/TR 16355-8:2017, Clause 17.

5.3 Robust parameter design, QFD, and TRIZ

QFD is a framework for new product development quality assurance. This framework facilitates integration with multiple quantitative and qualitative analytic tools, as described in the QFD tools matrix in ISO 16355-1:2015, A.1. ISO 16355-5:2017, 10.4.3.4, describes the basic process for the theory of inventive problem solving, abbreviated in Russian as TRIZ. Like robust parameter design, TRIZ examines functions and their ability to satisfy customer needs. When TRIZ is conducted first and identifies multiple solutions to a problem, robust parameter design can be used to select and further improve the most robust[1],[6].

The following steps integrate QFD, TRIZ, and Taguchi's robust parameter design[14]. Their relationships are shown in Annex A.

1) Project level

   i) Identify and prioritize customer segments as described in ISO 16355-2:2017, 9.2.

ii) Identify future technology trends that address future customer problems as described in ISO 16355-5:2017, 10.4.3.5.1.1.

2) Customer level

i) Understand the customer's usage environment (gemba) as described in the customer segments table in ISO 16355-2:2017, 9.2.2.2, the customer process model described in ISO 16355-2:2017, 9.2.5.2.3, and gemba visit table described in ISO 16355:2:2017, 9.2.5.2.4.

ii) Taguchi methods for robust design can be adapted for dynamic customer needs[9].

iii) TRIZ looks for available system or environment of use resources to contribute to ideality (high function, low cost), historical constraints, and useful or harmful functions as described in the innovative situation questionnaire in ISO 16355-5:2017, 10.4.3.4.1.2.

iv) Taguchi methods would look for sources of variation due to the environment or user as described in 8.5.5.

3) Transfer voice of customer into voice of engineer

i) QFD uses the maximum value table as described in ISO 16355-5:2017 or the customer needs – functional requirements matrix (house of quality) as described in ISO 16355-5:2017, 9.3.6, to transfer the voice of the customer into technical product requirements.

ii) TRIZ looks to minimize technical and physical contradictions without trading off target values as described in ISO 16355-5:2017, 10.4.3.4.2.2, and ISO 16355-5:2017, A.3.

iii) Taguchi methods can take advantage of positive interactions as described in 8.5.6.

iv) Taguchi's loss function is an effective way to technically benchmark competitive products as described in 8.2.

4) Technology concept level

i) TRIZ develops many solution concepts for functions and performance measures described in the inventive principles in ISO 16355-5:2017, 10.4.3.4.2.3 and A.4.

ii) TRIZ identifies patterns of evolution that lead to exciting products described in ISO 16355-5:2017, 10.4.3.5.1.1.

iii) Taguchi methods determine best values for robust design for each concept under consideration as described in 8.2.

5) Manufacturing level

i) TRIZ can improve manufacturing equipment and processes by examining their patterns of evolution described in ISO 16355-5:2017, 10.4.3.5.1.1.

ii) TRIZ can broaden application of manufacturing processes to other products.

iii) TRIZ can improve the manufacturing workflow.

iv) Taguchi methods can make manufacturing more robust to variation[3][12].

v) Taguchi design of experiments and QFD house of quality can build a knowledge database for the future as describe in ISO 16355-5:2017, 9.3.7.

6 Types of QFD and robust design projects

QFD projects encompass new developments, as well as generational improvements to existing products. The types of QFD projects are described in ISO 16355-1:2015, Clause 6, and ISO 16355-2:2017, Clause 6 notes.

7 QFD and robust parameter design team membership

7.1 QFD uses cross-functional teams

Cross-functional teams are described in ISO 16355-1:2015, 7.1.

7.2 Core team membership

Core team membership is described in ISO 16355-1:2015, 7.2.

7.3 Subject matter experts

Subject matter experts involvement is described in ISO 16355-1:2015, 7.3.

7.4 QFD team leadership

QFD team leadership is described in ISO 16355-1:2015, 7.4.

NOTE Robust parameter design projects are typically led by the engineering department.

8 Robust parameter design

8.1 General

Robust parameter design in the design phase of QFD can minimize defects, failures, and quality problems due to functional variability that can occur during the use of the product. In robust parameter design, optimum nominal values of the product's design parameters are considered control factors that can be studied and made more robust under certain noise factors. The use of robust parameter design at development and design stages help the QFD team determine optimum design specifications that lead to better product quality in application.

8.2 Signal-to-noise ratio

8.2.1 General

The function of a product's system is to convert an input into an output. Any input variable to the system that is intentionally changed by the user to get a desired response is a signal; any undesired input or output is noise. Taguchi expresses the relationship between desired and undesired input using terminology from the telecommunications industry: the louder the desired input signal sent, the louder the desired output signal received. However, the telecommunications system also has undesired noise due to many factors. The relationship between the desired signal and the undesired noise is called the signal-to-noise ratio (SN) can be expressed in decibels (dB). For example, 40 dB means that the magnitude of the output is 10 000 that of the noise. In robust parameter design, the higher the SN ratio, the better the quality. A robust product has minimal variability of its functions under various noise conditions; its functions are more sensitive to signal and less sensitive to changes in levels of noise.

8.2.2 Signal

There are two kinds of signal: active signal and passive signal. An active signal is operated by the user to get an intended or desired response. For example, rotating the angle of an automobile's steering wheel causes a change the vehicle's direction. A passive signal is operated by the user to know the value of an input response. For example, the temperature gauge in an automobile exhibits a thermal measurement.

8.2.3 Noise

Noise is composed of internal noise and external noise. Internal noise results from changes of an internal constant of the system or its parts over time due, for example, to deterioration, aging and wear, and manufacturing variations. External noise results from usage or application conditions, such as automobile tires used mostly in city driving or in highway driving, and environmental conditions such as the conditions of the road or seasonal variations in ambient air temperature and humidity.

8.2.4 Three types of SN ratios

8.2.4.1 General

There are three kinds of SN ratios according to their characteristics.

8.2.4.2 Dynamic characteristics

Depending on the physics of the system, dynamic characteristics have multiple ideal output responses depending on the value of the signal. They are:

a) zero-point proportional ideal function, as described in ISO 16336:2014, 5.4.1;

b) linear formula ideal function, as described in ISO 16336:2014, 5.4.2;

c) reference-point proportional ideal function, as described in ISO 16336:2014, 5.4.3.

8.2.4.3 Non-dynamic or static characteristics

Depending on the intent of the system, non-dynamic or static characteristics have a fixed ideal output response which can be classified as:

a) nominal-the-best, where the target value is a fixed value, as described in ISO 16336:2014, 5.4.4;

b) smaller-the-better, where the target value is zero, as described in ISO 16336:2014, 5.4.5,

$$\eta = -10 \log \sigma^2 = 10 \log \frac{1}{\sigma^2},$$

where σ^2 is the mean squared sum;

c) larger-the-better, where the target value is infinity, as described in ISO 16336:2014, 5.4.6,

$$\eta = -10 \log \sigma^2 = 10 \log \frac{1}{\sigma^2},$$

where σ^2 is the mean squared sum of inverted values.

NOTE When used in the design planning table described in ISO 16355-5:2017, Clause 9, the direction of the characteristic or functional requirement depends on the strength of each customer need it relates to. For example, a characteristic of a folding umbrella is its diameter. If the related customer need is "I stay dry in the rain," then the larger-the-better is considered. If the related customer need is "I can carry it with me easily," then the smaller-the-better is considered. In this case, nominal-the-best can be studied for a possible trade-off value, or an innovation method such as TRIZ can help the QFD team discover a way to eliminate the trade-off and make the umbrella both small and large. TRIZ is described in ISO 16355-5:2017, 10.4.3.4.

8.2.4.4 Digital systems

Digital systems have binary inputs and outputs of 0 or 1. The input should match the output, and after threshold calibration of the system, the SN ratio represents its capability. This is as described in ISO 16336:2014, 5.4.7.

8.3 Assessing robustness

It is useful to have a rational way to accurately assess and efficiently improve the robustness of a product, system, or components. The signal-to-noise ratio (SN) can be calculated to test the characteristics under various usage conditions. Internal and external noise complicate this measurement. To clarify any hidden factors, comparison of the actual function to the ideal function should be done under real-life noise conditions. Evaluation of the robustness strongly depends on the choice of noise factors and their levels. This can be done by strategically designing experiments to test changing use conditions and pre-determined noise factors that can result in a characteristic deviating from the target. When competitive products are benchmarked or multiple solution concepts are compared, the same levels of the same noise factors are to be used.

8.4 Two-step optimization

8.4.1 General

To find the optimum values of design parameters, sensitivity (mean value in case of nominal-the-best response), and SN ratio should be calculated for some combination of design parameter values. The first step is to optimize the design for robustness by SN ratio, and the second step is to adjust the magnitude to the target value by sensitivity.

8.4.2 Design of experiments (DOE)

When there are many design parameters with different performance levels and many noise factors at different levels, it is not efficient to test all possible combinations to determine which are optimal. For example, just three design parameters at two performance levels each would require $2^3 = 8$ trials to test. With DOE, only 4 trials may be necessary to predict the optimal values. An orthogonal array can define a balanced subset of trials that can help predict the missing combinations. Different subset arrays are defined in the Taguchi methods according to the number and levels of variables[11]. Figure 3 shows how a selected subset of variable levels are displayed in an L_4 orthogonal array and a linear graph shows the assigned points.

		Variable A (2 levels)	Variable B (2 levels)	Variable C (2 levels)
Trials	1	1	1	1
	2	1	2	2
	3	2	1	2
	4	2	2	1

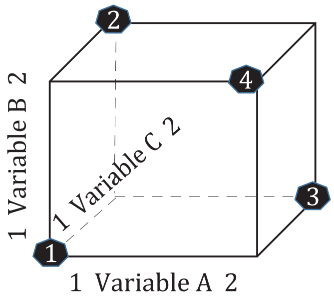


Figure 3 — L_4 orthogonal array

8.5 Steps to robust parameter designed experiments

8.5.1 General

The following steps ensure a rational way to accurately assess and efficiently improve the robustness of a product. More detailed guidance is described in ISO 16336:2014, 5.3.

a) Select basic technologies and systems, sub-systems, and component to be tested. This is described in ISO 16355-5:2017, 10.4.3.7.2.

b) Perform a detailed product design by selecting key functional requirements (characteristics and capabilities) with optimal values for robustness and efficiency. Determining key functional requirements from the maximum value table and house of quality is described in ISO 16355-5:2017, 9.2 and 9.3.6, respectively.

NOTE In the optimum state, the product gives the best performance in all conceivable use conditions and applications. Actual use conditions can be determined from the customer segments table described in ISO 16355-2:2017, 9.2.2.2, the customer process model described in ISO 16355-2:2017, 9.2.5.2.3, and the gemba visit table described in ISO 16355-2:2017, 9.2.5.2.4.

8.5.2 Step 1. Clarify the system's ideal function

Function is the work that a system performs in order to fulfil its objective. In QFD, functions are what the product must do in order for the product to be acceptable to the customer. Functions are generally a performance description using an active verb plus a noun that have measurable parameters. Products can have both use functions and aesthetic functions[4]. Functional requirements are more generally defined as characteristics and capabilities of a product, independent of the solution or enabling technology, as defined in ISO 16355-1:2015, 3.4.

In QFD, functional requirements are identified in the maximum value table and customer needs – functional requirements matrix (house of quality) described in ISO 16355-5:2017, 9.2 and 9.3.6, respectively. Functional requirement priorities and targets are identified in the design planning table described in ISO 16355-5:2017, Clause 9.

In robust parameter design, the ideal function is described in ISO 16336:2014, 6.2.

NOTE With non-dynamic or static characteristics, the following step 2 can be skipped.

8.5.3 Step 2. Select signal factor and its range

Selecting signal factor and its range is described in ISO 16336:2014, 6.3.

In QFD, expected use conditions can be determined from the customer segments table described in ISO 16355-2:2017, 9.2.2.2, the customer process model described in ISO 16355-2:2017, 9.2.5.2.3, and the gemba visit table described in ISO 16355-2:2017, 9.2.5.2.4.

In QFD, customer segments are prioritized according to their importance to project goals. This is described in ISO 16355-2:2017, 9.2.3.

8.5.4 Step 3. Select measurement method of output response

Selecting measurement method of output response is described in ISO 16336:2014, 6.4.

In QFD, the output characteristics are the functional requirements and can be extracted from customer needs using an effects-to-cause diagram as described in ISO 16355-5:2017, 9.2.2. The method of measurement can be determined at the same time as described in ISO 16355-5:2017, 9.3.6.2.2.

In QFD, the measurement method and level necessary to satisfy customers better than alternative solutions is documented in either the unweighted or weighted quality planning table described in ISO 16355-4:2017, 12.2.

NOTE New measuring methods to better assess robustness can be developed for time-dependent responses that are difficult to measure.

8.5.5 Step 4. Develop a noise strategy, and select noise factors and levels

Developing a noise strategy, and selecting noise is described in ISO 16336:2014, 6.5.

In QFD, noise conditions and factors as well as expected use environment can be learned from the customer segments table described in ISO 16355-2:2017, 9.2.2.2, the customer process model described in ISO 16355-2:2017, 9.2.5.2.3, and the gemba visit table described in ISO 16355-2:2017, 9.2.5.2.4.

8.5.6 Step 5. Select control factors and their levels from design parameters

Selecting control factors and their levels from design parameters is described in ISO 16336:2014, 6.6.

In QFD, design parameters and control factors are derived from functional requirements as described in ISO 16355-5:2017, 9.3.6.2.2. Functional requirements that are design-independent characteristics and capabilities avoid problems with interactions and correlations.

If the project is constrained to use the same design, materials, or other components, then the functional requirements may not be independent. Interactions can be discovered by using the functional requirements correlation matrix, also known as the "roof" of the house of quality, described in ISO 16355-5:2017, 10.4.3.4.1.1.

8.5.7 Step 6. Assign experimental factors to inner or outer array

Assigning experimental factors to inner or outer array is described in ISO 16336:2014, 6.7.

Table 1 — Inner and outer array for L_4 experiment

		Inner array (controllable)			Outer array (uncontrollable)			
		Factor A (2 levels)	Factor B (2 levels)	Factor C (2 levels)	Noise level 1 Signal 1	Noise level 2 Signal 1	Noise level 1 Signal 2	Noise level 2 Signal 2
Trials	1	1	1	1				
	2	1	2	2	*Test response data*			
	3	2	1	2				
	4	2	2	1				

NOTE In smaller experiment arrays such as the L_4, the interaction between any two columns is compounded and so it is not robust against strong interactions between control factors. Relatively strong main effects can be identified without specific compounded interactions in the larger orthogonal arrays such as L_{12}, L_{18}, L_{36}, and L_{54}.

8.5.8 Step 7. Conduct experiment and collect data

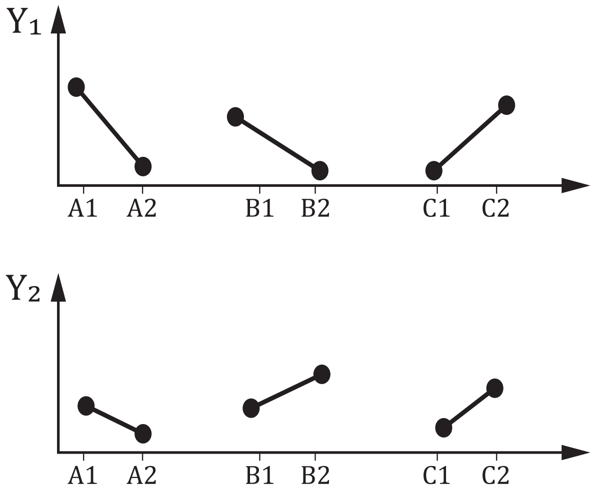
Conducting experiment and collect data is described in ISO 16336:2014, 6.8.

8.5.9 Step 8. Calculate the SN ratio (η) and sensitivity (S)

The signal-to-noise ratio and sensitivity are calculated depending of the type of characteristic as described in 8.2.4. The average SN and S are calculated for each level of each control factor. The formulae are described in ISO 16336:2014, 6.9.

8.5.10 Step 9. Generate factorial effect diagrams on SN ratio and sensitivity

Plot factorial effect diagrams of both the SN ratio and sensitivity based on the data of averages. The diagrams in Figure 4 show how each control factor affects the SN ratio and sensitivity. The SN ratio represents variability while sensitivity represents linear slope or mean of the response. This is described in ISO 16336:2014, 6.10.



Key

Y_1 SN ratio (dB)

Y_2 sensitivity (dB)

Figure 4 — Factorial effect diagrams

8.5.11 Step 10. Select the optimum condition

Selecting the optimum condition is described in ISO 16336:2014, 6.11.

In QFD, the optimum values can be entered as target values in the maximum value table described in ISO 16355-5:2017, Clause 9, or in either the unweighted and weighted design planning tables described in ISO 16355-5:2017, 10.3.4.1.

8.5.12 Step 11. Estimate the improvement in robustness by the gain

Estimating the improvement in robustness by the gain is described in ISO 16336:2014, 6.12.

8.5.13 Step 12. Conduct a confirmation experiment and check the gain and reproducibility

Conducting a confirmation experiment and check the gain and reproducibility is described in ISO 16336:2014, 6.13.

In QFD, the confirmation should be noted in the maximum value table described in ISO 16355-5:2017, Clause 9, and in either the unweighted and weighted design planning tables described in ISO 16355-5:2017, 10.3.4.1.

8.5.14 Conclusions

By decreasing the loss to the user, changes in market price can be estimated. By decreasing loss to the company, improvements in cost can be estimated. By decreasing loss to society, improvements in brand strength and regulatory compliance can be estimated. In many cases, designing in the optimum value of design parameters causes no or very little increasing in cost.

Both QFD and robust parameter design aim for these conclusions.

8.6 Case studies in robust parameter design

ISO 16336:2014, Clause 7, and ISO 16336:2014, Annex B, include several case studies in robust parameter design. Additional details are found in Reference [11]. QFD related case studies can be found in ISO/TR 16355-8:2017, 12.3, and in the Bibliography.