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

Part 5: **Solution strategy**

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

Partie 5: Stratégie de solution

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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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.

Introduction

Quality Function Deployment (QFD) is a method to ensure 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. These requirements can be 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, QFD improves the process by which new products are developed.

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 can find these improvements make QFD easier and faster to use. The methods and tools shown and referenced in the standard represent decades of improvements to QFD; the list is neither exhaustive nor exclusive. Users can consider the applicable methods and tools as suggestions, not requirements.

This document is descriptive and discusses current best practice, it is not prescriptive by requiring specific tools and methods.

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

Part 5:
Solution strategy

1 Scope

This document describes the process of developing a solution strategy for new products. Since organizations can address their new product development process by a customer-driven or a technology-driven set of solutions, this document explains both alternatives. It provides recommendations on the use of the applicable tools and methods, offering guidance on translating the voice of the customer (VOC) and voice of the stakeholder (VOS) into product, service, information, and process attributes, transferring the priorities of the customer and stakeholder needs into priorities for these attributes, and then developing technology, cost, and reliability plans for attributes.

Users of this document include all organization functions necessary to ensure 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, and other phases in hardware, software, service, and system organizations.

2 Normative references

The following documents are referred to in 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 16355-1:2015, *Applications of statistical and related methods to new technology and product development process*

3 Terms and definitions

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

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

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

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

4 Management summary

4.1 Basic concepts of QFD

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

4.2 Evolving classical QFD into modern QFD

4.2.1 General

QFD was first systematized in Japan in 1966 for applications in the automotive industry.[3] As new industries and applications emerged, the method, tools, and flow of information evolved to address the unique factors of each company. In recent years, the methods in 4.2.2 to 4.2.6 are most commonly used.

4.2.2 Classical QFD

Automotive component suppliers created a simplified flow that translated original equipment manufacturer (OEM) specifications into component specifications and process requirements using a series of four matrices, as follows:

a) customer requirements into product requirements;

b) product requirements into component requirements;

c) component requirements into manufacturing requirements;

d) manufacturing requirements into process requirements.

NOTE 1 Classical QFD is also called 4-phase QFD because of the four matrices used.[16] These four matrices are highlighted in yellow in Figure 3.

NOTE 2 The 4-phase QFD charts in this document and ISO/TR 16355-8 use improved mathematics and tighter definitions to guide the user, resulting in faster implementation and more confident results.

4.2.3 Comprehensive QFD

The 4-phase QFD was readily adopted around the world for its simplicity and easy implementation. As QFD gained popularity, other industries, including finished goods, services, software and information systems, and processes struggled to make it fit their products and business models. This led adding more tools and flows to create a more comprehensive approach. Comprehensive QFD ensures the quality of new products by including market research to understand customer needs as referred to in ISO 16355-2 and ISO 16355-4, translating customer needs into design quality targets, and then deploying to innovation, cost, and reliability phases. It enables greater flexibility in application to a broad variety of industries including aerospace, architecture, construction, electronics, materials processing, services, and software.[1][24] The many tools and information flows enable the user to select which ones are applicable to their project. In Figure 3, the vertical deployments are quality, technology, cost, and reliability. The horizontal deployments are customer, product, function, components, and build. The purpose of this document and ISO/TR 16355-8 is to guide users in harnessing the full capabilities of comprehensive QFD.

4.2.3.1 Quality deployment

10.4.2 describes how product-independent customer needs are translated into functional requirements of the product, service, process, or information technology. Additionally, customer priorities and satisfaction targets are transferred into functional requirement priorities and performance targets, independent of the enabling technology. This technology independence allows for greater freedom of design in technology deployment. Functional requirements are then deployed to components, processes, and quality assurance.

4.2.3.2 Technology deployment

Either in response to unachievable product function and performance, or in engineering-driven innovation, technology deployment matches systems and subsystems to assess how well they achieve the prioritized functions and performance targets. This can trigger additional innovation efforts, refinement of technology concepts regarding user experience and interface, redirection of technologies to more appropriate markets and customers, and establish criteria for technology assessment and selection, including costs. This is detailed in 10.4.3.

4.2.3.3 Cost deployment

As technologies are explored, the costs to develop and produce them must align with market price and business financial requirements such as revenues and profits. Selling price targets drive product cost targets which flow down to system, subsystem, component, and build cost targets. This flow down is managed through the tables and matrices in cost deployment. Since costs are absolute and not relative, the calculations in cost deployment matrices are more precise and are detailed in 10.4.4.

4.2.3.4 Reliability deployment

New technology increases risks related to many unknowns in actual customer usage, interactions with other systems provided by other suppliers, new materials, new software, and others. Risk of unknown failures can be, to some degree, forecasted based on known failures. Reliability deployment is detailed in 10.4.5.

NOTE 1 The comprehensive QFD charts in this document use improved mathematics and tighter definitions to guide the user, resulting in faster implementation and more confident results.

NOTE 2 Additional tools and methods have been added to comprehensive QFD such as strategic planning and market segmentation (referred to in ISO 16355-2), voice of customer translation into customer needs and improved mathematics (referred to in ISO 16355-4), and innovation and costing methods referred to in this document in 10.4.3.4 and 10.4.4, respectively.

NOTE 3 According to the scope of the project, a subset of these deployments and their associated tools can be required. Management awareness that such deployments exist helps improve their directives to product development teams, monitor their process, in order to increase their confidence in the results.

4.2.4 Matrix of matrices

A version of the comprehensive QFD models was developed to make the matrices easier to follow thought a systematic re-drawing of the information flows. It is called the matrix of matrices[28] and displays the charts independent of each other. It is referenced in the standard when applicable.

4.2.5 Modern Blitz QFD® 1)

As modern businesses work to improve efficiency in a highly competitive global marketplace, the need for speed in new product development has emerged as an important constraint on QFD. The resources and time required for the classical and comprehensive approaches is not always feasible, and so a faster approach was developed by the U.S. QFD Institute called Blitz QFD® as shown in Figure 2. The idea is to get the benefits of comprehensive QFD more quickly by focusing on only a small number of the highest priority customer needs. The emphasis on high priority customer needs requires additional analyses to ensure greater confidence in the prioritization process. Identifying high priority customers, semantic analysis, and situation analysis is explained in ISO 16355-2. Identifying high priority customer needs is explained in ISO 16355-4. Detailed design work is explained here in 9.2.

4.2.6 German QFD Institute model

This model includes several of the tools for market research, innovation, cost reduction, and reliability in the updated comprehensive QFD added to the classical 4-phase QFD. Many users find this a middle way through the other models.[19]

1) Blitz QFD® is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

5 Integration of QFD and product development methods

5.1 QFD support for product development methods

QFD support for product development methods is referenced in ISO 16355-1:2015, 5.1.

5.2 Flow of solution development with QFD

5.2.1 Organization of the QFD flow

The flow of QFD methods and tools can vary according to the organization and project requirements. Typically, they begin with broad concerns and through prioritization flow down to specifics. Figure 3 shows the flow of product development from quality to technology to cost to reliability deployments.

5.2.2 Flow charts of strategy and translation of VOC into engineering solutions and cost planning

The detailed flow charts are presented in Figure 2 and Figure 3. These flow charts represent how the various tools in this document link together as a standard operating procedure that can be applied to individual projects. Not all tools are required on all projects. Custom tailoring of appropriate tools and sequence are recommended.

6 Types of QFD projects

QFD projects can encompass new developments as well as generational improvements to existing products. The types of QFD projects are referenced in ISO 16355-1:2015, Clause 6 and ISO 16355-4:2017, Clause 6, notes.

NOTE QFD tools and sequence have evolved since the first studies in the 1960s in the automobile parts industry that used simple diagrams and matrices to identify design elements and downstream manufacturing details. When end-user products, non-manufactured products such as service and software, and business processes began using QFD, additional tools were added to address human tasks, information, and other complexities (see Figure 3). In more recent years, organizational resource constraints have led to a quicker approach that addresses both complexity and speed (see Figure 2). It is consistent with quality methods in general and with customer-driven methods like QFD in particular that the methods and tools evolve and adapt to the ever-changing business environment of its practitioners, in order for them to remain viable and practicable. This evolution is demonstrated in the bibliography of case studies.

7 QFD team membership

7.1 QFD uses cross-functional teams

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

7.2 Core team membership

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

7.3 Subject matter experts

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

NOTE The matrix relationships and quantifications can be determined by the QFD team with representatives of customer-facing and technology-facing departments, such as marketing and operations or engineering. It is becoming more common with technology products for customers and stakeholders to be invited to participate, often in multiple meetings as the products are iterated. This is called continuous[18][20] or collaborative QFD.[54]

7.4 QFD team leadership

QFD team leaders or moderators can be trained in the QFD tools and methods in order to effective lead the QFD project. Additional tools, as identified in the appendices can be useful. Basic team facilitation and moderation skills are recommended.

NOTE 1 The QFD team leader can take a position of being function-agnostic so as to remain neutral to any business department or activity.

NOTE 2 Team membership and responsibilities can be indicated according to the development process and functional departments and human resources. This can be detailed in a process map, supplier-input-process-output-customer (SIPOC) steps and inputs, or a cause-and-effect L-matrix.

EXAMPLE Table 1 indicates the product development process in the rows and which departments or resources have what level of responsibility to the project.

Table 1 — QFD team responsibility L-matrix

Process \ Resource	Project owner	Finance	Marketing/Sales	R&D	Engineering	Supply chain	Manufacturing/Production	Logistics	Tech support
Strategize	●	◕	◕	◑	◔	·	·	·	·
Fund	◑	●	◔	◑	·	·	·	·	·
Define customer problem	◑	·	●	◕	◔	·	·	.	◔
Define product solution	○	·	○	●	◕	◔	◔	○	○
Develop	○	·	◔	◑	●	◕	◑	◔	◔
Test	○	·	○	◔	●	◕	◑	·	·
Source/Supply	○	·	·	◔	◕	●			
Build	○	·	·	○	◕	◑	●	.	○
Commercialize	○	◔	◑	.	◔	◑	◕	●	◔
Support	·	·	◔	○	◔	◔	◑	◕	●
Retire	·	·	·	·	·	·	·	◑	●

Key

●	Primary responsibity
◕	Secondary responsibilty
◑	Subject matter expert
◔	Support resource
○	Keep informed

8 Seven management and planning tools

The use and purpose of the seven management and planning tools are referenced in ISO 16355-2:2017, 8.2.

9 Translation of one information set into another

9.1 General

QFD flows information sets through the various development and commercialization functions of the organization and design dimensions. These flows are called deployments and often require the language of one information set to be translated into another information set, or a single information set broken down into more detail. This translation can be visually displayed to check for completeness and accuracy, and can be mathematically quantified for complex information sets. The first transformation is often from customer needs into product functional requirements, quality characteristics and capabilities, and specification values. There are two approaches to doing this,

a) maximum value table, and

b) L-matrices.

9.2 Maximum value table

9.2.1 General

The maximum value table is used to show everything on the project that is most important to the customers and stakeholders. It identifies where to apply best efforts to the tasks that are essential to delivering value to customers. By doing so, maximum value to customers results from minimum efforts by the QFD team.

9.2.2 Effect-to-cause diagram

Early QFD studies used an effect-to-cause diagram to show the relationship between product attributes and customer needs.[39] Product attributes cause a customer need to be fulfilled. For each customer need, the QFD team can determine what product attributes, from development through commercialization are essential to delivering quality and satisfaction.

NOTE 1 The traditional cause-and-effect diagram (also known as Ishikawa diagram or fishbone diagram) is adapted in QFD to uncover the root causes of success rather than failure. It has two formats: cause-to-effect, which is explained in ISO 16355-4, and effect-to-cause. Note that the arrows point from one effect to many causal factors.

NOTE 2 The customer need is the effect. The names of causal bones and sub-bones depend upon the product. Technical staff with sufficient product knowledge can be invited to the QFD team to help identify them.

NOTE 3 Target values sufficient to meet the customer need can be determined by experimentation and testing as soon as possible.

NOTE 4 Each customer and stakeholder need can have a separate effect-to-cause diagram. Do high priority customer and stakeholder needs first. The analytic hierarchy process (AHP) can be used by customers and stakeholders to prioritize their needs.[48][17]

EXAMPLE Figure 1 is adapted from the first published QFD case study by Bridgestone Tire in 1966. It shows that the desired effect of smooth ride can be positively caused by proper design of the tire characteristics of tire trueness and sidewall strength, proper setting of the moulding process characteristics of pressure, time, and accurate fit of the mould halves, and proper raw material handling storage humidity and rotating the materials so that the oldest polymers are used first.

NOTE 5 The “head” of the fishbone diagram in QFD is oriented on the left side to indicate the flow of information from left-to-right as will be seen in the maximum value table in 9.2.3. This change in orientation better demonstrates the QFD matrix construction as a set of effect-to-cause diagrams with the heads becoming the rows of the matrix and bones becoming the columns.

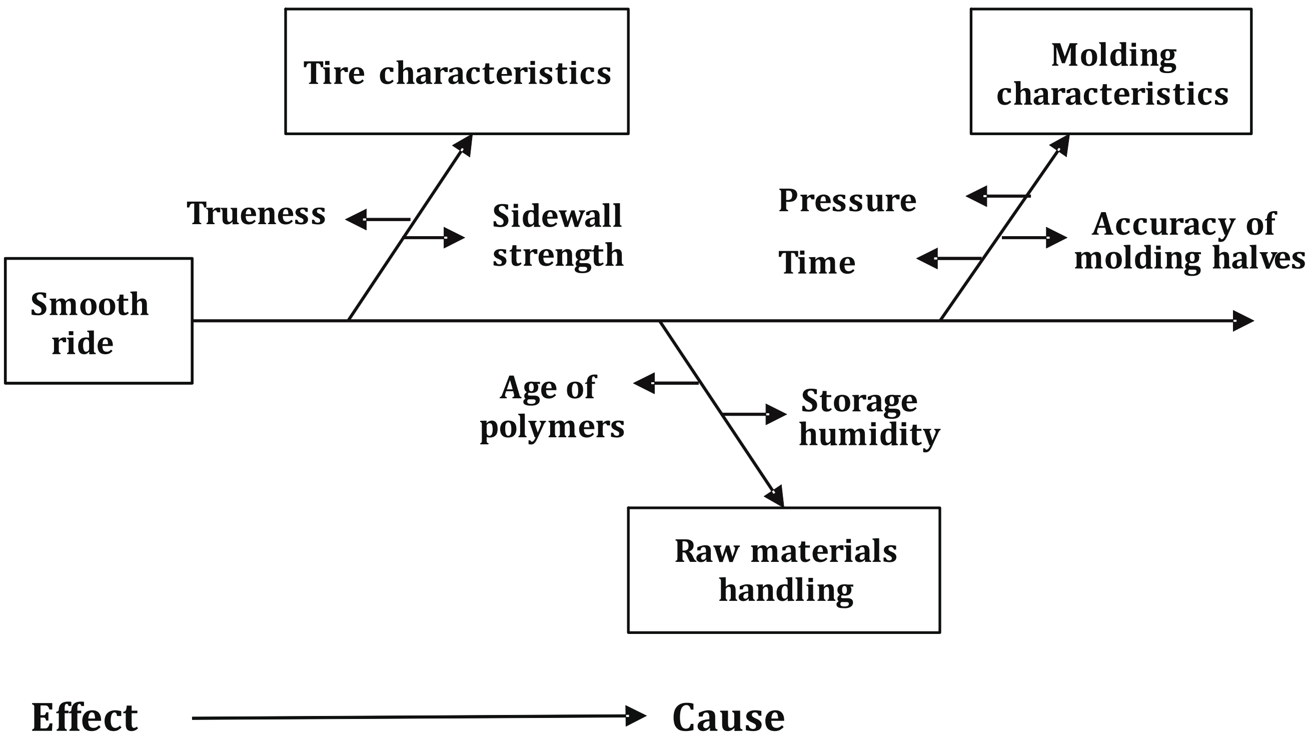


Figure 1 — Effect-to-cause diagram

9.2.3 Steps to make a maximum value table

The effect-to-cause diagram can be presented in a spreadsheet by putting the information into the columns. This is called the maximum value table.

— Enter information regarding the customer such as segment, application and use modes, problem, and other contexts that help the QFD team determine appropriate target values.

— Enter high priority customer and stakeholder needs. The analytic hierarchy process (AHP) can be used by customers and stakeholders to prioritize their needs.[17][48]

NOTE 1 The number of needs to include depend upon the priorities of the needs as well as the project schedule, budget, and available resources. The guideline is to analyse only those needs for which the project can take action. Many projects can have only three to five high-priority needs.

— Identify the necessary design dimensions necessary to address the project. Make these separate column headers.

— For each high priority customer or stakeholder need, enter into the appropriate column any information, target values, tests to be done, and other relevant information as it becomes known. The maximum value table grows as the project progresses end-to-end throughout the development and realization process

— Indicate any special tasks related to this acquiring or acting on this information. Special tasks can be protected from de-scoping by the project manager in cases of budget or schedule conflict, as they are critical to addressing the most important customer or stakeholder needs.

EXAMPLE In Table 2, the highest priority customer need is my employees appreciate the benefits I provide to them.[17] To fulfill this need and ensure that downstream service activities are performed sufficiently, the following must take place:

a) contract should show savings to employee of using insurance;

b) provider network (doctors and hospitals) should show their Blue Cross network is superior to care offered by competing provider networks;

c) to communicate this, the sales broker or representative should explain exactly how the claims mechanism works;

d) system should collect user feedback to ensure it works as promised;

e) system level design should report employee savings and comparisons to street (uninsured) fees.

NOTE 2 Customer needs are transformed into product functional requirements which can include capabilities (technology-independent functions), quality and performance characteristics, and specification targets. In this example, which focuses on communication of information to the employees, only the capabilities of show savings, explain richness of benefits, and show employees how much employer paid are presented.

NOTE 3 The effort to develop and realize a solution strategy for the highest priority needs can consume the available budget, schedule, and human resources. The maximum value table helps ensure the highest value customer and stakeholder needs are addressed first and best. If available resources are consumed, this is possibly all the QFD the team can perform. All other customer and stakeholder needs can then receive standard engineering attention.

NOTE 4 QFD teams needing to address a larger set of customer and stakeholder needs can use an L-matrix to analyse two design dimensions at a time. The maximum value table is useful in determining which design dimensions warrant the L-matrix analysis.

NOTE 5 The maximum value table can be done early in the QFD study to analyse the solution to the most important customer or stakeholder needs. Even if other tools such as L-matrices are employed later, doing the maximum value table first can give the QFD team a head start on the critical needs.

NOTE 6 Maximum value tables from similar products or generations of products can be aggregated into comprehensive QFD L-matrices. This spreads the time and effort over several projects, eventually yielding the benefits of the deeper analysis of comprehensive QFD.

Table 2 — Maximum value table for health insurance company

Solution							Design	Implementation
Customer need	**Contract**		**Broker/Representative**	**Operations**		**Feedback**		
	Benefits	**Provider network**		**Member service**	**Claims**			
My employees appreciate the benefits I provide them.	Show savings to employee of using insurance	Explain to employees how Blue Card and BCBSF provider netrowrk is superior	Explain how benefits mechanism works			Assure benefits are working as promised and useful.	Employee savings report information	Expand PHR to include billing comparison to street rate.
	Explain richness of benefits offered through BCBSF	Employee does not have to change “critical” MD (pedia, OBGYN) to conform to plan	Explain to employees industry averages if employer is above average			Employees know they have a conduit for feedback	Provide customer advocate/ombudsman	
	Show employees how much the employer paid for their benefits		Explain network savings				Network savings report info	
							Report to summarize employer payments	
							Validate in PHR that decisions were good decisions (by staying in network/generics/etc.) or alternatives that would offer better outcomes/savings	
							Provide tools to employees that recommend plans based on current provider selections.	
							Provide tools to show employees what their costs would be for various benefit plans based on their experience.	

9.2.4 Modern QFD

The maximum value table can be used with other modern Blitz QFD® tools for analysing the voice of the customer and voice of the stakeholder. Guidance for the semantic analysis and situation analysis phases is explained in ISO 16355-2 and guidance for the goal analysis phase is explained in ISO 16355-4. The maximum value table is in the project strategy phase at the right in Figure 2[35][57] and is positioned between the prior steps and the L-matrices used in comprehensive QFD.

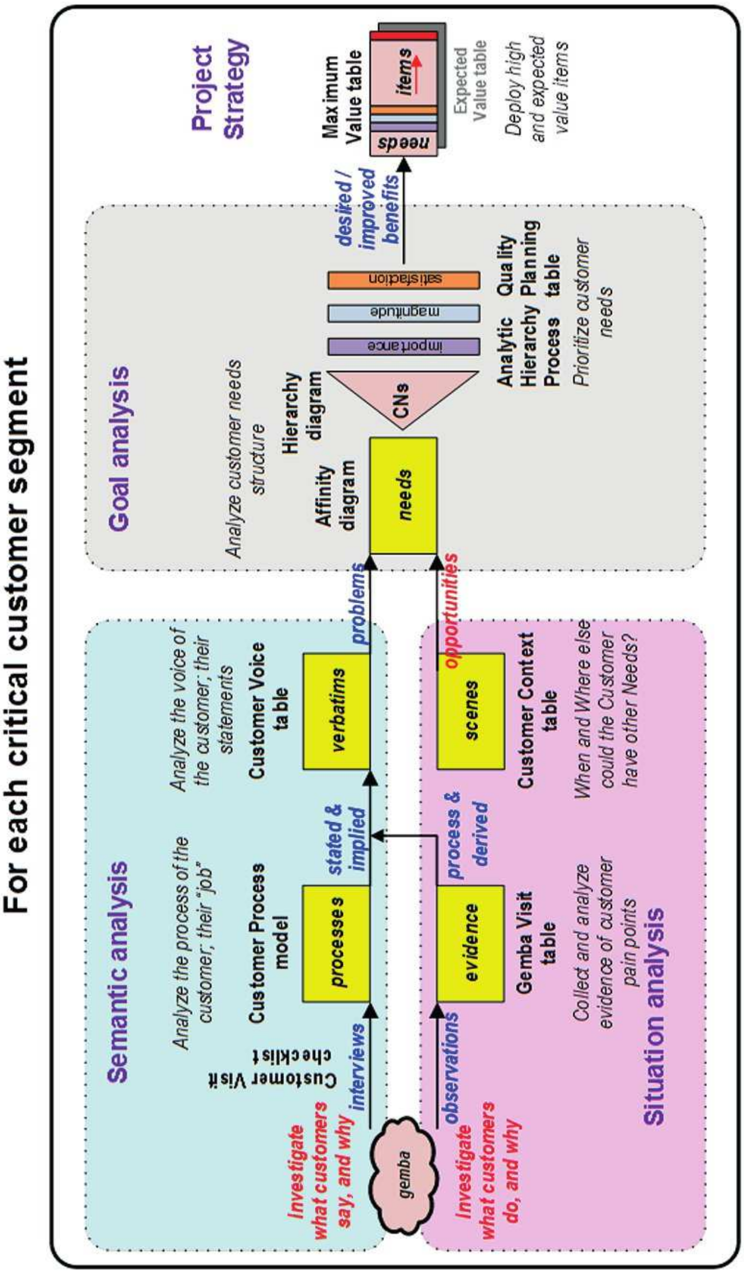


Figure 2 — Modern Blitz QFD® flow

9.3 L-matrices

9.3.1 General

The seven management and planning tools include several types of matrices. The most common matrix in QFD is the L-matrix which is used to examine two dimensions of information. L-matrices can be used to examine goals and the means to achieve them, responsibilities, and relationships. The most common L-matrix in QFD is used to examine effect-to-cause relationships.

9.3.2 Entering information into L-matrices

When the row and column information sets are large, they can be organized with the affinity diagram and hierarchy diagram. Most common are three to four levels of primary, secondary, tertiary, and quaternary levels of abstraction. When building an L-matrix, the level of abstraction of the row can match the level of detail of the column. If mixed, the weight calculations of the matrix can have errors due to over- or under-counting relationships that are mismatched.

9.3.3 Determining effect-to-cause relationships in a QFD L-matrix

The QFD L-matrix is essentially a collection of effect-to-cause fishbone diagrams to show many effects to causes relationships. Effects are commonly placed in the rows of the matrix and causes in the columns. If this orientation is rotated, the effect-to-cause relationship can be preserved. The strength or contribution of a causal relationship can be indicated with words, symbols, or numbers. If the relationships between the effects and causes are subjective, then words and symbols are commonly used to indicate the strength or level of the relationship, as follows:

a) classical QFD matrices use three levels of relationships described as weak (W), moderate (M), strong (S); symbols or icons used are:

Weak: △ Moderate: ○ Strong: ◎

NOTE 1 Strengths of this approach: familiarity. Weaknesses of this approach: with only three levels, QFD teams can struggle to agree on the appropriate level.

b) modern QFD matrices use five or nine levels of relationships described as weak (W), moderate (M), strong (S), very strong (V), or extremely strong (X), as well as intervals such as weak-to-moderate (W-M), and so forth. These levels align with the analytic hierarchy process (AHP) that are used later to transfer priorities from the effects to the causes. Symbols or icons used are:

W ○ W-M ◔ M ◔ M-S ◑ S ◑ S-V ◕ V ◕ V-X ◕ X ●

NOTE 2 Strengths of this approach: when the level of relationship requires a judgment, human short-term memory capacity is best when there are 7 ± 2 (5 or 9) levels. This allows first a judgment of high, medium, low, and then within each category another high, medium, low. This creates nine levels ranging from high-high to low-low, giving QFD teams more relationship levels to select from, and thus improving agreement. Weaknesses of this approach: unfamiliar but has a short learning curve, commercial QFD software cannot support these symbols.

NOTE 3 Certain symbol or icon patterns indicate the health of the matrix. For example, blank rows or columns indicate missing information. Nearly identical rows or columns indicate problems with comingled levels of abstraction of the row or column hierarchies.[31]

NOTE 4 In addition to the L-matrix, QFD can use T-matrices, Y-matrices, C-matrices, and others in the seven management and planning tool set.[5][38][41]

9.3.4 Linking matrices

Since each L-matrix relates two columns from the maximum value table, several matrices can be required to complete the QFD analysis. It is common that the columns of one matrix cascade into the rows of the next matrix in sequence. Thus, the matrices can be linked so that information flow downs and flow ups can be established such that changes in one matrix can be updated in later matrices. This can be useful if the matrices are later weighted with priorities and quantifications. A set of linked matrices can create a comprehensive QFD framework that can be used again on other projects.

9.3.5 Comprehensive QFD

In 1988, a comprehensive QFD model was developed that added to the quality deployment additional deployments to address issues related to technology, cost, and reliability. These deployments could be applied at the product level, system level, component level, and build level, as shown in Figure 3.[1] These deployments are explained in later clauses of this document.

NOTE 1 Comprehensive QFD is referred to in JIS Q 9025, 6.1.[24]

NOTE 2 Comprehensive QFD was used as the model for the US-developed matrix of matrices.[28]

9.3.6 House of quality

9.3.6.1 General

One of the most common L-matrices in QFD is the house of quality. The first published use of this matrix was in 1972 in Japan for a ship-building program. Later enhancements earned it the nickname "house" of quality due to its shape and several rooms.[3] It is also referred generically as a quality table. In the comprehensive QFD flowchart in Figure 3, the house of quality is located in the upper-left corner as Table 1–I. The house of quality is not shown in Figure 2 but can be used after the maximum value table when greater detail is required.

9.3.6.2 Information for building the house of quality

The house of quality is so named for the several "rooms" or tables and the sometimes used "roof" that comprise it. These rooms, explained in this document and guidance for creating them, are as follows:

a) customer needs hierarchy in the rows of the house of quality (in 9.3.6.2.1 and ISO 16355-4);

b) functional requirements in the columns of the house of quality (in 9.3.6.2.2);

c) customer needs — functional requirements matrix in the centre of the house of quality displays the strength of the contribution or relationship of each functional requirement to each customer need (in 9.3.6.2.3);

d) quality planning table in the right-side room of the house of quality adjusts the priorities of the customer needs in response to customer satisfaction with current and competitors' products, strategic product planning, and sales activities (in 10.3.2.1 and ISO 16355-4);

e) design planning table in the basement of the house of quality adjusts the priorities of the functional requirements in response to competitive benchmarking, technical advantage, technical difficulty, and Kano dimensions of quality (in 10.3.4.1);

f) functional requirements correlation matrix in the roof of the house of quality looks for conflicts and tradeoffs among the functional requirements that could impact design decisions (in 10.4.3.4.1.1).

These rooms are assembled as shown in Table 17.

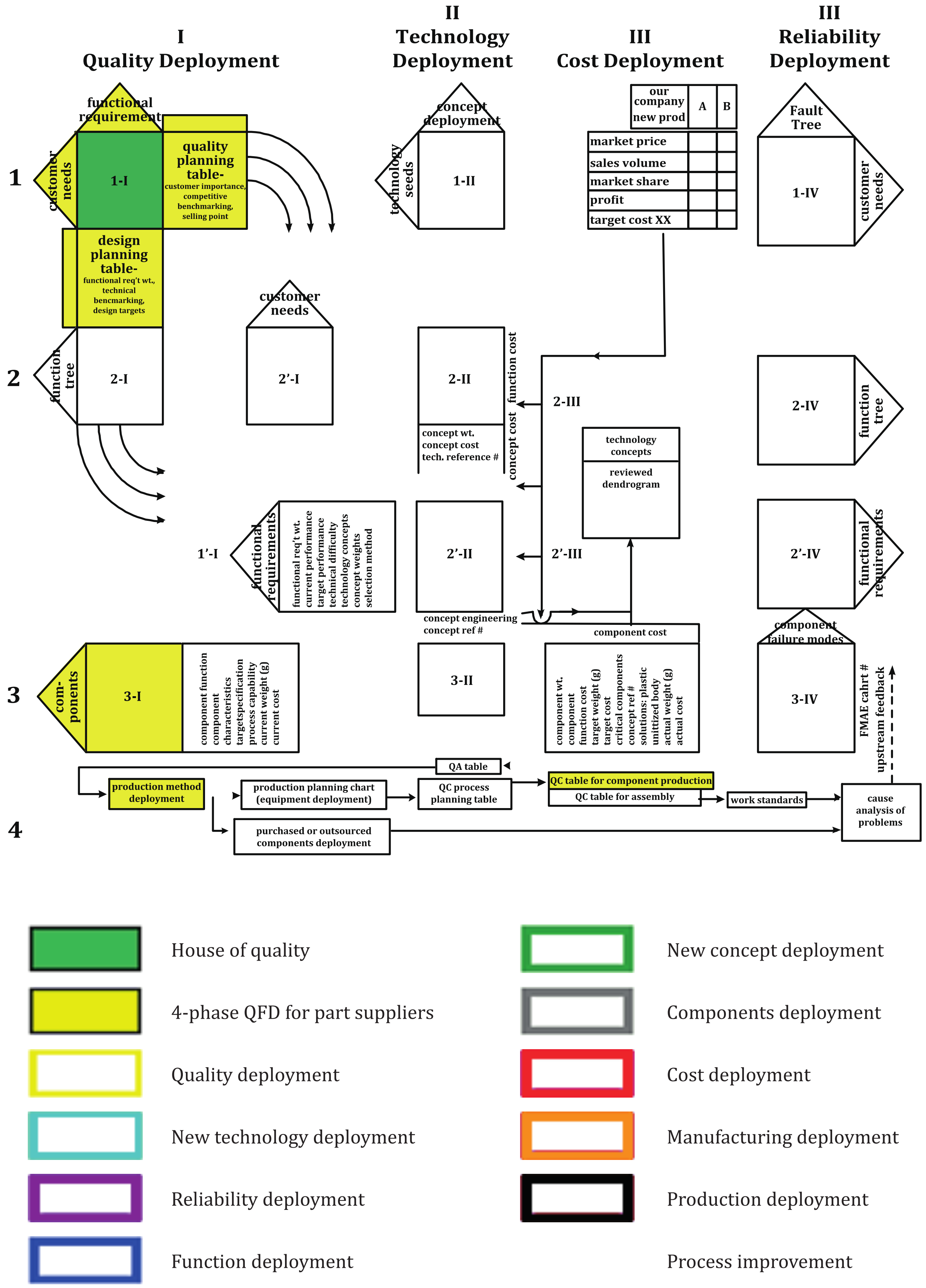


Figure 3 — Comprehensive QFD

9.3.6.2.1 Customer needs hierarchy diagram

In the rows of the house of quality are the customer needs. As noted in Clause 3, customer needs describe the benefit to the customer of their problem solved, their opportunity enabled, or their image enhanced, independent of the product. Historically, these were called demanded quality items. The customer needs can be entered as a hierarchy diagram with only the most detailed level, usually tertiary level, being assigned relationships. This is explained in ISO 16355-4 in the customer voice table.

NOTE 1 In QFD, the voice of customer is sometimes referred to as requirements because it comes directly from the customer. Requirements can include a raw mix of needs, solutions, and features. However, it is important to understand why the customer has specified these requirements, and so the customer voice table in ISO 16355-4 explains how to translate voice of customer requirements into true customer needs. Getting the underlying customer needs has two benefits. One, customers can prioritize them more accurately and two, they more clearly separate the problem space from the solution space which can lead to more innovative solutions. Another confusing term, “wants and needs,” actually refers to priorities with needs having a higher priority than wants. In QFD, these priorities are clearly calculated using the AHP process explained in ISO 16355-4.

NOTE 2 In Figure 3, the customer needs hierarchy is represented as a triangle on the left side of the matrix. It is not a correlation matrix or trade-off matrix, since customer needs have priorities, not conflicts.

9.3.6.2.2 Functional requirements hierarchy diagram

In the columns of the house of quality are the functional requirements. Historically, these were called quality characteristics, but to make QFD easier to apply in non-manufacturing applications, the more universal term functional requirements has been adopted. As noted in Clause 3, functional requirements describe what the product is or does without defining how it does it. Thus, they can be technology-independent. Functional requirements can already be known by the QFD team or can be extracted from each customer need using an effect-to-cause diagram. If possible, determine the method of measuring each functional requirement to ensure that measurable targets can be set. Functional requirements can be structured with an affinity diagram and a hierarchy diagram. Affinity and hierarchy diagrams are explained in ISO 16355-4.

NOTE Some QFD users use the terms customer needs for the rows and product requirements for the columns. Product requirements can include both functional requirements and non-functional requirements. Non-functional requirements such as aesthetics are described in ISO/TR 16355-8. In value engineering, however, non-functional requirements such as aesthetics are called attractive functions.

EXAMPLE In Figure 4, notice the arrows come out of the customer need from the customer need “I can get a taste I like” (head of fishbone diagram) and point to the functional requirements (bones). Figure 5 and Figure 6 illustrate the structuring of the functional requirements.

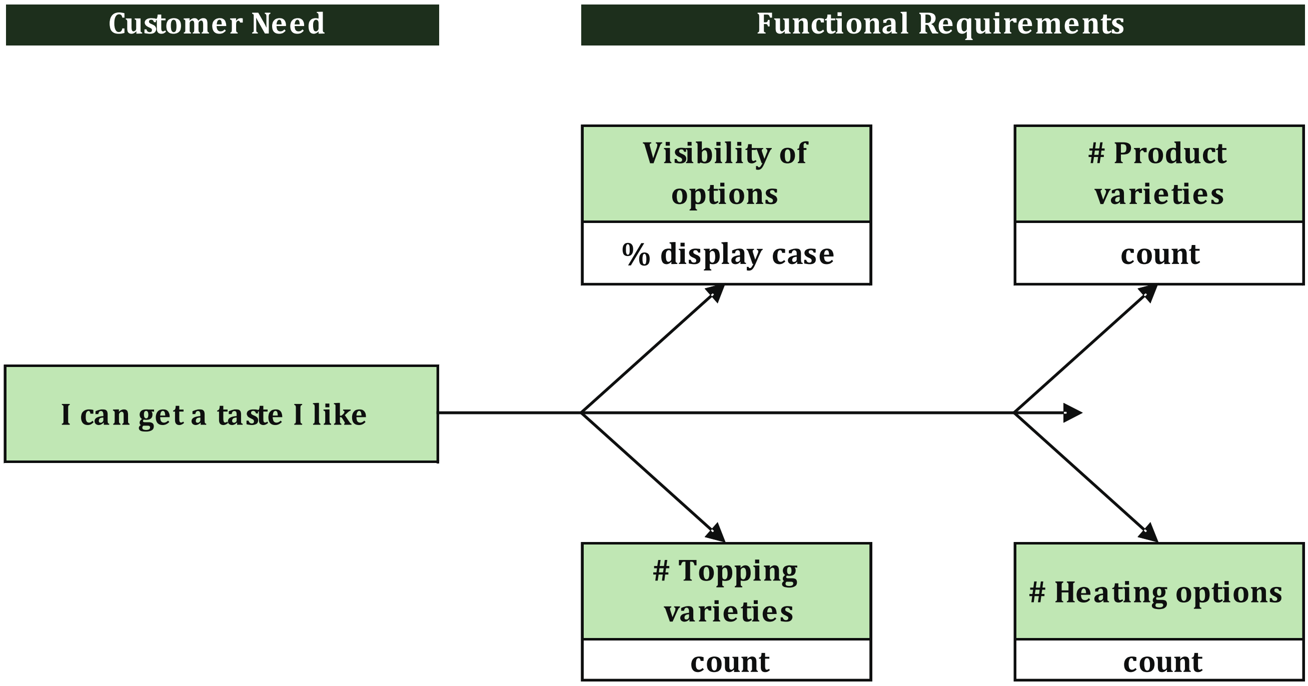


Figure 4 — Fishbone diagram used to extract functional requirements from customer needs in airport breakfast kiosk

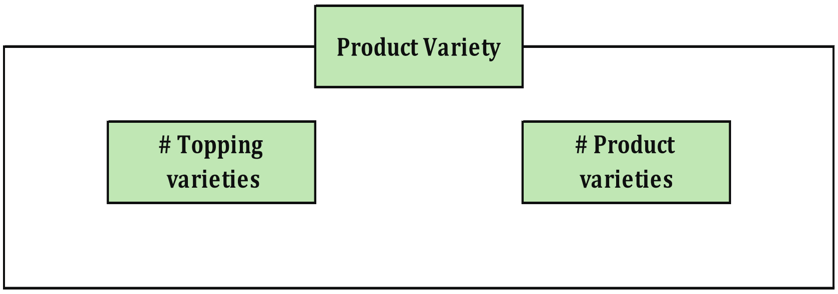


Figure 5 — Affinity diagram of functional requirements in airport breakfast kiosk

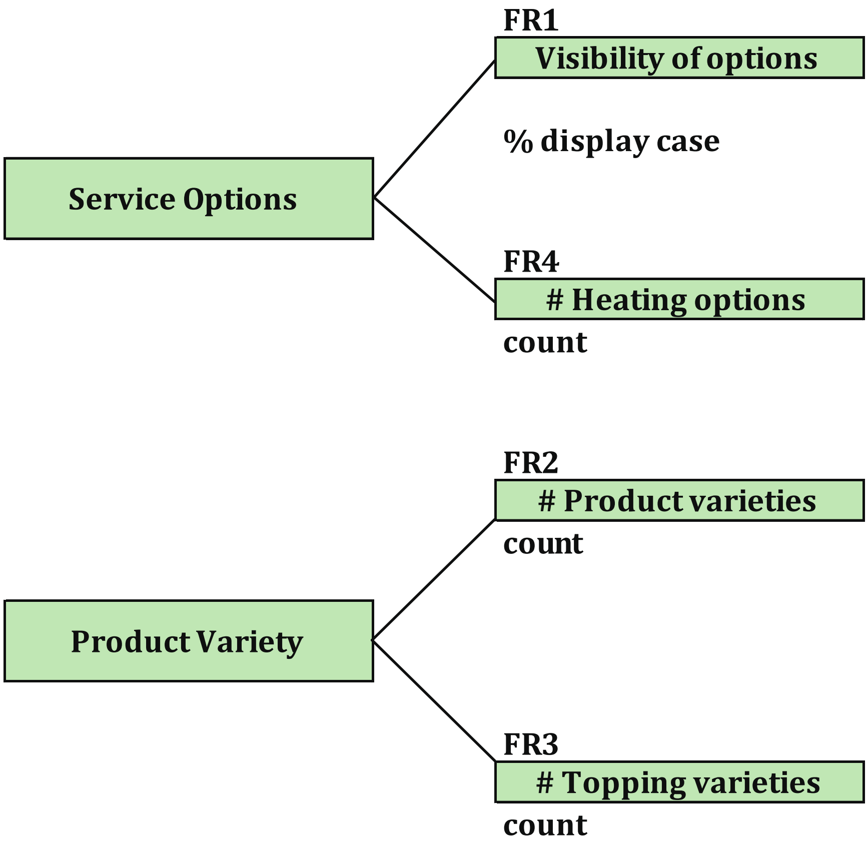


Figure 6 — Hierarchy diagram of functional requirements in airport breakfast kiosk

9.3.6.2.3 Matrix

Functional requirements are entered into the columns of an L-matrix, matching the same level of detail as the customer needs. Working row-by-row, the strength of contribution or relationship of each functional requirement noted in the intersecting cells of the matrix. The strength of contribution or relationship is explained in 10.2.1.

NOTE 1 In Figure 3, the functional requirements hierarchy is represented as a triangle on the top of the matrix. It is not a correlation matrix or trade-off matrix since these arise only in technology specific characteristics or attributes.

NOTE 2 Historically, this is the only matrix to have the term quality in both the rows and columns, thus earning it the nickname “house of quality.” The modern approach is to name matrices by the names of their information sets. Thus, the house of quality can be referred to as the customer needs-functional requirements matrix. This avoids confusion of the many matrices in comprehensive QFD.

NOTE 3 Normally, each functional requirement has a relationship with more than one customer need. In some cases, increasing the performance of the functional requirement helps achieve the customer need, in other cases, meeting a target value of the functional requirement helps achieve the customer need, and in still other cases reducing the performance of the functional requirement helps achieve the customer need. For example, increasing the size of an umbrella helps achieve the customer’s need to stay dry in the rain, but decreasing the size of an umbrella helps achieve the customer’s need to carry it easily. Therefore, functional requirements do not have direction until setting targets in the design planning table discussed in 10.3.4.3.

NOTE 4 Functional requirements are referred to in JIS Q 9025, 5.4.2.[24]

NOTE 5 The functional requirements correlation matrix, often referred to as the “roof” of the house of quality is most useful to examine for positive (as one functional requirement improves, so does another) or negative correlations (as one functional requirement improves, another is reduced), after an enabling technology is selected. Since the positive or negative correlations are technology dependent (change the enabling technology and the correlations change), doing this matrix can prematurely imbed a solution paradigm into the analysis, thus limiting the QFD team’s ability to innovate.

EXAMPLE Table 3 is an example of an unweighted matrix. This matrix shows that the customer need of I can make a healthy choice is moderately achieved by making the food and preparation options visible, strongly achieved by having a number of product varieties, and strongly achieved by having a number of topping varieties. Number of heating options as no impact.[30]

Table 3 — Customer needs-functional requirements matrix (house of quality) for airport breakfast kiosk (unweighted)

Customer Needs \ Functional Requirements (for service)		Visibility of options SR1	# Product varieties SR2	# Topping varieties SR3	# Heating options SR4
1.1.1	I can make a healthy choice	◔	◑	◑	·
1.1.2	I can get a taste I like	◑	◕	◑	◔
1.1.3	I can make an appealing choice	●	◕	◑	◔
1.1.4	I can choose quickly	◕	◑	◑	◔

9.3.7 Knowledge management

Unweighted L-matrices are also useful in knowledge management to capture intrinsic or “tribal” knowledge of individuals in the organization.[2] Information in L-matrices can later be weighted for a specific project. This can be valuable in the following scenarios:

a) mature organizations whose engineering technology and methods are poorly documented;

b) organizations facing employee turnover due to retirements, short-term project work, mergers and acquisitions;

c) organizations expanding their technical staff. Knowledge management matrices can be helpful in training new hires.

10 Transfer of prioritization and quantification from one information set into another

10.1 General

Prioritizations and quantifications of one information set can be transferred into prioritizations and quantifications of another information set. This is used to flow the results of each analytic tool into the next tool in order to ensure that upstream priorities and targets are deployed downstream into solution priorities and targets. In a QFD L-matrix, prioritization builds on relationships that show the strength of relationship or contribution of the columns of the matrix to the rows of the matrix as explained in 9.3.3.

NOTE Typically, the transfer of prioritization and quantification are done by the QFD team, involving both customer facing (marketing, sales, product managers) and technology facing (R&D, engineering, and others) members.

10.2 Transfer of prioritization

10.2.1 Quantify strength of relationships in the matrix

There are different approaches to quantifying the weights of contributions or strengths of relationships in a matrix. An approach that is appropriate for the analysis can be used.

a) Classical QFD matrices using three levels of relationships described as weak (W), moderate (M), strong (S) and assigned values of 1, 2, 4 or 1, 3, 5 or 1, 3, 9 respectively.

   NOTE 1 Strengths of this approach: familiarity, 1, 3, 9 addresses problem of transferred priorities being too close in value. Weaknesses of this approach: with only three levels, QFD teams can struggle to agree on the appropriate level, these are ordinal scales without fixed intervals so that resulting QFD math functions have results that only tell order but not relative importance.

b) Modern QFD matrices use five or nine levels of relationships described as weak (W), moderate (M), strong (S), very strong (V), or extremely strong (X), as well as intervals such as weak-to-moderate (W-M), and so forth. Assigned values can be adapted using the analytic hierarchy process, but the following are commonly used.

   Five levels: W (0,069), M (0,135), S (0,267), V (0,518), X (1,00)

   Nine levels: W (0,059), W-M (0,079), M (0,112), M-S (0,162), S (0,237), S-V (0,344), V (0,498), V-X (0,712), X (1,000)

   NOTE 2 Strengths of this approach: When the level of relationship requires a judgment, human short-term memory capacity is best when there are 7 ± 2 (5 or 9) levels. This allows first a judgment of high, medium, low, and then within each category another high, medium, low. This creates nine levels ranging from high-high to low-low, giving QFD teams more relationship levels to select from, and thus improving agreement. These ordinal judgments are transformed into absolute scale values with fixed intervals using the AHP principle eigenvector, so that resulting QFD math functions tell both order and relative importance. Weaknesses of this approach: unfamiliar but has short learning curve, if commercial QFD software does not support assigning ratio scale values, QFD team can build its own spreadsheet.

c) Nonlinear relationships can be used in cases where other scales are justified.

d) Technical L-matrices can use the formula $Y = f(x_1, x_2, \ldots x_n)$. Where measureable data exists between the input (x) and output (y), the Pearson product moment correlation coefficient can be used to measure the degree of linear relationship between the two variables. The correlation coefficient assumes a value between −1 and +1. If one variable tends to increase as the other decreases, the correlation coefficient is negative. Conversely, if the two variables tend to increase together the correlation coefficient is positive. However, in most QFD L-matrices such as the house of quality, the absolute value of the correlation can be used so that when column values are summed, positive and negative correlations do not cancel each other out but rather add to indicate a higher priority.

e) Display of relationships or contribution can include icons representing the various levels. Icons can visually increase according to the strength of relationship or contribution they reflect, from weak to extremely strong, as shown in 9.3.3.

10.2.2 Weight the rows

10.2.2.1 Customer need priorities

ISO 16355-4 explains how to get prioritized customer needs in the form of a hierarchy. Priorities can be as accurate, unbiased, and unambiguous as possible as they can serve later QFD activities related to cost and resource allocation. Thus, the mathematical limitations of different numerical scales cannot be ignored.

NOTE 1 Prioritization can be done by the group that "owns" the information. For example, customer needs can be prioritized by the customer.

NOTE 2 The analytic hierarchy process (AHP) enhances the precision of the statistical methods of QFD by employing absolute relative scale values with meaningful ratios that can be added, subtracted, multiplied, and divided.[48] AHP also gives customers a forced-choice, paired comparison model that yields more accurate results. Finally, when applied to a hierarchy, the prioritization process is broken into smaller groups which is less fatiguing than presenting customers with single, long list of needs to rate on an ordinal scale.

NOTE 3 Ordinal scale values do not contain sufficient information to perform QFD mathematical functions properly. There are these problems.

a) The ratios between the levels are not equal; the effort to go from 1 to 2 is 100 %, while the effort to go from 4 to 5 is only 25 %. In ratio scale, the ratios between the scale values are close to equal.

b) Because of the inequality or ratios, ordinal scales tend to bias towards the higher values.

c) Ordinal scale values cannot be divided, nor can most other mathematical functions be performed. Ordinal numbers do support mode and median, which is why early QFD studies recommended using response mode (most frequent count) rather than mean (average) response.

NOTE 4 Those preferring 1–5 scale surveys can still survey with ordinal numbers. However, before any mathematical functions are performed, such as averaging, the responses can be converted to ratio scale. The five level ratio scale shown in 10.2.1 b) can be used as follows. 1 (0,069), 2 (0,135), 3 (0,267), 4 (0,518), 5 (1,00).

10.2.2.2 Cascading linked matrix priorities

In comprehensive QFD as shown in Figure 3, matrices can be linked together so that the columns of one matrix cascade into the rows of the next matrix in the sequence. Similarly, the column weights of one matrix can be cascaded into the row weights of the next matrix in the sequence. This is important for transferring the information sets and priorities from customer needs through functional requirements into quality, technology, cost, and reliability factors as shown in Figure 3 and detailed later in this document.

NOTE 1 If only a subset of columns are cascaded into the next matrix in the sequence, those weights can be normalized to 100 % before cascading. This keeps downstream weights from displaying too many zeros after the decimal and thus making their priorities more difficult to recognize. Ratio scale weights can be used or downstream weights can lose accuracy.

NOTE 2 Avoid confusion by not referring to rows as "whats" and columns as "hows" in all the matrices. In fact, the rows of the house of quality (customer needs) are "why" the customer wants the product and the columns are "what" the product must be or do (functional requirements). Functional requirements specifically do not include "how" to do it.

NOTE 3 If the effect-to-cause orientation of rows-to-columns is rotated as in some of the matrices in Figure 3, then the cascading matrix weights can also be rotated so that the row weights cascade to the columns of the next matrix in the sequence.

EXAMPLE Table 4 shows the flow of information and priorities from columns of one matrix to rows in the next matrix in the sequence. In this example, the columnar functional requirements for service and their weights at the bottom flow into the rows of the next matrix which is the functional requirements (for service)-function matrix. This example is explained in detail in 10.4.2.4.3.

Table 4 — Cascading linked matrices for airport breakfast kiosk

Customer Needs \ Functional Requirements		Priority (from unweighted QPT)	Visibility of options FR1	# Product varieties FR2	# Topping varieties FR3	# Heating options FR4
1.1.1	I can make a healthy choice	19,3%	0,022	0,046	0,046	0,000
1.1.2	I can get a taste I like	60,6%	0,143	0,302	0,143	0,068
1.1.3	I can make an appealing choice	11,6%	0,116	0,058	0,027	0,013
1.1.4	I can choose quickly	8,6%	0,043	0,020	0,020	0,010
weighted	Absolute Weight		0,324	0,425	0,237	0,091
	Functional Requirement Weight		30,1%	39,5%	22,0%	8,4%
	Functional Requirement Rank		2	1	3	4

Functional Requirements (for service) \ Functions		FR weights	COMMISSARY Source Product FN1	Acquire Product FN2	Prepare Product FN3	Ship Product FN4	OPERATIONS Finish Preparation FN5	Sell Product FN6	Display Product FN7	Maintain Product FN8
SR1	Visibility of options	30,1%	0,071	0,071	0,071	0,071	0,150	0,000	0,301	0,150
SR2	# Product varieties	39,5%	0,395	0,395	0,094	0,395	0,044	0,094	0,395	0,395
SR3	# Topping varieties	22,0%	0,220	0,220	0,052	0,220	0,052	0,052	0,052	0,052
SR4	# Heating options	8,4%	0,020	0,020	0,000	0,000	0,000	0,020	0,000	0,000
weighted	Absolute Weight		0,706	0,706	0,217	0,686	0,246	0,166	0,748	0,597
	Function Weight		17,3%	17,3%	5,3%	16,9%	6,0%	4,1%	18,4%	14,7%
	Function Rank		2	2	7	4	6	8	1	5

10.2.3 Calculate the column weights

Transfer of priorities from rows to columns can be calculated as:

$$W_j = \sum_{i=1}^{n} X_i a_{ij} \qquad (1)$$

where

X_i is the priority of the row item (for example, customer need priority in the house of quality);

a_{ij} is the strength of the relationship between the row and the column.

NOTE 1 Because ordinal scale weights such as 1,2,4 or 1,3,5 or 1, 3, 9 do not support mathematical functions such as addition, subtraction, multiplication, or division, ratio scale weights described in 10.2.1 b) can be used.

EXAMPLE Table 5 adds relationship weights to Table 3 . Working the first customer need I can make a healthy choice, it has a customer priority of 19,3 % derived from the unweighted quality planning table explained in part four of the standard (ISO 16355-4). Functional requirement visibility of options has a moderate relationship contributing to achieving this need. A moderate relationship is indicated by the quarter-pie symbol or icon, and it has a relationship weight of 0,112 as shown in 10.2.1 b). Multiply the customer need weight of 19,3 % × 0,112 = 0,022 rounded to three decimals. This is shown in the lower-right portion of the split cell. This is repeated for all relationships. The values in the lower-right portions of the split cells are then summed for each column to calculate an absolute weight. Thus, 0,022 + 0,143 + 0,116 + 0,043 = 0,324 rounded to three decimals. The absolute weights are then summed across: 0,324 + 0,425 + 0,237 + 0,091 = 1,077 rounded to three decimals. The absolute weights are then normalized into functional requirement weights by dividing each absolute weight by the sum of all absolute weights. Thus, 0,324/1,077 = 0,301 or 30,1 % rounded to three decimal places. If desired, rank order can be displayed as shown here.

NOTE 2 The use of split cells is optional. Specialized QFD software can display this easily, but most QFD software does not support ratio scale numbers, without which these calculations lose accuracy. Another solution is to use a spreadsheet and just show the relationship strengths as ratio scale values. The spreadsheet function sumproduct can be used to calculate an array of the row weights × the relationship strengths in the cells, and then sum the products as absolute weights.

NOTE 3 This example is the house of quality showing customer needs and functional requirements. The math calculations shown here apply to all QFD L-matrices. There are three methods of calculations depending on the distribution method described in 10.2.4. Table 5 uses the ideal distribution. If cost deployment is going to be used later in the QFD, then the proportional distribution method is recommended.

Table 5 — Customer needs-functional requirements matrix (house of quality) for airport breakfast kiosk (weighted, ideal distribution)

	Functional Requirements / Customer Needs	Priority (from unweighted QPT)	Visibility of options FR1	# Product varieties FR2	# Topping varieties FR3	# Heating options FR4
1.1.1	I can make a healthy choice	19,3%	0,022	0,046	0,046	0,000
1.1.2	I can get a taste I like	60,6%	0,143	0,302	0,143	0,068
1.1.3	I can make an appealing choice	11,6%	0,116	0,058	0,027	0,013
1.1.4	I can choose quickly	8,6%	0,043	0,020	0,020	0,010
weighted	Absolute Weight		0,324	0,425	0,237	0,091
weighted	Functional Requirement Weight		30,1%	39,5%	22,0%	8,4%
weighted	Functional Requirement Rank		2	1	3	4

10.2.4 Distribution methods

10.2.4.1 Use of scales

The mathematical calculations in the various distribution methods require addition, multiplication, and division. To preserve the accuracy of these calculations, ratio scale values can be used for row weights and relationship strengths as described in 10.2.1 b).

10.2.4.2 Independent distribution

Independent distribution treats each column independently of the other columns, so that no single column can dilute the others. In QFD, this is the most common distribution method. This identifies which columns are most critical and can be investigated further. For example, in the house of quality, functional requirements are prioritized and the most critical can be investigated first.

10.2.4.3 Ideal distribution

Ideal distribution yields the same column priorities as independent distribution, but the scale maximum is set to 1,000 and all other relationship strengths are represented in ratio to 1,000. This is the method used in Table 5.

NOTE Since independent and ideal distributions yield the same column priorities, the distribution method easiest for the QFD team can be used. When using the ideal distribution, be careful not to confuse a relationship value of 1,0 with a statistical correlation of 1,0 which would erroneously imply that one column completely explains the row.

10.2.4.4 Proportional distribution

Proportional distribution is used when the number and strengths of the correlations in each row are important to consider. It normalizes each relationship row-by-row. This is useful when there is a limiting factor to consider, such as cost, weight (mass), time, or human resource. The row weight is then proportioned by the relationship weights to the columns. This is useful when all columns must all be considered. For example, a cost plan must assign a target cost to each system, subsystem, and component in proportion to its contribution to the function of the product.

NOTE Independent and proportional distribution is referred to in JIS Q 9025, 5.2.3.[24]

EXAMPLE 1 The airport breakfast kiosk example is repeated here but in proportional distribution. To simplify, the relationship strengths have been displayed as numbers instead of the symbols, as in Table 5. For example, the relationship between I can make a healthy choice and visibility of options is a moderate relationship which has a ratio scale value of 0,162 as shown in Table 6. The ratio scale values are entered in all intersecting cells. Each row is then summed across, thus 0,112 + 0,237 + 0,237 + 0,000 = 0,586. Numbers are rounded to three decimal places.

Table 6 — Customer needs-functional requirements matrix for airport breakfast kiosk (displaying relationship weights as numbers)

Customer Needs \ Functional Requirements (for service)	CN Wt.	Visibility of ptions SR1	# Product varieties SR2	# Topping varieties SR3	# Heating options SR4	Row sum of SR
I can make a healthy choice	19,3 %	0,112	0,237	0,237	0,000	0,586
I can get a taste I like	60,6 %	0,237	0,498	0,237	0,112	1,084
I can make an appealing choice	11,6 %	1,000	0,498	0,237	0,112	1,847
I can choose quickly	8,6 %	0,498	0,237	0,237	0,112	1,084

EXAMPLE 2 The ratio scale values of the relationships are then normalized by dividing each intersecting cell value by its row sum, as shown in Table 7. The row sum of the normalized relationships equals 1,00, thus 0,191 + 0,404 + 0,404 + 0,00 = 1,00. Numbers are rounded to three decimal places.

Table 7 — Customer needs-functional requirements matrix for airport breakfast kiosk (displaying normalized relationship weights)

		Normalized				
Customer Needs \ Functional Requirements (for service)	**CN Wt.**	**Visibility of options SR1**	**# Product varieties SR2**	**# Topping varieties SR3**	**# Heating options SR4**	**Row sum of SR**
I can make a healthy choice	19,3 %	0,191	0,404	0,404	0,000	1,000
I can get a taste I like	60,6 %	0,218	0,460	0,218	0,103	1,000
I can make an appealing choice	11,6 %	0,541	0,270	0,128	0,061	1,000
I can choose quickly	8,6 %	0,460	0,218	0,218	0,103	1,000

EXAMPLE 3 The ratio scale values of each relationship is then multiplied by the row weight (customer need weight in house of quality). These products are then summed and normalized to a percentage column weight (functional requirement weight in house of quality), as shown in Table 8. Thus 0,191 × 19,3 % = 0,037. For SR1, the functional requirement weight is calculated as 0,037 + 0,132 + 0,063 + 0,039 = 0,271 or 27,1 %. Numbers are rounded to three decimal places. Because the relationship weights were normalized already, the absolute weight and column weight (functional requirement weight in the house of quality) are the same.

Table 8 — Customer needs-functional requirements matrix for airport breakfast kiosk (displaying row weight × relationship weights, summed and normalized)

Functional Requirements (for service) / Customer Needs	CN Wt.	Visibility of options	# Product varieties	# Topping varieties	# Heating options
		SR1	SR2	SR3	SR4
I can make a healthy choice	19,3%	0,037	0,078	0,078	0,000
I can get a taste I like	60,6%	0,132	0,278	0,132	0,063
I can make an appealing choice	11,6%	0,063	0,031	0,015	0,007
I can choose quickly	8,6%	0,039	0,019	0,019	0,009
Absolute Weight		0,271	0,406	0,244	0,079
Functional Requirement Weight		27,1%	40,6%	24,4%	7,9%

10.3 Transfer of quantification

10.3.1 General

Quantification is used to set target values or specifications for the column information that ensures the target values or specifications of the row information can be met. How to achieve the target values of specifications of the columns could be known or not known yet, and are analyzed further in subsequent matrices in the sequence.

10.3.2 Quantify row information

10.3.2.1 Use of pre-existing quantification information

In many cases, the quantification of row information can be done in a previous step such as in a table or matrix preceding the current matrix in the sequence. In some cases, the pre-existing quantifications can be prioritized or not. Quantification information can include target values, specifications, competitive information, and other relevant details.

EXAMPLE Table 9 (from ISO 16355-4) displays quantifications for the row information. For the customer needs-functional requirements matrix (house of quality), this can come from the unweighted or weighted quality planning table described in ISO 16355-4. In this example, the target value for I can get a taste I like with a priority of 60,6 %, includes a target value of something delicious enough to beat the competitive offering of food from a professional kitchen. This information came from gemba visits and customer interviews.

Table 9 — Unweighted quality planning table for airport breakfast kiosk

Customer information		Importance	Current situation		Hoped for situation		Competitiveness		Kano
CN#	Key Customer Needs	From Renormalized CN Hierarchy diagram	Magnitude of current performance level	Satisfaction with current peformance level	Magnitude of hoped for performance level	Satisfaction with hoped for peformance level	Magnitude of Competitor	Selling Point Potential if hoped for level	Prediction of Kano Catergory
1.1.1	I can make a healthy choice	19,3%	only junk food	Dissatisfied	at least one healthy choice	Neutral	protein bar	minor	Expected
1.1.2	I can get a taste I like	60,6%	OK	Neutral	delicious	Very satisfied	professional kitchen	major	Exciting
1.1.3	I can make an appealing choice	11,6%	nothing looks good	Neutral	local specialty	Very satisfied	professional kitchen	minor	Exciting
1.1.4	I can choose quickly	8,6%	don't know if time to choose meal	Dissatisfied	at gate at 1st boarding call	Neutral	onboard snack box	none	Expected

10.3.2.2 Creation of new quantification information

When quantification is necessary and pre-existing quantification information is insufficient, new quantification information can be created by conjecture subject to discussion or surveys with customers and stakeholders, or other means of validation.

10.3.3 Use relationship weights to connect row quantification to column quantification

The logic of QFD L-matrices is that if there is a high priority row, the columns with strong relationships with that row can also be high priority. Further, quantifications of the high priority rows can indicate a problem, deficiency, or opportunity with the current level of performance of the row and consequently a corresponding problem, deficiency, or opportunity with the current level of performance of the strongly related columns.

EXAMPLE In Table 5, the highest priority row, I can get a taste I like (60,6 %) has a very strong relationship with # product varieties. The row quantification of delicious enough to beat a professional kitchen can create a corresponding opportunity to improve the # product varieties to better than what would be offered by a professional kitchen.

10.3.4 Quantify column information

The quantification information for columns can come from hypotheses subject to discussion or surveys with customers and stakeholders, experimentation, test, technical benchmarking or teardowns, prototype, or other means of validation. It can include additional information related to competition, technical difficulty, or other important decision factors. Target values or specifications can reflect what performance is sufficient to fulfill the strongly related customer needs and exceed the competitive alternatives.

NOTE 1 If specifications or targets are technically difficult, this can trigger innovation or creativity efforts to resolve the difficulty, or tradeoff decisions to optimize any technical conflicts. These are addressed elsewhere in this document.

NOTE 2 The customer needs-functional requirements matrix (house of quality) has a unique column information table that corresponds to the row information table (quality planning table). The column information table is called the design planning table.

10.3.4.1 Design planning table information for the house of quality

10.3.4.2 General

The design planning table is used in the house of quality to help the QFD team set target specifications needed to fulfill high priority needs better than the competition. The design planning table can be unweighted information only or can be additionally weighted to adjust the column prioritizations.

NOTE 1 Which information to use in the design planning table is optional, according the project.

NOTE 2 Since the effort to obtain accurate information is not trivial, the QFD team can elect to analyse only the highest priority functional requirements.

10.3.4.3 Unweighted design planning table

Common information displayed in the design planning table includes the following, as shown in Table 10.

Table 10 — Unweighted design planning table for airport breakfast kiosk

	Functional Requirements (for service)			Visibility of options SR1	# Product varieties SR2	# Topping varieties SR3	# Heating options SR4
	Customer	Priority		30,1 %	39,5 %	22.0 %	8,4 %
information	technical evaluation	performance	current	10 % display	2	3	0
			competitor	5 % menu	2	2	1
			target	60 % am display	6	5	1
	Relative to Competition	Judgment		Much Better	Much Better	Better	Equal
	Technical Challenge	Judgment		None	Minor	Minor	Major
	Technical Advantage	Judgment		Minor	Major	Minor	None
	Kano	Survey		Exciting	Exciting	Expected	Expected

a) Functional requirements and their priorities from the house of quality.

EXAMPLE 1 Table 10 brings over the functional requirement priority weights of 30,1 % for visibility of options, 39,5 % for # product varieties, 22,0 % for # topping varieties, and 8,4 % for # heating options.

b) Performance levels of the current product and competitive products, corresponding to the competitors in the quality planning table.

EXAMPLE 2 Table 10 shows that the level of visibility of options is 10 % of the display case and the competitor which has a traditional menu devotes about 5 % to breakfast items. Number of bagel (a type of breakfast roll) varieties is currently 2 and the competitor is also 2.

c) A performance target or specification sufficient to meet the strongly related customer needs and to beat the competition to a degree that the customer would consider purchasing the new product, despite the costs associated with a new purchase, learning curve, operator and service training, and other factors required to change from the existing product to the new one.

EXAMPLE 3 Table 10 shows a target value of 60 % of the display case can be devoted to breakfast items during the morning. The number of bagel varieties can be increased to 6.

NOTE 1 The performance target takes into account the operating environment of the target customers identified earlier in the QFD study, as explained in ISO 16355-2. For example, in the design of a hand-held light or torch, a reduction in weight (mass) of the light from 100 g to 98 g is probably insignificant if the target customer is a camper in the campground. If the target customer is an astronaut in a space vehicle or station, however, a two gram reduction in weight can lower launch costs by as much as € 1 000. Performance target optimization and competitive benchmarking is explained in detail in ISO 16355-6.

NOTE 2 If the current performance of a functional requirement strongly related to a high priority customer need already exceeds the competition, it can indicate that neither product is sufficient to meet the customer need.

NOTE 3 If the current performance of a functional requirement strongly related to a high priority customer need already exceeds the competition, it can indicate that there is a problem with marketing or advertising the current product. This means that the customer perception captured in the quality planning table of the competitor's product being superior is contradicted by the actual performance of the product. This means that the customer perception is misled either by insufficient advertising of the product or confusing advertising by the competition.

d) Judgment relative to competition can be useful in capturing the QFD team's opinion about whether the performance target can enable a marketing or advertising campaign.

   1) If the strongly related high priority customer need has a major selling point in the quality planning table, there can be a judgment of much better relative to the competition.

   2) If the strongly related high priority customer need has a minor selling point in the quality planning table, there can be a judgment of better relative to the competition.

   3) If the strongly related high priority customer needs has no selling point in the quality planning table, there can be a judgment of equal to the competition.

   4) In some cases, it can be determined that the current product is exceeding the competition, which could create a cost penalty. In such a case, the judgment might be to set the target at worse than the competition.

EXAMPLE 4 Table 10 shows that the QFD team judges that achieving the 60 % of display in the morning can make our product much better than the competition. Offering six varieties of bagels also makes the company's product much better than the competition.

e) Judgment relative to technical challenge can be useful in capturing the QFD team's opinion about the difficulty in achieving the target value with the current or available technology in time for any market launch commitment.

   1) If the current or available technology can be sufficiently improved to meet the target value, then there is no technical challenge.

2) If the current or available technology cannot be sufficiently improved to meet the target value, but there is a reasonable opportunity for innovation or creativity to result in a technology in time for any market launch commitment, then there is a minor technical challenge.

3) If the current or available technology cannot be sufficiently improved to meet the target value, and there is not a reasonable opportunity for innovation or creativity to result in a technology in time for any market launch commitment, then there is a major technical challenge that can require research and development efforts, trade-offs, patent licensing, or other paths to a solution.

EXAMPLE 5 Table 10 shows that the QFD team believes there is no technical challenge to arranging the display case to hold 60 % breakfast items. Increasing the number of bagel varieties presents a minor technical challenge in terms of inventory management.

f) Judgment relative to technical advantage can be useful in capturing the QFD team's opinion about technical leverage for other product lines or future products.

1) If meeting the target value in this product has little or no potential to be leveraged for other current or future products, then there is no technical advantage.

2) If meeting the target value in this product has real potential to be leveraged for other current or future products, then there is a minor technical advantage.

3) If meeting the target value in this product has great potential to be leveraged for other current or future products, then there is a major technical advantage.

EXAMPLE 6 Table 10 shows that the QFD team judges there can be a minor technical advantage to making the display case time-of-day flexible. This then allows more lunch and dinner products to be offered at the appropriate time, which is a major technical advantage.

g) Results from a Kano model survey can be displayed in the design planning table.

EXAMPLE 7 Table 10 shows Kano survey results confirming that increasing visibility of options to 60 % of the display case in the morning can be satisfying to customers but that keeping it at 10 % is not dissatisfying, which is an exciting quality category. Kano survey results confirm that increasing number of bagel varieties to six can be very satisfying to customers but that keeping it at two varieties is not dissatisfying.

10.3.4.4 Traditional and new Kano model

10.3.4.4.1 General

The Kano model is a survey method that seeks to understand the relationship between physical fulfillment (or not) of a product function or feature and customer satisfaction.[26] The new Kano model extends the binary survey question to a series of performance levels.[47] Since a functional requirement as defined in ISO 16355–1:2015, 3.4 is a product characteristic or capability, the traditional Kano question addresses capabilities and the New Kano question addresses characteristics.

10.3.4.4.2 Traditional Kano survey questions

For each product capability or feature, an inversely-paired set of questions is asked.

EXAMPLE For the airport breakfast kiosk, these questions were surveyed.

a) If the bagel can be toasted, are you satisfied, neutral, or dissatisfied? (Largest response was neutral.)

b) If the bagel cannot be toasted, are you satisfied, neutral, or dissatisfied? (Largest response was dissatisfied.)

As shown in Table 11, a response of neutral if fulfilled and dissatisfied if unfulfilled, it is interpreted as "expected quality."

10.3.4.4.3 New Kano survey questions

For each product characteristic, questions at various specific performance levels are asked.

EXAMPLE For the airport breakfast kiosk, these questions were surveyed. The results are entered into the design planning table. It was determined that offering four standard varieties plus two seasonally changing varieties would achieve good choice without the risk of too many choices causing a queue to form.

a) If two bagel varieties are offered, are you very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied? (Largest response was neutral.)

b) If four bagel varieties are offered, are you very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied? (Largest response was satisfied.)

c) If six bagel varieties are offered, are you very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied? (Largest response was very satisfied.)

d) If eight bagel varieties are offered, are you very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied? (Largest response was very satisfied.)

e) If seasonal bagel varieties are offered, are you very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied? (Largest response was extremely satisfied.)

NOTE 1 At least five performance levels can be queried to establish a very satisfied, satisfied, neutral, dissatisfied, and very dissatisfied response.

NOTE 2 Customers knowledgeable about the product tend to respond accurately. Fielding respondents can focus on the target customers identified in ISO 16355-2. Number of respondents can reflect sample size calculations explained in ISO 16355-4.

NOTE 3 Queried functional requirements can be limited to 20 to avoid survey fatigue.

10.3.4.4.4 Interpreting the traditional and new Kano survey responses

Depending on the question and response, the following interpretations can be made, as shown in Table 11:

— Exciting (Kano originally termed Attractive) — an exciting product function or feature which gives satisfaction when fulfilled, but is not dissatisfying when unfulfilled;

— Desired (One-dimensional) — a desired product function or feature which results in satisfaction when fulfilled, and dissatisfaction when unfulfilled;

— Expected (Must-be) — a product function or feature which is taken for granted when fulfilled and thus not responded as satisfaction, but results in dissatisfaction when not fulfilled;

— Indifferent — a “don’t care” product function or feature which results in neither satisfaction nor dissatisfaction, regardless of being fulfilled or unfulfilled;

— Reverse — an undesired product function or feature which results in dissatisfaction when fulfilled and satisfaction when unfulfilled;

— Skeptical — an illogical response where the paired responses are both dissatisfied or satisfied, suggesting the question was poorly constructed.

Table 11 — Traditional Kano survey response interpretations

Quality Characteristic Fulfillment		Physically Fulfilled		
	Feeling of Satisfaction	Dissatisfied	Neutral	Satisfied
Physically Unfulfilled	Dissatisfied	Skeptical	Expected	Desired
	Neutral	Reverse	Indifferent	Exciting
	Satisfied	Reverse	Reverse	Skeptical

10.3.4.4.5 Graphing the traditional Kano model

Each function or feature can be graphed, as shown in Figure 7. Since the traditional Kano survey asks only binary questions, it yields only two data points, sufficient to graph only a line. This example is from the airport breakfast kiosk.

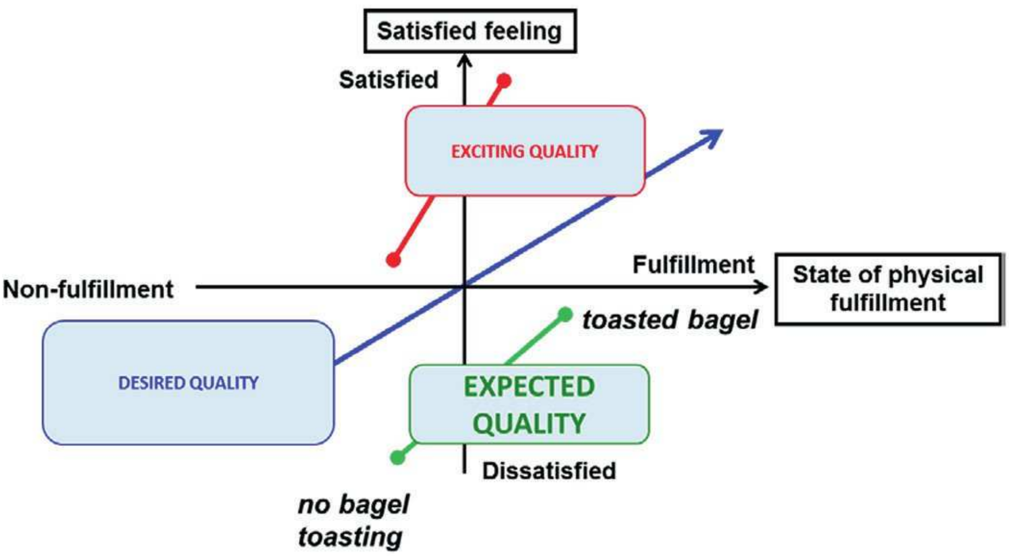


Figure 7 — Traditional Kano model graph of exciting quality and expected quality

10.3.4.4.6 Graphing the new Kano model

With three or more data points from the new Kano survey questions of performance levels, curves can be graphed to interpolate additional values as shown in Figure 8. This example is from the airport breakfast kiosk.

Figure 8 — New Kano model graph of exciting quality and expected quality

10.3.4.4.7 Using Kano survey results in the design planning table

If the functional requirement is a capability, it can be entered as the target value in the design planning table along with the appropriate Kano survey result. If the new Kano survey result is a characteristic, the level the QFD team determines it wishes to achieve can be entered as the target value in the design planning table along with the appropriate Kano survey result.

EXAMPLE The results of the binary Kano survey questions about bagel toasting are entered into the Kano survey section of the quality planning table as "expected." This can be used to validate or adjust the target value above. The results of the performance levels in the new Kano survey questions about # varieties are entered into the Kano survey section of the quality planning table as "exciting." This can be used to validate or adjust the target value above.

NOTE Look for a correspondence between the predicated Kano category for the customer needs in the quality planning table and the actual Kano survey results for functional requirements that are strongly related to the customer needs.

10.3.4.4.8 Other uses of Kano model

10.3.4.4.8.1 Adjustments for market segments based on Kano model

Survey responses are market specific. Key market or customer segments identified earlier in the QFD process can be surveyed first, since different segments can yield different response categories. For example, remote control starting that would be exciting by an entry level vehicle consumer might be considered expected by a luxury level vehicle consumer. Market and customer segmentation concerns are explained as follows:

a) identifying and prioritizing key market segments are explained in ISO 16355-2;

b) survey creation and fielding methods are explained in ISO 16355-3;

c) survey sample size calculations are explained in ISO 16355-4;

d) sorting survey responses by market demographics can reveal hidden segments.

EXAMPLE An automotive manufacturer discovered in a new Kano study of stopping distance that aggregating all responses masked the variation between male and female drivers of an entry level vehicle. When these were broken out by sex, they were able to see product variations that satisfied male and female drivers which could then be reflected in different performance packages available to the consumer.[47] This is graphed in Figure 9.

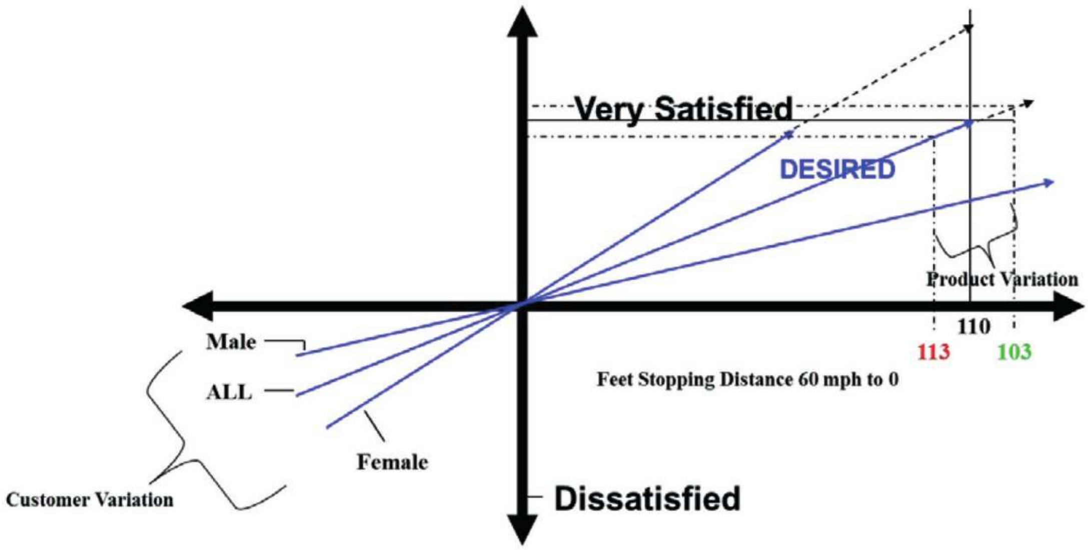


Figure 9 — New Kano model graph of stopping distance targets, by sex

10.3.4.4.8.2 Adjustments for competitive products and time based on Kano model

When an exciting product feature or performance level is introduced, competitors seek to copy it. Eventually, all products can have this feature or performance level, and it can become expected. For example, automatic syncing a personal device with an automobile infotainment system was once found only on luxury vehicles, but is now standard on almost all vehicles. The effects of competition and time on the Kano model are shown in Figure 10.[47]

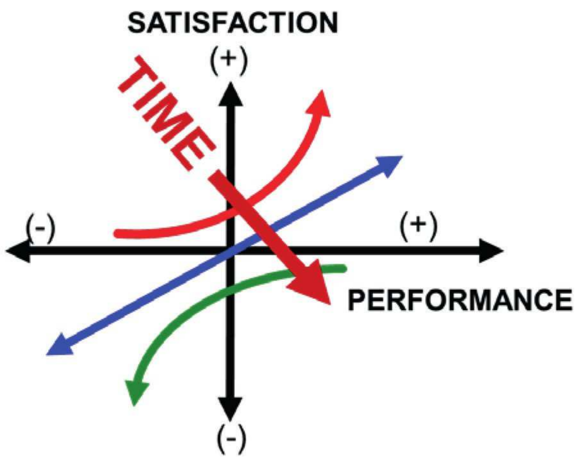


Figure 10 — New Kano model graph of influence over time

10.3.4.5 Weighted design planning table

Weighting of the design planning table allows for adjusting the impact of these other factors on the functional requirement priorities. Weight adjustments help the QFD team allocate constraints such as human resources, schedule, and budget with greater precision. According to the project goals determined earlier in the QFD project, it can be that the customer need-prioritized functional requirements, competitive benchmark, technical challenge, and Kano survey results are not equally important factors. For example, if the company is trying to grow the market, then customer need-prioritized functional requirements can be the most important factor. If a competitor has a preferred product, then competitive benchmark can be the most important factor. If there are no preferred solutions, then technical challenge can be the most import factor. If the company is considering a new technology, then the Kano survey can be the most important factor. Modern QFD allows weighting of these factors as shown in Table 16.

NOTE 1 The weighted design planning table adds absolute weights to the unweighted design planning table in 10.3.4.3 which contains verbal information only.

EXAMPLE 1 In this example from the airport breakfast kiosk, an AHP paired comparison was done by the QFD team on these four factors yielding these factor priorities: customer-prioritized functional requirement priorities: 57,3 %, competitive benchmark: 10,6 %, technical challenge: 5,9 %, and Kano survey: 26,2 %, as shown in Table 12. The QFD team did not consider the technical advantage information found in Table 9 significant enough to include in this fine-tuning.

Table 12 — AHP weighting of design planning table adjustment factors

factors	Customer	Competition	Technical Challenge	Kano	normalized columns				sum	row avg
Customer	1	**5**	**8**	**3**	0,603	0,526	0,500	0,662	2,291	**0,573**
Competition	1/5	1	**2**	**1/3**	0,121	0,105	0,125	0,074	0,424	**0,106**
Technical Challenge	1/8	1/2	1	**1/5**	0,075	0,053	0,063	0,044	0,235	**0,059**
Kano	1/3	3	5	1	0,201	0,316	0,313	0,221	1,050	**0,262**
	1,66	9,50	16,00	4,53	1,000	1,000	1,000	1,000	4,000	1,000
									Inconsistency Ratio	0,02

EXAMPLE 2 The customer need-prioritized functional requirements weights are already normalized and sum to 100,0 % as shown in Table 16. In AHP, these are called local priorities. To adjust these weights, each local priority is multiplied by the factor weight for customer of 0,573. Thus, 30,1 % × 57,3 % = 17,2 %, rounded to three decimal places. These are called global priorities. This is repeated for all columns. As a check, the global priorities sum to the factor weight.

EXAMPLE 3 In this example from the airport breakfast kiosk, an AHP paired comparison was done by the QFD team on the competitive levels of much better, better, equal to, or worse than the competition, as shown in Table 13. When the judgment is much better, a value of 55,8 % is entered into the table. This is repeated for all columns. The values are then normalized by summing them and dividing each by the sum. These values are entered into Table 16 as a local priority. To adjust these weights, each local priority is multiplied by the factor weight for competition of 0,106. Thus for visibility of options, 37,2 % × 10,6 % = 3,9 %, rounded to three decimal places.

Table 13 — AHP weighting of levels of competition

Competition	Much Better	Better	Equal	Worse	*normalized columns*				sum	row avg
Much Better	1	3	5	7	0,597	0,662	0,536	0,438	2,232	**0,558**
Better	1/3	1	3	5	0,199	0,221	0,321	0,313	1,053	**0,263**
Equal	1/5	1/3	1	3	0,119	0,074	0,107	0,188	0,487	**0,122**
Worse	1/7	1/5	1/3	1	0,085	0,044	0,036	0,063	0,228	**0,057**
	1,68	4,53	9,33	16,00	1,000	1,000	1,000	1,000	4,000	1,000
									Inconsistency Ratio	0,04

EXAMPLE 4 In this example from the airport breakfast kiosk, an AHP paired comparison was done by the QFD team on the technical challenge levels of major minor, or none, as shown in Table 14. When the judgment is none, a value of 10,6 % is entered into the table. This is repeated for all columns. The values are then normalized by summing them and dividing each by the sum. These values are entered into Table 16 as a local priority. To adjust these weights, each local priority is multiplied by the factor weight for technical challenge of 0,059. Thus for visibility of options, 8,4 % × 5,9 % = 0,5 %, rounded to three decimal places.

NOTE 2 In this example, a major technical challenge is scored very strongly, which adds weight for the purpose of directing development effort to this challenge. In projects where speed-to-market, insufficient resources, or a small budget constrains the team, they can score a major technical challenge inversely, which lowers the weight for the purpose of directing development effort away from this challenge.

Table 14 — AHP weighting of levels of technical challenge

Technical Challenge	Major	Minor	None	*normalized columns*			sum	row avg
Major	1	3	5	0,652	0,692	0,556	1,900	**0,633**
Minor	1/3	1	3	0,217	0,231	0,333	0,781	**0,260**
None	1/5	1/3	1	0,130	0,077	0,111	0,318	**0,106**
	1,53	4,33	9,00	1,000	1,000	1,000	3,000	1,000
							Inconsistency Ratio	**0,03**

EXAMPLE 5 In this example from the airport breakfast kiosk, an AHP paired comparison was done by the QFD team on the Kano model categories of exciting, desired, expected, indifferent, and reverse, as shown in Table 15. When the survey indicates the functional requirement target level would be exciting, a value of 50,3 % is entered into the table. This is repeated for all columns. The values are then normalized by summing them and dividing each by the sum. These values are entered into Table 16 as a local priority. To adjust these weights, each local priority is multiplied by the factor weight for Kano of 0,262. Thus for visibility of options, 39,5 % × 26,2 % = 10,4 %, rounded to three decimal places.

NOTE 3 The AHP scoring of the Kano categories can be changed according the project and customers. In very new technology projects, for example, just meeting expected quality can be judged by the team to be more important than exciting quality.

EXAMPLE 6 The global priorities are then summed for each functional requirement to calculate the adjusted priority. For visibility of options, 17,3 % + 3,9 % + 0,5 % + 10,4 % = 32,0 % rounded to three decimal places. Optionally, rank order can also be displayed, as shown at the bottom of Table 16.

Table 15 — AHP weighting of Kano categories

Kano	Exciting	Desired	Expected	Indifferent	Reverse	*normalized columns*					sum	row avg
Exciting	1	**3**	**5**	**7**	**9**	0,560	0,642	0,524	0,429	0,360	2,514	**0,503**
Desired	1/3	1	**3**	**5**	**7**	0,187	0,214	0,315	0,306	0,280	1,301	**0,260**
Expected	1/5	1/3	1	**3**	**5**	0,112	0,071	0,105	0,184	0,200	0,672	**0,134**
Indifferent	1/7	1/5	1/3	1	**3**	0,080	0,043	0,035	0,061	0,120	0,339	**0,068**
Reverse	1/9	1/7	1/5	1/3	1	0,062	0,031	0,021	0,020	0,040	0,174	**0,035**
	1,79	4,68	9,53	16,33	25,00	1,000	1,000	1,000	1,000	1,000	5,000	1,000
											Inconsistency Ratio	0,05

Table 16 — Weighted design planning table for airport breakfast kiosk

Factors		Row	Weight	Visibility of options (SR1)	# Product varieties (SR2)	# Topping varieties (SR3)	# Heating options (SR4)	
				Functional Requirements (for service)				
factors	Customer	Priority	weight	30,1%	39,5%	22,0%	8,4%	100,0%
		Local Priority		30,1%	39,5%	22,0%	8,4%	100,0%
		Global Priority	57,3%	17,2%	22,6%	12,6%	4,8%	57,3%
	technical evaluation	current	performance	10% display	2	3	0	
		competitor		5% menu	2	2	1	
		target		60% am display	6	5	1	
	Competition	Judgment	weight	Much Better	Much Better	Better	Equal	
		Value		55,8%	55,8%	26,3%	12,2%	150,1%
		Local Priority		37,2%	37,2%	17,5%	8,1%	100,0%
		Global Priority	10,6%	3,9%	3,9%	1,9%	0,9%	10,6%
	Technical Challenge	Judgment	weight	None	Minor	Minor	Major	
		Value		10,6%	26,0%	26,0%	63,3%	126,0%
		Local Prioroty		8,4%	20,7%	20,7%	50,2%	100,0%
		Global Priority	5,9%	0,5%	1,2%	1,2%	2,9%	5,9%
	Kano	Judgment	weight	Exciting	Exciting	Expected	Expected	
		Value		50,3%	50,3%	13,4%	13,4%	127,4%
		Local Prioroty		39,5%	39,5%	10,5%	10,5%	100,0%
		Global Priority	26,2%	10,4%	10,4%	2,8%	2,8%	26,2%
		Adjusted Priority		32,0%	38,1%	18,4%	11,4%	100,0%
		Adjusted SR Rank		2	1	3	4	

10.3.4.6 Assembling the house of quality

The customer needs-functional requirements matrix (house of quality) is often displayed with the various "rooms" of the quality planning table and design planning table attached, as shown in Table 17. This can be useful in confirming analyses of correspondence between the quality planning table and design planning table, as well as in management presentations. The quality planning table is referenced in ISO 16355-4. The L-matrix is referenced in 9.3.6. The design planning table is referenced in 10.3.4.1.

NOTE 1 The example of the airport breakfast kiosk has been reduced to only four customer needs and four functional requirements to simplify the explanation. It is not impossible for QFD L-matrices in general and the house of quality specifically to grow to 1 000 rows by 1 200 columns for very complex projects. In such cases, building the various "rooms" separately and assembling them later can be easier to manage.

NOTE 2 Modern QFD teams can begin with the maximum value table in 9.2 before doing any L-matrices. By definition, the maximum value table include all the high priority information contained in the house of quality and the subsequent matrices in the comprehensive QFD sequence in Figure 3.

10.4 Transferring deployment sets by dimensions and levels

10.4.1 Deployment sets

10.4.1.1 General

Transfers of prioritization and quantification can be done in deployment sets with matrices and tables organized into both dimensions of design (displayed vertically in Figure 3) and levels of design (displayed horizontally). A matrix or table occurs where a design dimension and a design level intersect. Not every deployment is required for every project. The layout of the deployments, which charts to use, and in what sequence can be tailored to the organization's product development process.

NOTE L-Matrix deployment sets are examples of priority transfers using cascading matrices as shown in 10.2.2.2.

10.4.1.2 Classical and modern QFD design dimension deployment sets

The deployment sets are as follows:

a) quality deployment is used to improve the performance of a new or existing product;

b) technology deployment is used to ensure customer satisfaction with new technologies;

c) cost deployment is used to target cost for new products or reduce component cost without negatively impacting customer satisfaction;

d) reliability deployment is used to prevent failures in the new product;

Modern QFD dimensions include schedule deployment to improve project timelines, security deployment to prevent unauthorized access to information, safety deployment to ensure consumer health and safe use, regulatory deployment to ensure compliance with environmental and other laws, organizational deployment to ensure policies are complied with, and others.

NOTE Generally, design dimension deployment sets have a departmental or business function focus, such as quality, technology, reliability, and the others mentioned above. This is useful in determining which departments or business functions are to be involved in the QFD process as subject matter experts.

Table 17 — House of quality assembled from L-matrix ([Table 5](#)), quality planning table ([Table 9](#) and ISO 16355-4), and design planning table ([Table 16](#))

	Customer Needs \ Functional Requirements	Priority (from unweighted QPT)	Visibility of options (FR1)	# Product varieties (FR2)	# Topping varieties (FR3)	# Heating options (FR4)	Customer: Priority	Customer: Local Priority	Customer: Global Priority (57,3%)	Customer survey satisfaction: current	competitor	target	Competition: Improvement Level-up	Level-up Value	Local Priority	Global Priority (10,6%)	Sales: Selling Point Evaluation	Selling Point Value	Local Priroty	Global Priority (5,9%)	Kano: Kano Potential Evaluation	Kano Value	Local Priroty	Global Priority (26,2%)	Adjusted Priority
1.1.1	I can make a healthy choice	19,3%	◔ 0,022	◑ 0,046	◑ 0,046	· 0,000	11,5%	19,3%	11,0%	2	3	4	Better	26,3%	37,3%	4,0%	Minor	26,0%	20,7%	1,2%	Expected	13,4%	11,6%	3,0%	19,3%
1.1.2	I can get a taste I like	60,6%	◑ 0,143	◕ 0,302	◑ 0,143	◔ 0,068	36,1%	60,6%	34,7%	4	5	5	Better	26,3%	37,3%	4,0%	Major	63,3%	50,2%	2,9%	Exciting	50,3%	43,4%	11,4%	53,0%
1.1.3	I can make an appealing choice	11,6%	● 0,116	◕ 0,058	◑ 0,027	◔ 0,013	6,9%	11,6%	6,6%	5	4	3	Worse	5,7%	8,1%	0,9%	Minor	26,0%	20,7%	1,2%	Desired	26,0%	22,5%	5,9%	14,6%
1.1.4	I can choose quickly	8,6%	◕ 0,043	◑ 0,020	◑ 0,020	◔ 0,010	5,1%	8,6%	4,9%	5	4	5	Equal	12,2%	17,3%	1,8%	No	10,6%	8,4%	0,5%	Desired	26,0%	22,5%	5,9%	13,1%

factors		weight	FR1	FR2	FR3	FR4	Total
Customer	Priority	weight	30,1%	39,5%	22,0%	8,4%	100,0%
	Local Priority		30,1%	39,5%	22,0%	8,4%	100,0%
	Global Priority	57,3%	17,2%	22,6%	12,6%	4,8%	57,3%
technical evaluation	current	performance	10% display	2	3	0	
	competitor		5% menu	2	2	1	
	target		60% am display	6	5	1	
Competition	Judgment	weight	Much Better	Much Better	Better	Equal	
	Value		55,8%	55,8%	26,3%	12,2%	150,1%
	Local Priority		37,2%	37,2%	17,5%	8,1%	100,0%
	Global Priority	10,6%	3,9%	3,9%	1,9%	0,9%	10,6%
Technical Challenge	Judgment	weight	None	Minor	Minor	Major	
	Value		10,6%	26,0%	26,0%	63,3%	126,0%
	Local Prioroty		8,4%	20,7%	20,7%	50,2%	100,0%
	Global Priority	5,9%	0,5%	1,2%	1,2%	2,9%	5,9%
Kano	Judgment	weight	Exciting	Exciting	Expected	Expected	
	Value		50,3%	50,3%	13,4%	13,4%	127,4%
	Local Prioroty		39,5%	39,5%	10,5%	10,5%	100,0%
	Global Priority	26,2%	10,4%	10,4%	2,8%	2,8%	26,2%
	Adjusted Priority		32,0%	38,1%	18,4%	11,4%	100,0%
	Adjusted SR Rank		2	1	3	4	

10.4.1.3 Classical and modern design level deployment sets

The various QFD deployments help the team understand different dimensions of the product, as follows:

a) customer deployment to understand the customer problem space, independent of the solution space;

b) function deployment to examine in detail what a product does;

c) new concept deployment to identify and select innovative and inventive technologies;

d) component deployment to identify and prioritize the subsystems, components, parts, materials, tasks, instructions, software code, and other basic elements of the product;

e) manufacturing deployment to identify and prioritize what steps, equipment, resources are required to build the product;

f) production deployment to identify, prioritize, and set targets for what activities, performance levels, setups, are required to produce and assemble the product;

g) process deployment to identify, prioritize, and set targets for processes and parameters.

Modern QFD levels include testing and validation deployment to prioritize testing and compliance, systems engineering to define customer problems space and solution space independent of enabling technologies, and others.

NOTE 1 Generally, design level deployment sets have a sequential focus that can vary according to the project. Some projects begin at a product system level, then subsystem, then component, and then process level. This is useful in determining when departments or business functions are involved in the QFD process as subject matter experts.

NOTE 2 The maximum value table described in 9.2 can include the strongly related items for each customer need from all design dimensions and all design levels in the deployment sets. This is very effective and efficient but for only 3–5 of the highest priority customer needs. If more customer needs are to be examined, than the deployment sets described here are useful. QFD teams can begin with the maximum value table so that key design elements can be identified and addressed right away, while the other deployment sets are being completed.

10.4.2 Quality deployment

10.4.2.1 General

10.4.2.1.1 Objective

Quality Deployment focuses on transferring prioritized customer needs into prioritized functional requirements and performance targets structured at the product level, system level, subsystem level, component level, and process level in order to systematically assess what information can improve the consistency of quality of design and build and be identified in quality assurance and quality control tables. This creates a development process that is customer driven and ensures the product and process are consistent with these drivers.

NOTE 1 Deployments for service and software products can be different. For example, iterative and incremental processes like software development with scrum or other agile processes, the deployment layout can reflect an explicit iterative and incremental structure.[18][54]

NOTE 2 Quality deployment is referred to in JIS Q 9025, 6.2 and 9.2.[24]

10.4.2.1.2 Composition

As shown in the quality deployment section of Figure 3 (left-most section as well as the bottom row), quality deployment consists of the following matrices, tables, and charts which transfers priorities from the customer needs to the following dimensions:

a) functional requirements (see 10.4.2.2);

b) functions (see 10.4.2.3 and 10.4.2.4);

c) components (see ISO/TR 16355-8);

d) quality assurance (see ISO/TR 16355-8);

e) processes charts (see ISO/TR 16355-8);

f) quality control tables (see ISO/TR 16355-8).

NOTE An example of the quality deployment flow of charts and tables is shown in B.4.3.

10.4.2.2 Customer needs-functional requirements matrix (house of quality)

This matrix is detailed in 9.3.6. It is the most popular of matrices because it starts the analysis of transferring weighted customer needs and targets into weighted functional requirements and targets. It helps the QFD team determine what functional and performance levels can really make a difference to customers, and what is technically feasible. These concerns can lead the team to explore new technologies, consider the impact of tradeoffs, and then optimize the design. Later clauses and parts of this document include methods and tools for this.

NOTE The customer needs-functional requirements matrix (house of quality) is labelled matrix 1-I in the Comprehensive QFD flow chart in Figure 3.[1] Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers recognize this as house I.[16] Readers familiar with the matrix of matrices recognize this as the A-1 matrix.[28]

10.4.2.3 Customer needs-function matrix

10.4.2.3.1 General

The use of the word "function" in QFD is explained in ISO 16355-1. 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 measureable parameters. Products can have both use functions and aesthetic functions.[37] Functions serve many roles in QFD in order to address product features, technology concepts, cost, reliability, and other design dimensions.

10.4.2.3.2 Purpose of the customer needs-function matrix

The customer needs-function matrix serves the following purposes.

a) The use of functions in QFD comes from its association with value analysis (VA) and value engineering (VE), a method used for cost reduction at the design level.

b) The matrix identifies which functions have a strong relationship with customer needs. If there are high priority customer needs without strongly related functions, there can be a gap in the product concept that can result in dissatisfaction. If there are functions without strongly related customer needs, there can be overdesign or no-longer-necessary features that can drive up cost.[50][51]

c) The matrix transfers customer needs priority weights into function priority weights, which helps the QFD team allocate technical resources to functions with high value to customers.

NOTE The customer needs-function matrix is labelled matrix 2'-I in the Comprehensive QFD flow chart in Figure 3. Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers notice that this matrix is not included, since product functions were usually defined by the equipment manufacturer in the 1980s when this approach was truncated from comprehensive QFD. Readers familiar with the matrix of matrices recognize this as the B-1 matrix.[28]

10.4.2.3.3 Building the function tree

Like most deployments in QFD, building a new information set requires a structuring process to ensure the information is mutually exclusive and collectively exhaustive (MECE). This is necessary when making subjective judgments on the strengths of relationships between the columns and rows in order to use the analytic hierarchy process (AHP) to improve the accuracy of the transfer of customer need weights into function weights. The following steps can be followed.

a) Brainstorm the functions. Technical members of the QFD team can lead this analysis.

NOTE 1 Value engineers recommend avoiding the verb provide in describing functions, as this is a weak substitute for the actual action.

EXAMPLE 1 For the airport breakfast kiosk, service functions include source product, sell product, and others.

b) Structure the functions into a function tree, a type of hierarchy diagram described in ISO 16355-2. A function tree is structured using a why-what technique. When moving from detailed to abstract levels, the items to the left describe why the function is being performed. When moving from abstract to detailed levels (left to right), the items to the right describe what function is performed.

NOTE 2 If the next level to the right describes a specific method or technology, stop and do not include these. Check for MECE. Some branches of the function tree can have different levels of detail to the right.

EXAMPLE 2 Figure 11 shows the various detailed functions for the departments of the kiosk.

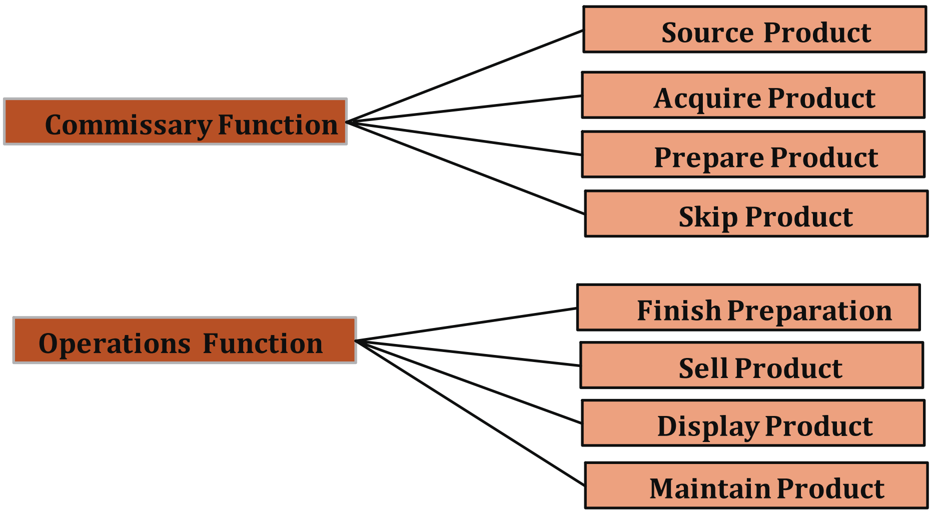


Figure 11 — Function tree for airport breakfast kiosk service functions

10.4.2.3.4 Building the customer needs-function matrix

The L-matrix is used for the customer needs-function matrix. This document follows the convention of using matrix rows for the already-derived information and weights and the columns for the to-be-derived information and weights. Note that this matrix is rotated 90 degrees in the comprehensive QFD flow diagram for display purposes only. The steps are as follows.

a) Insert into the rows the customer needs and weights from Table 5. If the weighted quality planning table described in ISO 16355-4 is used, the adjusted priorities can be used.

b) Insert into the columns the function tree to the most detailed level.

c) Using the cause-to-effect approach and working row-by-row, determine the strength of the relationship of each most detailed level function to achieving the customer need. Use the icons and symbols shown in 9.3.3.

d) Transfer the priorities of the customer needs into priorities for the functions following the steps in 10.2. If cost deployment is to be used later in the QFD study, then the proportional distribution method in 10.2.4.4 is recommended. Optionally, the prioritized functions can also be rank-ordered.

EXAMPLE Table 18 uses proportional distribution to transfer the customer needs priorities to the functions.

Table 18 — Customer needs-function matrix for airport breakfast kiosk (proportional distribution)

Customer Needs \ Functions	Priority	COMMISSARY: Source Product Fn1	COMMISSARY: Acquire Product Fn2	COMMISSARY: Prepare Product Fn3	COMMISSARY: Ship Product Fn4	OPERATIONS: Finish Preparation Fn5	OPERATIONS: Sell Product Fn6	OPERATIONS: Display Product Fn7	OPERATIONS: Maintain Product Fn8
I can make a healthy choice	19,3%	◑ 0,015	◑ 0,015	◑ 0,015	◑ 0,015	◕ 0,033	· 0,000	● 0,065	◕ 0,033
I can get a taste I like	60,6%	● 0,107	● 0,107	◑ 0,025	● 0,107	◔ 0,017	◑ 0,025	● 0,107	● 0,107
I can make an appealing choice	11,6%	● 0,028	● 0,028	◑ 0,007	● 0,028	◑ 0,007	◑ 0,007	◑ 0,007	◑ 0,007
I can choose quickly	8,6%	◑ 0,029	◑ 0,029	· 0,000	· 0,000	· 0,000	◑ 0,029	· 0,000	· 0,000
weighted: Absolute Weight		0,179	0,179	0,048	0,151	0,057	0,061	0,179	0,147
weighted: Function Weight		17,9%	17,9%	4,8%	15,1%	5,7%	6,1%	17,9%	14,7%
weighted: Function Rank		2	2	8	4	7	6	1	5

10.4.2.4 Functional requirements-function matrix

10.4.2.4.1 General

This L-matrix is a more technical view of functions since it relates functional requirements (product characteristics and capabilities) and functions.

10.4.2.4.2 Purpose of the functional requirements-function matrix

The functional requirements-function matrix serves the following purposes.

a) The matrix identifies which functions have a strong relationship with product functional requirements. If there are high priority functional requirements without strongly related functions, there can be a gap in the product concept that can result in non-performance, under-performance, or missing features. If there are functions without strongly related functional requirements, there can be overdesign or no-longer-necessary features that can drive up cost.[50][51]

b) The matrix transfers functional requirements priority weights into function priority weights, which helps the QFD team allocate technical resources to functions with high value to customers.

c) The matrix is also helpful in addressing engineering bottlenecks, cost, and design optimization.

NOTE The functional requirements-function matrix is labelled matrix 2-I in the Comprehensive QFD flow chart in Figure 3. If this matrix is done with proportional distribution, functional requirement target costs can also be calculated and recorded in matrix 2'-III in Comprehensive QFD. Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers notice that this matrix is not included, since product functions were usually defined by the equipment manufacturer in the 1980s when this approach was truncated from comprehensive QFD. Readers familiar with the matrix of matrices recognize this as the A-2 matrix[28].

10.4.2.4.3 Building the functional requirements-function matrix

The L-matrix is used for the functional requirements-function matrix. This document follows the convention of using matrix rows for the already-derived information and weights and the columns for the to-be-derived information and weights. The steps are as follows.

a) Insert into the rows the functional requirements and weights from the columns of Table 5. If the weighted design planning table described in Table 16 is used, the adjusted priorities can be used.

b) Insert into the columns the function tree to the most detailed level.

c) Using the cause-to-effect approach and working row-by-row, determine the strength of the relationship of each most detailed level function to achieving the functional requirement. Use the icons and symbols shown in 9.3.3.

d) Transfer the priorities of the functional requirements into priorities for the functions following the steps in 10.2. If cost deployment is to be used later, then use the proportional distribution instead of the independent or ideal distribution. Optionally, the prioritized functions can also be rank-ordered.

NOTE Since customer need priorities drive both the customer needs-function matrix (directly) and the functional requirements-function matrix (indirectly through the house of quality), the rank-orderings of functions in both matrices can be checked for similarity. Typically, the top 10 % of functions are the same although the priorities and rank order can be different.

EXAMPLE Table 19 shows how the business functions of source product, acquire product, and display product are most important to improve. Later in the study, this can lead to new supplier, storage, and display solutions and requirements. The top ranking functions are the same as Table 18.

Table 19 — Functional requirements-function matrix for airport breakfast kiosk (ideal distribution)

	Functions / Service Requirements	Priority	COMMISSARY				OPERATIONS			
			Source Product Fn1	Acquire Product Fn2	Prepare Product Fn3	Ship Product Fn4	Finish Preparation fn5	Sell Product fn6	Display Product fn7	Maintain Product fn8
SR1	Visibility of options	30,1%	◑ 0,071	◑ 0,071	◑ 0,071	◑ 0,071	◕ 0,150	· 0,000	● 0,301	◕ 0,150
SR2	# Product varieties	39,5%	● 0,395	● 0,395	◑ 0,094	● 0,395	◔ 0,044	◑ 0,094	● 0,395	● 0,395
SR3	# Topping varieties	22,0%	● 0,220	● 0,220	◑ 0,052	● 0,220	◑ 0,052	◑ 0,052	◑ 0,052	◑ 0,052
SR4	# Heating options	8,4%	◑ 0,020	◑ 0,020	· 0,000	· 0,000	· 0,000	◑ 0,020	· 0,000	· 0,000
weighted	Absolute Weight		0,706	0,706	0,217	0,686	0,246	0,166	0,748	0,597
	Function Weight		17,3%	17,3%	5,3%	16,9%	6,0%	4,1%	18,4%	14,7%
	Function Rank		2	2	7	4	6	8	1	5

10.4.2.5 Functional requirements-components matrix

This matrix is used to prioritize components by transferring functional requirement priorities to component priorities. Since components depend upon the selected technology, it can be done after the high-level design in determined. Technology concepts and high priority components can benefit from design optimization. This is explained in ISO 16355-6, ISO 16355-7, and ISO/TR 16355-8.

10.4.3 Technology deployment

10.4.3.1 General

10.4.3.1.1 Objective

Technology deployment focuses on discovery and quality assurance of new technologies at the product level, system level, subsystem level, component level, and equipment/process level. This can include invention, patents and intellectual property search, registrations, licensing, corporate buy-outs, and other forms of acquiring technology. The goal is to focus the necessary resources to identify and resolve early in the development process any technological bottlenecks and constraints that can later become issues. Proper documentation of these solutions enables use on future issues and contributes to accumulating technical knowledge. QFD employs two approaches, as follows.

NOTE 1 Quality deployment is referred to in JIS Q 9025, 6.3 and 9.3.[24]

a) Needs to seeds deployment, where unsatisfied customer needs deploy into functional requirements with a major technical challenge as determined in the design planning table in 10.3.4.3 e). This is a reactive approach to solving a customer problem

   NOTE 2 This is customer-driven QFD, the most common mode of use. It is also called forward-QFD.

b) Seeds to needs deployment, where technologies are developed in advance of market opportunities or customer needs. This is a proactive approach to creating future products.

NOTE 3 This is technology-driven QFD. It is also called reverse-QFD. Additional reverse-QFD drivers include competitor, cost, regulatory, manufacturing method or location, and others[36].

NOTE 4 Deployments for service, process, and software can be different.

10.4.3.1.2 Composition

As shown in the technology deployment section of Figure 3, technology deployment consists of the following matrices, tables, and charts which transfers priorities from the customer needs to the following dimensions:

a) technology concepts (see 10.4.3.6);

b) subsystems (see 10.4.3.6.4);

c) functions (see 10.4.4.3);

d) refining concepts and resolving technology bottlenecks (see 10.4.3.8);

e) components (see ISO/TR 16355-8).

NOTE B.4.4 shows an example of the technology deployment flow of charts and tables.

10.4.3.2 Assessing technology readiness

Examine the characteristics and capabilities of current and proposed technologies to meet performance, functional and reliability requirements. Current and proposed technologies are evaluated for their ability to fulfill functional requirements at the performance level targets and to perform key functions in the operating and environmental applications of the key customer segments defined in ISO 16355-2.

NOTE Technology readiness can also be assessed after basic concepts are explored in the case of new products (not just next generation), supplier, manufacturing, and packaging.

EXAMPLE Table 20 is an L-matrix with the prioritized functional requirements in the rows and the technologies in the columns. Each functional requirement is examined to determine if an enabling technology is currently available or can be developed in time for the planned product launch. Any functional requirement with inadequate technology must be examined as a technical challenge, as indicated in the design planning table in Table 10. In this study, the theory of inventive problem solving (TRIZ) was used to develop a heating option.

Table 20 — Service technology readiness assessment for airport breakfast kiosk

			Technologies						
			Food			Service			
Functional requirements	Priorities	Target values	Purchased	Prepared	Make-to-order	Mobile order	Mobile pay	Counter queue	Deliver to plane
Visibility of options	30,1%	60% am display	●	◑	○	◑		●	
# Product varieties	39,5%	6	●	◑	○				
# Topping varieties	22,0%	5	◑	◑	◑				
# Heating options	8,4%	1						○	

● Technology available
◑ Technology developable
○ Technology inadequate

10.4.3.3 Needs to seeds technology development

When a functional requirement faces a technology challenge, the QFD team can seek an adequate solution. If a competitor has a solution, especially a patented one, the organization is at risk of losing customers. If there is no solution available, the organization has an opportunity to beat the competition and create differentiation in the market.

EXAMPLE The heating option inadequacy was a concern because toasting, the most popular bagel heating option, typically takes 4 min to 6 min in a standard bread toaster. This could result in a queue forming and discourage new customers from entering the kiosk. This was addressed by partnering with a bun toaster supplier to the fast food industry. The toaster supplier explained that toasting was a process of caramelizing the sugars on the cut surface of the bread. (Chemically, the sugar molecule $C_6H_{12}O_6$ gets excited by the heat. As the $H_{12}O_6$ evaporates as $6H_2O$ the carbon remains as caramel.) Since the outer surface of the bagel was caramelized during baking, only the sliced inner surface needs toasting. When making the dessert crème brûlée, if a butane torch is applied at a close distance, caramelization takes only a few seconds. A new toaster design enabled toasting to be completed in the time it takes to pay for the food.

10.4.3.4 TRIZ for creativity and innovation

One method commonly used QFD is the theory of inventive problem solving (TRIZ in its native Russian). The method seeks to solve technical contradictions and tradeoffs through a systematic and structured approach to adapting existing solutions, often from other scientific or engineering disciplines. One TRIZ tool seeks to reveal technical contradictions with the intent of eliminating them. TRIZ can be used in the solution strategy phase in Figure 2.

10.4.3.4.1 Revealing technical contradictions

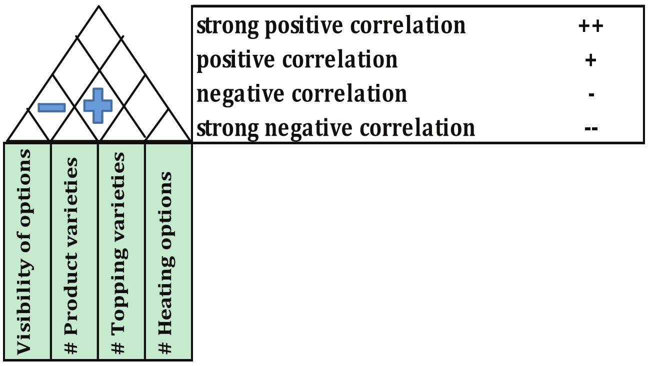
10.4.3.4.1.1 Functional requirements correlation matrix (roof of the house of quality)

This 45-degree rotated triangular L-matrix is used to identify positive and negative correlations among the functional requirements. It is often positioned on top of the house of quality, thus its nickname of "roof." This matrix is technology-dependent, so different enabling technologies can have different correlations. This matrix is better used in technology deployment than in quality deployment, even though it is positioned on the house of quality. Using the roof in quality deployment risks prematurely imbedding the current technology into the QFD analysis.

NOTE Several triangular objects appear in Figure 3. These are not "roofs" but hierarchy diagrams.

EXAMPLE Table 21 shows that increasing the visibility of individual products has a negative correlations with # of product varieties. This is having an adequate supply of too many varieties could make it difficult for customers to see what is available. This problem with # of varieties and product availability was addressed with TRIZ.

Table 21 — Functional requirements correlation matrix (roof) for airport breakfast kiosk



10.4.3.4.1.2 Innovative system questionnaire

These TRIZ questions are used by the QFD team to make hidden contradictions visible.[55]

a) What is the system name and its primary function?

b) What is the current and desired system structure?

c) How does the system execute its primary function now?

d) What is the operating environment?

e) What are the available resources and natural phenomena?

f) What are the problems or opportunities?

g) What mechanism constrains achievement? Provide history.

h) Can a substitute problem be solved?

i) What system changes are allowed? Prohibited?

j) What time, money, people issues constrain solutions? Previous attempts? Solved elsewhere.

10.4.3.4.2 Eliminating technical contradictions

The TRIZ steps to eliminating technical contradictions are as follows:

a) translate your problem into an analogous problem using Altshuller's engineering parameters;

b) look up inventive principles in the table of contradictions;

c) find energy source, transmission, tool, or control in TRIZ patent database, and adapt to solve your problem.

10.4.3.4.2.1 Altshuller's engineering parameters

Named after the creator of the TRIZ method, these parameters were generalized from an examination of problems which solutions were awarded patents. QFD functional requirements can be reworded into Altshuller's engineering parameters. Classical TRIZ has 39 engineering parameters and more are being added by the TRIZ user community. The classical engineering parameters are shown in A.2.

10.4.3.4.2.2 Table of contradictions

This rows in this table contain the engineering parameters to be improved and columns in this table contain the engineering parameters that are degraded as a result of the improvement. The intersecting cells indicate, in order of frequency of providing solutions, inventive principles based upon Altshuller's study of more than 40 000 patents. Additional principles are being added by the TRIZ user community. The classical tables of contradictions are shown in A.3.

10.4.3.4.2.3 Inventive principles

The inventive principles are generalized from the examined patents. Based on these principles, an analogous solution can be developed. Additional principles are being added by the TRIZ user community. The classical inventive principles are shown in A.4.

NOTE If no solution is possible, try going through the entire list of inventive principles for new ideas.

EXAMPLE In the bagel breakfast service at the airport kiosk, the problem of having all the varieties on hand but without waste is a good TRIZ analysis. The row parameter to improve is # 26 amount of substance, the amount of bagels. The column parameters #23 no waste of substance and #25 no waste of time are at risk of degradation if too many bagels are procured. The inventive principles shown in the intersection of row #26 and column #23 in Table 22 are as follows:

a) Inventive principle #6 universality (make objects perform multiple functions). The QFD team proposes that kiosk workers can also bake bagels.

b) Inventive principle #3 local quality (make each part of an object function in conditions most suitable for its operation). The QFD team proposes kiosk workers can perform actions most suitable for their skill level, such as warming bagels.

c) Inventive principle #10 prior action (perform a required action before it is needed, either fully or partially). The QFD investigates whether bagels can be partially baked in a professional bakery and flash frozen. Then in the kiosk, they are stored frozen and finished baked only when needed. Finish baking is about 6 min, so when display case inventory decreases to certain levels, fresh bagels can be baked. This solution provides maximum availability with no waste.

Table 22 — Table of contradictions for airport breakfast kiosk

	Parameter degraded / Parameter to improve	Power	Waste of energy	Waste of substance	Loss of Information	Waste of Time	Amount of substance	Reliability	Accuracy of measurement	Accuracy of manufacturing	Harmful factors acting on object
		21	22	23	24	25	26	27	28	29	30
21	Power	12,18 28,31	10, 35, 38	28, 27, 18, 38	10, 19	35, 20, 10, 6	4, 34, 19	19, 24, 26, 31	32, 15, 2	32, 2	19, 22, 31, 2
22	Waste of energy	3, 38		35, 27, 2, 37	19, 10	10, 18, 32, 7	7, 18, 25	11, 10, 35	32		21, 22, 35, 2
23	Waste of substance	28, 27, 18, 38	35, 27, 2, 31			15, 18, 35, 10	6, 3, 10, 24	10, 29, 39, 35	16, 34, 31, 28	35, 10, 24, 31	33, 22, 30, 40
24	Loss of Information	10, 19	19, 10			24, 26, 28, 32	24, 28, 35	10, 28, 23			22, 10, 1
25	Waste of Time	35, 20, 10, 6	10, 5, 18, 32	35, 18, 10, 39	24, 26, 28, 32		35, 38, 18, 16	10, 30, 4	24, 34, 28, 32	24, 26, 28, 18	35, 18, 34
26	Amount of substance	35	7, 18, 25	6, 3, 10, 24	24, 28, 35	35, 38, 18, 16		18, 3, 28, 40	13, 2, 28	33, 30	35, 33, 29, 31
27	Reliability	21, 11, 26, 31	10, 11, 35	10, 35, 29, 39	10, 28	10, 30, 4	21, 28, 40, 3		32, 3, 11, 23	11, 32, 1	27, 35, 2, 40
28	Accuracy of measurement	3, 6, 32	26, 32, 27	10, 16, 31, 28		24, 34, 28, 32	2, 6, 32	5, 11, 1, 23			28, 24, 22, 26
29	Accuracy of manufacturing	32, 2	13, 32, 2	35, 31, 10, 24		32, 26, 28, 18	32, 30	11, 32, 1			26, 28, 10, 36
30	Harmful factors acting on object	19, 22, 31, 2	21, 22, 35, 2	33, 22, 19, 40	22, 10, 2	35, 18, 34	35, 33, 29, 31	27, 24, 2, 40	28, 33, 23, 26	26, 28, 10, 18	

10.4.3.5 Seeds to needs technology development

10.4.3.5.1 General

Organizations can continuously explore new technology before market and customer demand arises, and before competitors. This technology must then be matched to unfulfilled customer needs in a QFD process called seeds to needs development.[29]

10.4.3.5.1.1 TRIZ patterns of evolution

Examination of current technology and where it sits in the evolutionary patterns can give insight into what the next generation and next-next generation can look like. Evolutionary patterns can nest inside of other patterns. Classical TRIZ identifies eight common patterns,[55] as follows:

a) S-curve life cycle (growth curves from technology concept, early adoption, maturity, and replacement);

EXAMPLE 1 Airplanes grew from bicycles with wings that failed to fly, to bi-planes made of internal wood skeletons, to metal tube planes with exoskeletons.

b) increased ideality (goodness divided by badness);

EXAMPLE 2 The ENIAC computer in 1946 weighed several tons, took a whole room, and did only computational functions. Todays smart phones weight a few ounces, fit in a pocket, and communicate, keep your calendar and alert you, take video, navigate, keep track of your exercise, and so much more

c) non-uniform development of elements (primitive subsystems hold back development of the total system; a common mistake is to focus on improving the wrong subsystem);

EXAMPLE 3 Poor aerodynamics were limitations of early planes but developers focused on engine power instead of improving aerodynamics.

d) increase dynamism and controllability (growth in options);

EXAMPLE 4 Early automobiles were controlled by engine speed, then manual gearboxes, followed by automatic transmissions, and continuously variable transmissions.

e) increased complexity, then simplification (increase in systems followed by integration);

EXAMPLE 5 Music systems evolved from separate components such as speakers, AM/FM radio, record turntable, to integrated boom boxes, to MP3 players, to streaming music from the Internet.

f) match/mismatch of parts;

EXAMPLE 6 Early automotive suspension springs were assembled from horse carriages parts, later fine-tuned into a matched shock absorber system. Future methods could include mismatched bimetals that change rates when a current is applied.

g) transition to micro level and use of fields;

EXAMPLE 7 Cooking systems evolved from wood burning, to gas, to electric coils, to microwaves.

h) decreased human interaction (automate);

EXAMPLE 8 Development of clothes washing from washboard to washing machine with ringer, to automatic washing machine, to computer controlled washing machine with automatic bleach and softener dispensers, and single tub washer-dryer combinations.

NOTE 1 Patterns of evolution can be examined with competitors' technologies to create patent fences around their future developments.

NOTE 2 TRIZ includes additional methods and tools which can be utilized.

10.4.3.5.1.2 Reverse QFD

While most of this document focuses on customer-driven QFD models (often referred to as forward QFD), internally generated ideas can be used in reverse to discover their effects on customer needs. There are several types of reverse QFD.[36] Most common are as follows:

a) Technology-driven QFD which is used when a company wants to introduce a new technology and must confirm target customer segments and refine the product in line with their needs.[21] This can also be used to determine if the customer segment is clearly understood.[9]

b) Concept-driven QFD which is used when a company wants to test new ideas in the market.

c) Executive-driven or strategy-driven QFD is used when a senior manager has a "gut" feeling about a new product opportunity, often related to technology or market strategy. It has also been used with management responses to threats in the marketplace. QFD can be used to validate this gut feeling by investigating the impact of the opportunity.

d) Competitor-driven QFD which is used when a competitor introduces a new feature and marketing insists it must be copied. This helps determine if the competitor's feature makes sense and if it can be improved.

e) Cost-driven QFD is used when a lower-cost competitor enters the market and the company seeks to remove unnecessary cost from unwanted or over-engineered features.

f) Regulatory-driven QFD is used when a legal, regulatory, or standards body changes applicable rules or regulations that require product change, such as the removal of harmful materials or processes. QFD helps ensure changes do not negatively impact customer satisfaction.

g) Manufacturing-driven QFD is used when a company changes a manufacturing process or location and must ensure the changes do not negatively impact customer satisfaction.

EXAMPLE Table 23 shows how concepts offered by employees were used to discover if the needs addressed by these had a high priority. For example, offering health club memberships would have the characteristic of making members accountable for their own physical activity which could address the customer need of "I need help with appropriate physical activity." If this need was highly prioritized by customers, then the insurance company would offer it.[21]

Table 23 — Reverse QFD at a health insurance company

customer needs	characteristics & capabilities	functions	reliability	technology	information	commun-ications
I need help with appropriate physical activity.	member accountability for their physical activity			health club membership		
I need help with appropriate nutrition.	member accountability for their nutrition			diabetic nutrition education (Josylin)		
I need to know the progress of my condition.	diabetes progress reportability	patient self-reporting AIC		incent patient A1C reduction		
I need up-to-date information on my condition.				provide free testing supplies for 3 months		

10.4.3.5.1.3 Gemba walkabouts

Walk about the gembas (where customers live and work) of your key customers and customers representing future trends, as defined in ISO 16355-2. Do so without a product in mind, but with an eye towards what customers are saying and forecasting about their future, their industry. Ask lots of questions, record lots of images. Look for today's unsolvable problems and ungraspable opportunities. Look for images that represent hope and aspirations. Record these in a gemba visit table and translate into unmet customer needs and benefits in the customer voice table.[32][44]

10.4.3.5.1.4 Lead user research

This approach combines R&D technologists with key opinion leaders and other authoritative industry prognostics to analyse trends and develop new technology concepts and working prototypes.[52] Key activities are taken over several months within a contracted relationship that ensures ownership of the ideas belong to the organization. The steps are as follows:

a) screen participants for strong personal interest in advancing their industries and science, and willingness to sign over ownership;

b) conduct interactive workshops with R&D and lead users to identify concerns and generate solutions;

c) uncover market opportunities and generate long-range strategies;

d) refine concepts.

NOTE Customer and employee generated ideas create a risk of patent conflict, especially in first-to-file legal systems. Organizations can check with their legal departments regarding proper disclosure statements with suggestors.

10.4.3.6 Develop system, subsystem concepts

10.4.3.6.1 General

Based on the technology seeds, the QFD team can generate system and subsystem level technology concepts and solutions. Modularization and interfaces can also be generated. Concepts and solutions can be combinations and integrations from other industries.

10.4.3.6.2 Formulating concepts

The QFD team can phrase concepts in a structured language to clarify among team members representing different departments and to increase the number different concepts. Concepts can be combined to create hybrid concepts.[42]

EXAMPLE An automotive components supplier researches new materials. The team discusses that a new material can require a new forming process and equipment. The words “material forming” can be structured into “material” and “forming,” thus leading to two technology issues: the material design and the manufacturing and process design.

10.4.3.6.3 Structuring concepts

As with other QFD matrices, concepts can be structured using an affinity diagram and hierarchy diagram as shown in 9.3.6.2 and in ISO 16355-4. Systems and subsystems can be represented as levels in the hierarchy diagram.

10.4.3.6.4 Determining relationships between technology seeds and system, subsystem concepts

Technology seeds can provide multiple attributes to the current and proposed systems and subsystems of the product. These relationships can be examined in an L-matrix. Careful examination of this matrix can reveal new design possibilities.

NOTE 1 Separate matrices for the design concepts and process concepts can be more useful when these are further hybridized.

NOTE 2 The technology seeds-system concept matrix is labelled matrix 1-II in the Comprehensive QFD flow chart in Figure 3.[1] Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers notice that this matrix is not included, since technology concepts were usually defined by the equipment manufacturer in the 1980s when this approach was truncated from comprehensive QFD. Readers familiar with the matrix of matrices recognize this as the C-1 matrix.[28]

EXAMPLE Table 24 indicates how the TRIZ-derived concepts and emerging smart phone technologies can be applied to the airport kiosk operations.

Table 24 — Technology seeds to system/subsystem matrix for airport breakfast kiosk

Technology seeds \ Systems/subsystems	Information		Ordering			Preparation			Payment			Delivery		
	signage	nutrition	menu	order-taking	order fulfillment	bagels	toppings	heating	calculation	money taking	receipt	packaging	utensils	hand-over
Kiosk worker multitasking				●	●	●	●	●	○	●		●	◑	●
Parbaked frozen bagels	◑	◑	●		◑	●								
On-site toppings mixing	◑	◑	●	◑			●							
Internet/app ordering	◑	◑	●	●					●					
Internet/app payment									◑	●	◑			
On-plane delivery					◑							◑		●

●	Technology direcly applicable
◑	Technology adaptable
○	Technology has problems/bottlenecks

10.4.3.7 Concept selection

Concepts can be selected in different ways.

10.4.3.7.1 Selecting concepts using customer needs

Customer needs are generally too abstract for selecting technologies. QFD recommends this be done with more technical analyses using functional requirements and functions. In cases where the customer is equally technical, these discussions can be carried out jointly between the QFD team and the customer, often in multiple iterations as the design progresses.

10.4.3.7.1.1 Agile development

There are many structured methods used in software development such as waterfall, rational unified process (RUP), agile, scrum, lean, and extreme programming. These methods provide a consistent, simple, proactive methodology to discover product requirements, especially when customers have only an abstract idea of an end result, but not what is required of the software to deliver it. Thus, incomplete, ambiguous, or even contradictory requirements can result. QFD develops clear, complete customer needs and the functional requirements in the initial stage of the project and is a consistent method to obtain the desired concept design strategy from those needs and translate them into actionable, useable requirements. Agile development teams can use QFD to capture the voice of the customer and customer needs priorities. This QFD tools shown below can be useful in providing software scalability without losing flexibility and when determining concept feasibility. These QFD tools support the scrum phases as follows:

a) project goals table in ISO 16355-2 supports scope and vision;

b) customer segments table in ISO 16355-2 supports defining personae;

c) customer process model and gemba visit table in ISO 16355-2 help write epic;

d) customer voice table in ISO 16355-4 supports writing themes;

e) AHP in ISO 16355-4 sets accurate priorities for the product backlog;

f) maximum value table and matrices in 9.2 and 9.3 support the stories and product backlog;

g) ongoing Blitz QFD® helps define incremental releases.

EXAMPLE Table 25 describes the software capabilities needed to help patients and parents participate in their own care or the care of a child. In this example from a children's hospital, software functional requirements are the capability to help parents set goals and communicate them to the doctor or health care provider prior to arriving at the clinic for treatment.[14]

Table 25 — Maximum value table to define healthcare provider software capabilities for a scrum team

Customer			Analysis	Design	
			Functional Requirements	Design Requirements	
task	problems	needs	characteristics & capabilities	solution technology	?
Pre clinic	Parents may or may not provide goals for their child	Patients and parents need to participate in their care	Capability to help parents to set goals for their child. Capability to help parents communicate goals to provider prior to clinic.	Selectable modality of comunication: email, written, verbal; signing, and online. Goals should be entered electronically prior to the clinic visit. Ability to communicate goals in family's native language.	
			Capability to help parents understand care requirements for their child, i.e. how to feed, how to give meds, monitoring of equipment, trouble-shooting equipment.	Telemetry for equipment to communicate directly to hospital.	
			Capability to help parents deliver care requirements for their child, i.e. how to feed, how to give meds, monitoring of equipment, troubleshooting equipment.	Follow up nurse monitoring.	

10.4.3.7.1.2 Continuous QFD

A QFD project can be a joint team effort of the customers' as well as the developers' side. QFD always aims at improving communication by establishing cross-departmental, interdisciplinary teams within the company and with the customers. Furthermore, the lack of experience and clarity in customer requirements (CR) or customer needs as well as product characteristics (PC) or functional requirements calls for an even closer and increased collaboration of all involved stakeholders, primarily indicated by the demand for a larger number of meetings and a simultaneous collection of requirements and solutions.[18][20][54] Adjusted customer needs are illustrated in Table 26.

Table 26 — Continuous QFD

	Problems/Requirements	Specifics of Continuous QFD: Incremental planning and implementation cycles — Simultanous collection of CR & PC	Large number of short meetings	Gradually refined weighting	Focus on important CR/PC	All matrices developed incrementally	Simultaneous planning and development	Employment of IT (QFD tools & internet)	Use of templates
Characteristics of fuzzy development tasks	Unclear CR/PC	●	●	●	◔	◔	●		◔
	Dynamic CR/PC		●	●				◔	
	Uncertain PC (feasibility)						●		
	Time pressure	●	◔		●		●	●	●

CR = customer requirements

PC = product characteristics

● = extremely strong relationship

◔ = moderately strong relationship

10.4.3.7.1.3 Customer needs-concepts matrix

With customer assessments, different technology solutions can be selected by how well they meet weighted customer needs.

NOTE 1 This table is not part of comprehensive QFD or 4-phase QFD. Readers familiar with the matrix of matrices recognize this as a type of E-1 matrix.[28]

EXAMPLE Table 27 illustrates the effort to understand all the various customer needs and organizational motives that were used in a concept selection exercise. It shows how the deployment process was used to select sensor design “C” by a significant margin. Given the clarity and traceability offered by QFD, the selection decision was both defensible and well documented.[25]

NOTE 2 In this example, the 5-level ratio scale relationship strengths were used in calculating this example. They are shown in 10.2.1 b).

Table 27 — Customer needs-system/subsystem concepts matrix

Adjusted Customer Needs	Adjusted Weight (Management priority)	Sensor Type: Sensor A	Sensor B	Sensor C	Sensor D
Apply design to multiple platforms without concern over sensor (plug & play)	0,337	○ 0,012	◔ 0,023	◑ 0,045	· 0,000
Uncomplicated assembly of sensor into actuation unit	0,191	◑ 0,026	◔ 0,013	◑ 0,026	○ 0,007
Consistent System operation	0,187	◔ 0,013	◔ 0,013	◑ 0,025	○ 0,006
Develop new vehicle applications with flexibility and low risk	0,144	◑ 0,019	◑ 0,019	◑ 0,019	○ 0,005
Robust to environmental noise-factors	0,140	◑ 0,019	◔ 0,010	◑ 0,019	○ 0,005
Absolute Weight		0,088	0,077	0,134	0,023
Normalized Weight		**0,273**	**0,239**	**0,416**	**0,071**

10.4.3.7.2 Selecting concepts using Pugh and Super Pugh methods

Pugh methods are used in QFD to select concepts.

10.4.3.7.2.1 General

Stuart Pugh, teaching a post-graduate course in engineering design, was concerned about the conceptual vulnerability of final designs that had the following issues:

a) were chosen without a thorough conceptual approach, since no amount of later attention to detailed technical requirements made up for a poor choice;

b) were strong concepts, but because they lacked a thorough conceptual approach, were easily refuted because the reasons for their strength were not known or understood.

Since it was not possible to evolve and evaluate all possible solutions to a particular problem, having a disciplined procedure minimizes the possibility of a wrong choice of concept.[42]

10.4.3.7.2.2 Pugh concept selection

Pugh outlined four steps to his approach:

a) Solution: The team develops embryonic solution concepts and the criteria by which to evaluate them. They are organized in a matrix with the current solution labelled as a datum to which the new concepts can be compared.

b) Evaluate: Each solution concept is compared to the datum and the team determines if it better (+), worse (-), or the same (S) as the datum. This is done for all the criteria. The +s and –s can be summed to identify the strongest concept. This matrix is shown in Table 28.

c) Iterate: The strongest concept is then used as a datum. Weaknesses (-) in the datum or other promising concepts can be strengthened by integrating ideas, subsystems, or parts from other concepts that have strengths (+) for the same criteria. New hybrids can become a new datum, and the process iterated until a viable concept emerged.

d) Agree: The team then agrees on the winning concept and continues with the development.

Table 28 — Pugh concept selection matrix model

		Concepts		
Criteria	**Datum**	**A**	**B**	**C**
one	S	–		+
two	S		–	
three	S	+		–
four	S			
+		1	0	1
–		1	1	1

10.4.3.7.2.3 Super Pugh concept selection

QFD adds customer driven priorities to the Pugh selection criteria. The analytic hierarchy process (AHP) allows for more accurate scoring of the concepts than a simple + or – by adding ratio scale judgments.[58]

10.4.3.7.2.4 Selecting concepts using QFD criteria

When using Pugh with QFD, the criteria come from prior QFD matrices, and include customer-driven priority weights. At this point in QFD, customer need weights, functional requirement weights and function weights have been calculated as follows and can be used to reflect customer-driven priorities.

a) Customer need weights were calculated and adjusted (optional) in ISO 16355-4. See Table 27.

b) Functional requirement weights were calculated and adjusted (optional) in 10.2.3. Functional requirement target values can also be shown to aid in the evaluation.

NOTE This table is a variation on matrix 2'-II in the Comprehensive QFD flow chart in Figure 3.[1] This table is not part of comprehensive QFD or 4-phase QFD. Readers familiar with the matrix of matrices recognize this as a type of E-3 matrix.[28]

EXAMPLE Table 29 is an example from a hand-held torch. Each concept is evaluated against the current oblong torch (datum) for each function. Concepts that outperform the datum are marked with a +, same as the datum an S, and weaker than the datum a -. The +s and –s are multiplied by the functional requirement weight and summed at the bottom. A hybridized "new" concept was created by using strengths of some concepts to compensate for weaknesses of the other concepts. The functional requirement weights were calculated in a flashlight house of quality not illustrated here.

Table 29 — Functional requirements-concepts matrix

Functional Requirements \ Concepts	CURRENT OBLONG	PUMP	HEAD LAMP	SLENDER	NEW CONCEPT	Functional Requirement W
Optics						
Transmissivity		-	+	+		10
Angle of reflection		S	+	+		7
Luminous Flux						
Luminous efficiency		+	+	+		11
Luminance		S	+	S		9
Power characteristics						
Power output		-	+	S		17
Physical properties						
Switch force		-	+	+		9
Weight		-	-	-		6
Center of gravity		-	+	-		13
# Steps to charge pwr.		+	-	+		6
SUM OF PLUSES		2	7	5		
SUM OF MINUSES		5	2	2		
WEIGHTED PLUS		17	76	42		
WEIGHTED MINUS		54	12	19		

c) Function weights were calculated in 10.4.2.3.4 and 10.4.2.4.3 from customer needs and functional requirements respectively. They can also be used to evaluate concepts.

10.4.3.7.2.5 Super Pugh with AHP criteria

With AHP, evaluation criteria can be objective or subjective, and both can be combined in one evaluation model by converting the objective from an absolute scale into ratio scale values and the subjective from a verbal scale into ratio scale values. Ratio scale values enable comparison of objective and subjective information on a common scale. Criteria other than from the prior QFD matrices can also be used.

a) Objective criteria can be counted or estimated with some degree of confidence and the values are in ratio scale. There are two types of objective criteria; bigger is better and smaller is better.

   EXAMPLE 1 Bigger is better. Sales revenue where € 1 000 000 is twice as good as € 500 000.

   EXAMPLE 2 Smaller is better. Number of full time equivalent (FTE) developers required where five FTEs is twice as good as 10 FTEs.

b) Subjective criteria are more experiential or heuristic. There are two types of subjective criteria, absolute or expert scale and relative.

EXAMPLE 1 Absolute or expert scale. Michelin stars for a restaurant. The scale is widely used and accepted. However, a three-star restaurant cannot be said to be three times better than a one-star restaurant. Absolute or expert scales can be converted into ratio scales.

EXAMPLE 2 Relative scale is useful when there is no objective or absolute or expert scale. For example, the fun of working on a project, one can say that one project would be more fun than another.

NOTE 1 Not all AHP models have both objective and subjective criteria.

NOTE 2 The AHP model can have several criteria of each type. Evaluate each concept against each criteria.

10.4.3.7.2.6 Evaluate each concept against each criteria

Each of the criteria types are demonstrated in the examples below, including how ratio scale scores for each concept are derived for each criteria.

EXAMPLE 1 Table 30 is an example of an objective criteria, where bigger is better, in this case, projected first-year revenue in million Euros. Each project is evaluated: a local vendor can help create sales estimated at € 7 000 per kiosk, a frozen bagel is estimated to produce € 3 000, and so forth. Since each criteria can be measured differently, it is helpful to normalize them into percentages by summing the estimated values and dividing each value by the sum. 7 + 3 + 13 + 6 = 29. 7/29 = 0,241 and so forth. These mathematical calculations are permitted because revenues in euros are already in ratio scale. Numbers are rounded to three decimal places.

Table 30 — Concept selection criteria — objective, bigger is better

	Local vendor	**Frozen**	**Par-bake Frozen**	**On-site Bakery**	
Revenue potential (in thousands) *[bigger is better]*					
Increased Sales					totals
estimated value	7	3	13	6	29
normalized	**0,241**	**0,103**	**0,448**	**0,207**	1,000

EXAMPLE 2 Table 31 is an example of an objective criteria, where smaller is better, in this case, product and labour cost. Each concept is evaluated: a local vendor is estimated to cost € 6 000, frozen bagel is estimated to cost € 4 000, and so forth. Since each criteria can be measured differently, it is helpful to normalize them into percentages. Since smaller is better, the values are first inversed and then the inverse values are summed. Then, each inversed estimated value is divided by the sum. 1/6 = 0,167, 1/4 = 0,025, and so forth. 0,167+0,250+0,091+0,167 = 0,683. 0,167/0,683 = 0,244 and so forth. These calculations are permitted because number of people are already in the ratio scale. Numbers are rounded to three decimal places.

Table 31 — Concept selection criteria — objective, smaller is better

	Local vendor	Frozen	Par-bake Frozen	On-site Bakery	
Good Product Cost	Estimated product and labor costs (thousands) **[smaller is better]**				totals
estimated value	6	4	6	10	26
the inverse	0,167	0,250	0,167	0,100	0,683
normalized	**0,244**	**0,366**	**0,244**	**0,146**	1,000

EXAMPLE 3 Table 32 is an example of a subjective criteria, where these is an absolute or expert scale, in this case, a taste comparison of each concept. Before evaluating each concept, the absolute or expert scale can be converted from ordinal to ratio scale so that mathematical calculations can be performed. For the example, three ordinal scales are presented, iconic (smiley faces), numerical (1–5 with 5 being the most delicious), and verbal (from not worth it to epicurean). Using AHP's pairwise decision grid, each ordinal scale value is compared with all the others. When two values are equal, a 1 is entered in the grid. Thus, the diagonal is always 1s. When the row is preferred to the column, an integer is entered in the grid to represent the strength of the preference. The choice of strengths and their integers are moderately preferred (3), strongly preferred (5), very strongly preferred (7), or extremely preferred (9). In this example, epicurean is moderately preferred to homemade taste, epicurean is strongly preferred to delicious, and so forth. When the column is preferred, the inverse fraction is entered. Thus, the lower left values are inverse of the upper right.

Each column in the ratio scale conversion grid is summed (epicurean is 1+1/3+1/5+1/7+1/9 = 1,79) and then normalized by dividing each value by the column total. 1/1,79 = 0,560, 1/3/1,79 = 0,187, and so forth. Notice the normalized columns sum to 1,000. Then, each row of normalized columns are summed (0,560+0,642+0,524+0,429+0,360 = 2,514). The row totals are then averaged to yield the ratio scale values of the ordinal scale (2,514/5 = 0,503 and so forth).

NOTE Subjective judgments are often inconsistent. For example, one might judge that a > b, b > c, and c > a. The AHP model is robust to inconsistency of as much as 0,100 or 10 %. Inconsistency ratios above 10 % are checked for math or judgment errors.

Once the ordinal scale has been converted into ratio scale, each project can be evaluated. In this example, both concepts local and par-bake are considered to have homemade taste and have earned four smiley faces, frozen is considered not worth it and has earned one smiley face, and on-site is considered epicurean and has earned five smiley faces. Substituting the ratio scale row averages from the conversion grid, one smiley face has a weight of 0,035, four faces has a weight of 0,260, and five faces has a weight of 0,503. These are summed (0,260+0,035+0,260+0,503 = 1,058) and normalized (0,260/1,058 = 0,246 and so forth). Numbers are rounded to three decimal places.

Table 32 — Concept selection criteria — subjective, absolute or expert judgment

absolute judgment scale:		*Improved Taste*	Consumer taste preference (expert judgment) epicurean	homemade taste	delicious	acceptable	not worth it	normalized columns					row total	row avg.
☺☺☺☺☺	5	epicurean	1	3	5	7	9	0,560	0,642	0,524	0,429	0,360	2,514	**0,503**
☺☺☺☺	4	homemade taste	1/3	1	3	5	7	0,187	0,214	0,315	0,306	0,280	1,301	**0,260**
☺☺☺	3	delicious	1/5	1/3	1	3	5	0,112	0,071	0,105	0,184	0,200	0,672	**0,134**
☺☺	2	acceptable	1/7	1/5	1/3	1	3	0,080	0,043	0,035	0,061	0,120	0,339	**0,068**
☺	1	not worth it	1/9	1/7	1/5	1/3	1	0,062	0,031	0,021	0,020	0,040	0,174	**0,035**
			1,79	4,68	9,53	16,33	25,00	1,000	1,000	1,000	1,000	1,000	5,000	1,000
													Inconsistency Ratio	0,05

Improved Taste Consumer taste preference (expert judgment)

	Local vendor	Frozen	Par-bake Frozen	On-site Bakery	
absolute judgment	☺☺☺☺	☺	☺☺☺☺	☺☺☺☺☺	no. of smiles
weight	**0,260**	**0,035**	**0,260**	**0,503**	1,058
normalized	**0,246**	**0,033**	**0,246**	**0,475**	1,000

EXAMPLE 4 Table 33 is an example of a subjective criteria, where these is no absolute or expert scale and so a relative scale is used, in this case, the resistance to wasted food or time. Similar to the ratio scale conversion grid in example 3, each concept is pairwise compared to each other concept relative to its resistance to waste. Concepts compared to themselves earn a score of 1 as shown in the diagonal of the grid. When the row concept is preferred to the column, an integer is entered in the grid to represent the strength of the preference. The choice of strengths and their integers are moderately preferred (3), strongly preferred (5), very strongly preferred (7), or extremely preferred (9). When the column is preferred, the inverse fraction is entered. Thus, the lower left values are inverse of the upper right. In this example, local is very strongly more likely to resist waste than a frozen bagel, par-baked is moderately more likely to resist waste than a local, and so forth.

The scoring grid is then normalized as above, with the row average results indicating the relative preference for each project. In the example, local vendor has a waste resistance score of 0,145, frozen of 0,040, and so forth. Numbers are rounded to three decimal places.

Table 33 — Concept selection criteria — subjective, relative judgment

Less Waste	Relative resistance to waste food or time (*relative judgement*) Local vendor	Frozen	Par-bake Frozen	On-site Bakery	normalized columns				row total	row avg.
Local vendor	1	7	1/3	1/6	0,099	0,292	0,096	0,094	0,580	**0,145**
Frozen	1/7	1	1/7	1/9	0,014	0,042	0,041	0,063	0,159	**0,040**
Par-bake Frozen	3/1	7/1	1	1/2	0,296	0,292	0,288	0,281	1,156	**0,289**
On-site Bakery	6/1	9/1	2/1	1	0,592	0,375	0,575	0,563	2,104	**0,526**
	10,14	24,00	3,48	1,78	1,000	1,000	1,000	1,000	4,000	1,000
									Inconsistency Ratio	0,10

10.4.3.7.2.7 Weight the criteria

Are all criteria equally important in project selection or are some criteria more important than others? For example, a company can evaluate revenue as being more important than cost.

EXAMPLE Table 34 uses the AHP pairwise grid to weight the concept selection criteria. Similar to the ratio scale conversion grid in example 3, each criteria is pairwise compared to each other criteria relative to the importance of the criteria to the concept selection. Criteria compared to themselves earn a score of 1 as shown in the diagonal of the grid. When the row criteria is more important than the column, an integer is entered in the grid to represent the strength of the importance. The choice of strengths and their integers are moderately more important (3), strongly more important (5), very strongly more important (7), or extremely more important (9). When the column is preferred, the inverse fraction is entered. Thus, the lower left values are inverse of the upper right. In this example, increased sales is very strongly more important than good product cost, and so forth. The relative importance of the criteria are increased sales (0,561), good product cost (0,064), improved taste (0,308), and less waste (0,067). Numbers are rounded to three decimal places.

Table 34 — Weight the concept selection criteria

(importance of criteria to concept selection)									row	row
criteria	Sales	Cost	Taste	Waste	normalized columns				total	avg.
Increased Sales	1	7	3	7	0,618	0,438	0,691	0,500	2,246	**0,561**
Good Product Cost	1/7	1	1/7	1	0,088	0,063	0,033	0,071	0,255	**0,064**
Improved Taste	1/3	7/1	1	5	0,206	0,438	0,230	0,357	1,231	**0,308**
Less Waste	1/7	1/1	1/5	1	0,088	0,063	0,046	0,071	0,268	**0,067**
	1,62	16,00	4,34	14,00	1,000	1,000	1,000	1,000	4,000	1,000
									Inconsistency Ratio	**0,05**

10.4.3.7.2.8 Synthesize concept priorities

The weighted criteria are then multiplied by the ratio scale values of each concept to calculate project priorities.

EXAMPLE In the centre of the synthesis grid in Table 35, the previous work is displayed. For example, the increased sales estimate for the local vendor was € 7 000, which was normalized to a ratio scale score of 0,241 in Table 3. Here it is represented as 24,1 %. This score is then multiplied by the criteria weight for sales (0,561 or 56,1 %) giving what is called a “global” weight of 13,6 %. This is repeated for each cell in the grid, and the global weights are then summed for each column to give a concept selection weight in ratio scale. Here, par-baked frozen (36,2 %) has four times the priority as frozen (9,4 %). Numbers are rounded to three decimal places.

Table 35 — Synthesized concept priorities

criteria	% wt.	Cpt1 Local vendor	Cpt2 Frozen	Cpt3 Par-bake Frozen	Cpt4 On-site Bakery	
		concepts				
Increased Sales	56,1%	7 24,1 13,6	3 10,3 5,8	13 44,8 25,2	6 20,7 11,6	count or estimate local priorities (%) global priorities (%)
Good Product Cost	6,4%	6 24,4 1,6	4 36,6 2,3	6 24,4 1,6	10 14,6 0,9	
Taste	30,8%	☺☺☺☺ 24,6 7,6	☺ 3,3 1,0	☺☺☺☺ 24,6 7,6	☺☺☺☺☺ 47,5 14,6	
Less Waste	6,7%	14,5 1,0	4,0 0,3	28,9 1,9	52,6 3,5	
	%	23,6	9,4	36,2	30,7	priorities

When there are many concepts to select from, this mathematical modelling with AHP can make the selection process both accurate and easy, even when both objective and subjective criteria are used.

NOTE There are many AHP software packages and Excel sheets that do the above math in the background.

10.4.3.8 Refining selected concepts

Concepts can be refined to address problems and concerns.

10.4.3.8.1 General

The above technology deployment methods and tools can be applied iteratively at the system and subsystem levels to achieve a design that can function and perform sufficiently to achieve the customer needs. The selected systems and subsystems come from 10.4.3.6.

10.4.3.8.2 Resolving engineering bottlenecks and problems

Engineering and technical challenges can be addressed as soon as possible. Solutions can be documented and made available for other project teams.

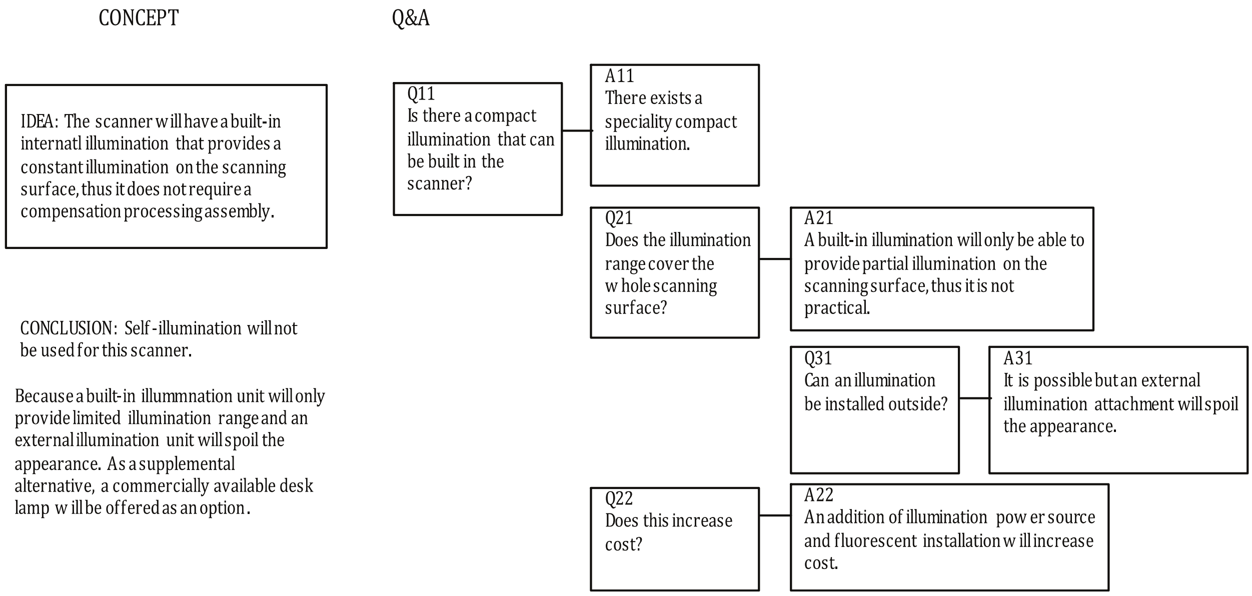
a) Iterate TRIZ methods and tools from 10.4.3.4.

b) Use a reviewed dendrogram to question and then answer challenging problems. Document solutions for future application to similar problems.

NOTE Readers familiar with the matrix of matrices recognize this as the F-3 chart.[28]

EXAMPLE Table 36 examines concerns related to illuminating the scanning surface without a compensating process. Question 11 askes if there is an illumination source compact enough to be built in. Answer 11 confirms a special device exists. This triggers question 21 about if the illumination can cover the entire scanning surface. Answer 21 confirms that only partial illumination is possible. The Q&A process continues until a satisfactory conclusion is reached or the idea is abandoned.[4]

Table 36 — Reviewed dendrogram method for scanner device



c) Optimize design. This is discussed in ISO 16355-5 and ISO 16355-7.

10.4.3.8.3 Finalizing concepts

Once concepts have been developed that satisfy the customer needs, more detailed analyses of cost, reliability, and other dimensions can be evaluated.

EXAMPLE The final concept for the airport breakfast kiosk is to procure partially baked and frozen bagels in four standard flavors and two seasonal flavors that can be finished baked on premise to sales demand. Cream cheese can be softened and flavored on premise. The selected systems and subsystems are from the columns in Table 24.

10.4.3.8.4 Components and build process

Technology deployment continues to improving the design of components and build processes. This is discussed in ISO/TR 16355-8.

EXAMPLE Florida Power and Light's power generation division utilizes information given from manufacturer bulletins, project lessons learned, user groups, and technology-specific conferences to help identify issues and opportunities to ensure reliable performance of new technology. Fleet teams are tasked, in conjunction with operations and other support teams, to not only identify new technologies to use, but also ensure they can meet the high standards of environmentally responsible and efficient operation. Taken into consideration are upgrades to components of larger pieces of equipment to meet certain targets. Cost is also be taken into account.

The flow of information is typically pushed from vendors, solicited and shared at users groups, and discussed internally with some of the industry's top subject matter experts.

NOTE The flow of technology information can also cross paths with reliability information

10.4.4 Cost deployment

10.4.4.1 General

10.4.4.1.1 Objective

Cost deployment is a systematic way to balance product cost and quality during the design and engineering phases of product development. It begins with a market analysis of the competitive products to determine a target price and from that, a target cost estimate. This target cost is then allocated to the functions, systems, subsystems, and components of the selected design concept. Traditional cost reduction methods, such as value analysis and value engineering are more suited to cost reduction in existing products, but can also be applied at the component level of QFD, which is discussed in ISO/TR 16355-8.

NOTE Quality deployment is referred to in JIS Q 9025, 6.4 and 9.4.[24]

10.4.4.1.2 Composition

As shown in the cost deployment section of Figure 3 (centre-right section), cost deployment consists of the following matrices, tables, and charts which transfers priorities from the customer needs to the following dimensions:

a) target cost estimation (see 10.4.4.2);

b) function and system and subsystem (see 10.4.4.3);

c) component cost and manufacturing cost (ISO/TR 16355-8).

NOTE B.4.5 shows an example of the cost deployment flow of charts and tables.

10.4.4.2 Target cost estimation

Figure 3 shows the cost estimation process of comparing the current product, the new product concept, and competing products.

a) Market or selling price. This can account for wholesale and other intermediary pricing where applicable, since cost reduction through distribution and logistics can be feasible.

b) Quantity of units that can be sold (estimate).

c) Market share, which is a ratio of estimated units/total units.

d) Profit required by the organization. Profit is calculated in many ways, such as gross profit, net profit, earnings before interest, taxes, depreciation, and amortization (EBITDA), and others. Confirm with the finance department member of the QFD team.

e) Target cost is calculated by subtracting profit from the selling price × quantity.

NOTE 1 Some organizations calculate selling price by adding profit to cost. In a competitive market, if this is not possible, target cost can be calculated by subtracting profit (determined by the stock market) from the selling price (determined by the customer).

NOTE 2 Product target price and subsystems can be market-tested using methods such as focus groups and conjoint analysis.[15] This captures customer responses to different feature combinations.

EXAMPLE Table 37 estimates a target cost of € 1,00 for the selected new concept of par baked frozen bagels with finish baking in the kiosk as needed, with no wasted product or time.

Table 37 — Target cost estimate for airport breakfast kiosk

	Our product		Competitor
	Current	New	
Market price	€ 0,75	€ 2,25	€ 3,25
Sales quantity (month)	2 000	6 000	1 500
Market share	8 %	68 %	25 %
Profit (gross)	€ 0,40	€ 1,25	€ 2,00
Target cost	€ 0,35	€ 1,00	€ 1,25

10.4.4.3 Function-system/subsystem matrix

Functions can be deployed to other dimensions.

10.4.4.3.1 General

The function-system/subsystem matrix looks at the relationships between the product functions and the systems and subsystems selected to perform these functions. Products employing modularization and interfaces can also use this matrix.

10.4.4.3.2 Purpose of the function-system/subsystem matrix

This matrix proportions target cost to system and subsystem cost by way of the function weights calculated in 10.4.2.3. Subsystem costs are later proportioned to component costs and is discussed in ISO/TR 16355-8.

NOTE The function-system/subsystem matrix is labelled matrix 2-II and the subsystem target cost is labelled 2-III in the Comprehensive QFD flow chart in Figure 3.[1] Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers notice that this matrix is not included, since costs were usually negotiated by the equipment manufacturer in the 1980s when this approach was truncated from comprehensive QFD. Readers familiar with the matrix of matrices recognize this as the C-2 matrix.[28][26]

10.4.4.3.3 Building the function-system/subsystem matrix

The following steps are used:

a) Insert into the rows of the matrix the functions and function weights from the columns of the customer needs-function matrix in 10.4.2.3.4. All functions can be used in order to properly allocate the target cost.

b) Insert into the columns of the matrix the selected concept's systems and subsystems from 10.4.3.6.

c) Transfer the function weights to the subsystem weights using proportional distribution method in 10.2.4.4. AHP derived ratio scale weights for the symbols in 10.2.1 b) can be used.

d) Allocate the target cost to the functions in proportion to the function weights.

e) Allocate the target cost to the subsystems in proportion to the subsystem weights.

EXAMPLE Table 38 shows the transfer of function weights to subsystem weights. These are then used to calculate target costs per function and target costs per subsystem. In the example, the function "source product" has eight relationships to the subsystems indicated with the symbols. Sum the ratio scale values for each symbol (0,498 + 0,498 + 0,000 + 0,112 + 1,000 + 1,000 + 0,000 + 0,000 = 3,109). Divide each value by the sum (0,160 0,160 0,000 0,036 0,322 0,322 0,000 0,000) to normalize to 100 %. Multiply the function weight by the normalized values to proportionally distribute the function weight to the symbols. Thus, 17,9 % × 0,160 = 0,029 rounded to three places. Sum these proportional weights for each column to calculate the subsystem weights. Thus, 0,029 + 0,000 + 0,000 + 0,027 + 0,000 + 0,001 + 0,019 + 0,000 = 0,076 rounded to three places. Function target costs are calculated by multiplying the product target cost from Table 37 × the function weights. Thus, the target cost for the new "source product" function is € 0,179, and so forth. Subsystem target costs are calculated by multiplying the product target cost × the subsystem weights. Thus, the target cost for the new bagel is € 0,279 per bagel and € 0,196 per cream cheese topping, and so forth.

Table 38 — Function-system/subsystem matrix for airport breakfast kiosk (proportional distribution)

	Systems/Subsystems / Functions	Function Weight	Information	Ordering			Preparation			Delivery	
			nutrition	menu	order-taking	order fulfillment	bagels	toppings	heating	utensils	
			Ss1	Ss2	Ss3	Ss4	Ss5	Ss6	Ss7	Ss8	Function target cost
COMMISSARY	Source Product	17,9%	0,029	0,029	0,000	0,006	0,058	0,058	0,000	0,000	0,179
	Acquire Product	17,9%	0,000	0,000	0,000	0,034	0,072	0,072	0,000	0,000	0,179
	Prepare Product	4,8%	0,000	0,000	0,000	0,012	0,024	0,000	0,000	0,012	0,048
	Ship Product	15,1%	0,027	0,057	0,000	0,000	0,027	0,027	0,000	0,013	0,151
OPERATIONS	Finish Preparation	5,7%	0,000	0,000	0,002	0,009	0,018	0,009	0,018	0,000	0,057
	Sell Product	6,1%	0,001	0,010	0,010	0,010	0,010	0,010	0,010	0,002	0,061
	Display Product	17,9%	0,019	0,082	0,041	0,009	0,019	0,009	0,000	0,000	0,179
	Maintain Product	14,7%	0,000	0,024	0,050	0,011	0,050	0,011	0,000	0,000	0,147
weighted	Absolute Weight		0,076	0,201	0,102	0,091	0,279	0,196	0,028	0,027	Target cost
	Subsystem Weight		7,6%	20,1%	10,2%	9,1%	27,9%	19,6%	2,8%	2,7%	1,00
	Subsystem Target Cost		0,076	0,201	0,102	0,091	0,279	0,196	0,028	0,027	Subsystem target cost

10.4.4.4 Component cost deployment and manufacturing cost deployment

As the design process flows downstream to components, materials, processes, and other details, the target costs can be calculated. Value analysis and value engineering can be used to further reduce costs. This is discussed in ISO/TR 16355-8.

NOTE Other constraints with targets such as weight (mass) can use a cost deployment-like process to proportion the target to functional requirements, functions, system/subsystems, components, and other details.

10.4.4.5 Design-to-cost analysis

Cost deployment can be used to support the following steps in design-to-cost:

a) cross functional team calculates customer affordability;

b) set target cost accounting for price elasticity, recurring and non-recurring costs;

c) acquire and prioritize customer requirements;

d) break down requirements into features, systems, and allocate costs;

e) look for unnecessary features, cost mismatches;

f) use value analysis and innovation methods like TRIZ to find alternatives.

10.4.4.6 Parametric cost analysis

Cost deployment can be used to support the following steps in parametric cost analysis,[8] as follows:

a) estimate development costs based on engineering complexity and new technology, prototype effort;

b) estimate production costs based on machining tolerances, materials costs, labour and energy;

c) costs to sustain product;

d) account for recurring and operational costs;

e) costs to retire product.

10.4.5 Reliability deployment

10.4.5.1 General

10.4.5.1.1 Objective

Reliability deployment can be used when designing new products that incorporate new technology, new functions, new components, new materials, new processes, new equipment, and others. Its purpose is to mitigate the negative risks inherent in design change. Reliability deployment focuses on product life and failure modes at the product, system, subsystem, module, component, and process levels. Its purpose is to help ensure that products continue to function throughout their expected product life when used under normal operating conditions. Deployments for service and software can be different.

NOTE Quality deployment is referred to in JIS Q 9025, 6.5 and 9.5.[24]

10.4.5.1.2 Composition

As shown in the reliability deployment section of Figure 3, Comprehensive QFD (right-most section), reliability deployment consists of the following matrices, tables, and charts which transfers priorities from the customer needs to the following:

a) fault tree analysis (see 10.4.5.3);

b) customer needs-failure modes matrix (see 10.4.5.5);

c) functional requirements (see 10.4.5.6);

d) function (see 10.4.5.7);

e) FMEA (see 10.4.5.8 and ISO/TR 16355-8);

f) components (ISO/TR 16355-8);

g) processes (ISO/TR 16355-8).

NOTE B.4.6 shows an example of the reliability deployment flow of charts and tables.

10.4.5.2 Measuring product risk

Different design concepts can embody a mix of potential risk factors, i.e. ways that the concept might fail to meet quality demands for the product, system, service, process. These risk factors are associated with failure to meet or exceed functional and non-functional requirements, including product performance targets.[11][7] Organizations measure product risk in many ways, among them are the following:

a) mean time to failure, for products that have components with limited serviceability;

b) mean time before failure, for products that have components with maintenance and service parts;

c) durability, to measure expected life of a product before its functionality or performance degrades to a level unacceptable to customers;

d) useful life, for products where technology changes or obsolescence renders the product no longer desirable;

e) acceptable life, for fashion products where customer tastes change.

10.4.5.3 Building the fault tree

Like most deployments in QFD, building a new information set requires a structuring process to ensure the information is mutually exclusive and collectively exhaustive (MECE). This is necessary when making subjective judgments on the strengths of relationships between the columns and rows in order to use the analytic hierarchy process (AHP) to improve the accuracy of the transfer of row weights into column weights in a matrix. The steps are as follows:

a) Brainstorm the failure modes. These are the failure to initially meet or continuously meet customer needs, functional requirements, functions, and other characteristics necessary for the product to be acceptable to the customer. Failure modes can be at the customer level, product level, system/subsystem level, component level, or process level.

b) Structure the failure modes into a fault tree, a type of hierarchy diagram described in ISO 16355-4. An affinity diagram can be used for initial structuring.

NOTE Readers familiar with the matrix of matrices recognize this as the F-2 chart[28].

EXAMPLE Figure 12 shows failure modes at the customer level. At the customer level, failure modes are technology independent.

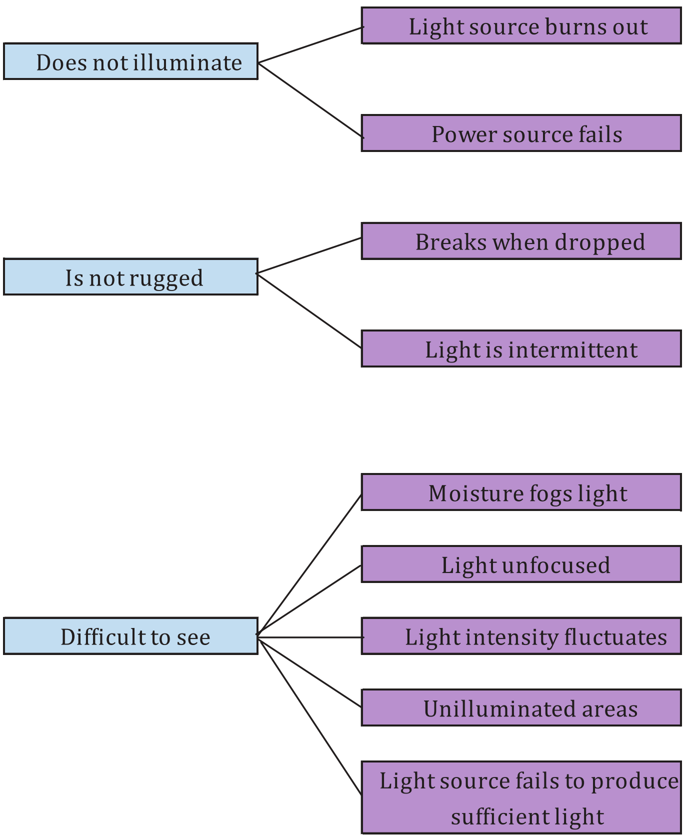


Figure 12 — Fault tree for hand-held torch

10.4.5.4 Fault tree analysis (FTA)

Fault tree analysis can be used to estimate failure probabilities. Fault tree analysis adds Boolean logic to the tree in the form of AND and OR gates, as well as probabilities of failure at the system, subsystem, component, or process level. Fault Tree Analysis can also be used for system level vulnerability to undesirable events due to interaction of causes.[56]

a) AND gates are used when lower level events must all occur for the system top event to fail. AND gates multiply the probabilities of each next level events failing, thus decreasing the likelihood of failure.

b) OR gates are used when any of the lower level events causes the system to fail. OR gates add the probabilities of each next level event failing.

c) Fault tree analysis prioritizes failure modes on the basis of probabilities of events occurring. Designs that change OR gates into AND gates are generally desirable.

EXAMPLE Figure 13 adds the probabilities of failure events to the fault tree. In the top event of "does not illuminate," there is an OR gate to the two lower level events of "light sources burns out" and "power source fails." Each OR gate lower event probability is summed to calculate the top event probability of failure. Thus, 0,02 + 0,06 = 0,08. In the top event of "Is not rugged," there is an AND gate to the two lower level events of "breaks when dropped" and "light is intermittent." Each AND gate lower event probability is multiplied to calculate the top event probability of failure. Thus, 0,009 × 0,006 = 0,000 054.

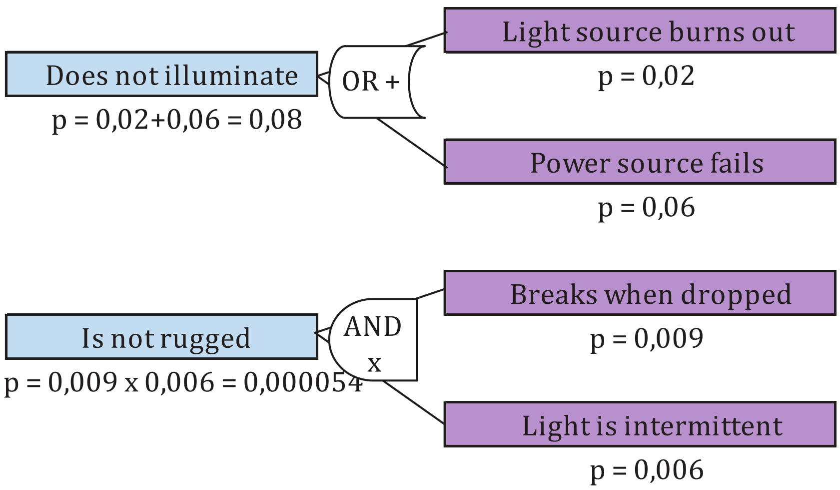


Figure 13 — Fault tree analysis for hand-held torch

10.4.5.5 Customer needs-failure mode matrix

Customer needs failures can be deployed.

10.4.5.5.1 General

The customer needs-failure mode matrix looks at how product failures effect customer satisfaction. the relationships between the product functions and the systems and subsystems selected to perform these functions.

10.4.5.5.2 Purpose of the customer needs-failure mode matrix

This matrix prioritizes failure modes from the effect they have on customer satisfaction. .

NOTE The customer needs-failure mode matrix is labelled matrix 1-IV in the Comprehensive QFD flow chart in Figure 3.[1] Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers notice that this matrix is not included. Readers familiar with the matrix of matrices recognize this as the D-1 matrix.[28]

10.4.5.5.3 Building the customer needs-failure mode matrix

a) Insert into the rows of the matrix customer needs and customer need weights from the rows of the customer needs-functional requirements matrix (house of quality) in 10.2.2.1. If the weighted quality planning table is used, then the adjusted weights can be entered. See ISO 16355-4 for details.

b) Insert into the columns of the matrix the fault tree from 10.4.5.3.

c) Transfer the customer needs weights to the failure mode weights using the method in 10.2.3. AHP derived ratio scale weights for the symbols in 10.2.1 b) can be used.

EXAMPLE Table 39 prioritizes failure modes on their effect on satisfying customer needs.

Table 39 — Customer needs-failure modes matrix for airport breakfast kiosk

	Failure Modes / Customer Needs	Priority	Product burnt FM1	Toppings fall off FM2	Fail Quality Stds. FM3	Tough Product FM4	Run out of condiments FM5	Run out of product FM6	Dirty environment FM7	Bad hygiene / dress FM8
1.1.1	I can make a healthy choice	19,3%	0,096	0,000	0,022	0,000	0,000	0,022	0,096	0,096
1.1.2	I can get a taste I like	60,6%	0,606	0,000	0,302	0,302	0,143	0,606	0,000	0,000
1.1.3	I can make an appealing choice	11,6%	0,116	0,058	0,058	0,013	0,013	0,116	0,058	0,027
1.1.4	I can choose quickly	8,6%	0,000	0,000	0,000	0,000	0,005	0,086	0,000	0,000
weighted	Absolute Weight		0,818	0,058	0,381	0,315	0,161	0,829	0,154	0,123
	Failure Mode Weight		28,8%	2,0%	13,4%	11,1%	5,7%	29,2%	5,4%	4,3%
	Failure Mode Rank		2	8	3	4	5	1	6	7

10.4.5.6 Functional requirements-failure mode matrix

Functional requirement failures can be deployed.

10.4.5.6.1 General

The functional requirements-failure mode matrix looks at how product failures diminish the performance of functional requirements (product characteristics and capabilities) over the life of the product. Since functional requirements define the solution space to achieve customer needs, this matrix prioritizes which product failures can lead to the most customer dissatisfaction.

10.4.5.6.2 Purpose of the functional requirements-failure mode matrix

This matrix prioritizes failure modes from the effect they have on product functional requirements and performance requirements. This can be at the product, system, or subsystem level.

NOTE 1 The functional requirements-failure modes matrix is labelled matrix 2'-IV in the Comprehensive QFD flow chart in Figure 3.[1] Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers notice that this matrix is not included. Readers familiar with the matrix of matrices recognize this as the D-3 matrix.[28]

NOTE 2 The functional requirements-failure modes matrix is not always necessary if performance is not critical.

10.4.5.6.3 Building the functional requirements-failure mode matrix

The steps are as follows:

a) Insert into the rows of the matrix functional requirements and their weights from the columns of the customer needs-functional requirements matrix (house of quality) in 10.2.2.1. If the weighted design planning table in Clause 33 is used, then the adjusted weights can be entered.

b) Insert into the columns of the matrix the fault tree from 10.4.5.3.

c) Transfer the functional requirement weights to the failure mode weights using the method in 10.2.3. AHP derived ratio scale weights for the symbols in 10.2.1 b) can be used.

10.4.5.7 Function-failure mode matrix

Functional failures can be deployed.

10.4.5.7.1 General

The function-failure mode matrix looks at how product failures effect product functions of the systems and subsystems selected to perform these functions.

10.4.5.7.2 Purpose of the function-failure mode matrix

This matrix prioritizes failure modes from the effect they have on product function.

NOTE The function-failure modes matrix is labelled matrix 2-IV in the Comprehensive QFD flow chart in Figure 3.[1] Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers notice that this matrix is not included. Readers familiar with the matrix of matrices recognize this as the D-2 matrix[28].

10.4.5.7.3 Building the function-failure mode matrix

The following steps are used.

a) Insert into the rows of the matrix functions and their weights from the columns of the customer needs-function matrix in 10.4.2.3. If the weighted quality planning table is used, then the adjusted weights can be entered. See ISO 16355-4 for details.

b) Insert into the columns of the matrix the fault tree from 10.4.5.3.

c) Transfer the function weights to the failure mode weights using the distribution method in 10.2.3. AHP derived ratio scale weights for the symbols in 10.2.1 b) can be used.

EXAMPLE Table 40 is a partial table showing the prioritization and rank ordering of failure modes based on the function priorities.

Table 40 — Function-failure mode matrix for hand-held torch (partial)

	Light not focused	Fluctuating intensity	Dark spots	Light too dim	Function Wt	Rank
Converts Light						
Radiates light	○		◎	◎	19	3
Regulates light						
Focuses light	◎	◎		○	7	6
Aims light	○				4	7
Absolute Wt	132	63	171	192		
Failure Mode W.t	24	11	31	34		
Rank	3	4	2	1		

10.4.5.8 Failure mode and effects analysis (FMEA)

Failure mode analysis can help prioritize the failures.

10.4.5.8.1 General

FMEA is a qualitative or quantitative analysis of failure modes known from past experiences. It can be used as a guide to preventing similar failures in the new product. FMEA can be applied at the product, system, subsystem, component, process, and equipment levels.[1][22][39][53] FMEA helps the QFD prioritize which failure modes have the greatest impact on customer satisfaction by analysing the impact failures have on product performance and function. Typically, each product, system, subsystem, component, process, and equipment failure mode is evaluated for the impact the failure has, how frequently it occurs, and how easy it is to detect when it has occurred or before it has occurred. These evaluations can be simply verbal as shown in Table 41, or they can be quantified as explained in ISO/TR 16355-8.

NOTE FMEA is associated with the components deployment level matrix 3-IV in the Comprehensive QFD flow chart in Figure 3.[1] Readers familiar with the 4-phase QFD model developed by build-to-print auto parts suppliers notice that this is not included. Readers familiar with the matrix of matrices recognize this as the F-2 Table.[28]

10.4.5.8.2 System/subsystem FMEA

At the system/subsystem level, there can be insufficient detail for the more mathematical FMEAs used at the component level. In such cases, a simplified FMEA can be used. The more detailed FMEA used at the component and process level is discussed in ISO/TR 16355-8.

EXAMPLE Table 41 is an example of a subsystem design FMEA table. Its columns identify the failure modes from Table 39. Additional columns then identify the source of the failure, the threat of the failure, what is threatened, how frequently the failure occurs, how much impact the failure has, ease of detecting the failure when it has occurred, and risk level on a 9-point scale from extreme risk (9) to minimal risk (1). Then, mitigating or corrective actions are identifies and referenced documents of standards noted.

Table 41 — FMEA (simple) for airport breakfast kiosk

		Who	*Why*	*What*	*When*	*How much*	*Where*	*How exp.*	*How*	
FMEA table										
#	**failure modes**	**source**	**threat**	**object**	**frequency?**	**impact?**	**detect?**	**risk level**	**mitigating action**	**std**
FM6	Run out of product	employee	order not enough	bagels	daily	small to large	easy	8	order more freqently	MA2-12
		customers	buy more than expected	bagels	hourly	small to large	hard	6	sale on available stock	AHP-3
									running record of sales	SPC-1
FM1	Product burnt	employee	bakes too long	bagels	very rare	huge	easy	1	error proof bagel baker	BK-7

10.4.5.8.3 Anticipatory failure determination

The TRIZ tool set attempts to anticipate failure modes and how to cause them. This analysis is used to mitigate or prevent them:[30][55]

a) brainstorm all potential failures;

b) look for ways the failures can be produced, as follows:

- — destroy system's resistance to specific effect;
- — make system vulnerable;
- — intensify the failure;
- — mask the failure;
- — transform harmless object into a source of danger;

c) prevent or eliminate the failure, as follows;

- — eliminate cause of failure;
- — remove source of harm or change its properties;
- — modify or counteract the harmful effect;
- — isolate the system from the harmful effect;
- — increase resistance to the harmful effect;
- — modify or substitute another object to be subject to the harmful effect;
- — localize or isolate the harmful effect;
- — reduce or blend in the harmful effect;
- — use the harmful effect for some beneficial purpose;
- — facilitate detection of the harmful effect.

EXAMPLE A transaxle bearing prone to slippage under heavy loads was replaced with a new metal with a different coefficient of expansion which tightened the bearings as loads generated heat. The harmful effect of heat was used to tighten the bearings.

10.4.5.8.4 Additional reliability tools

These additional tools have been used in QFD studies to address reliability concerns:

a) event tree analysis;[34]

b) reliability block diagrams and dependence diagrams;

c) failure mode, effects and criticality analysis (FMECA);[49]

d) failure mode effects and diagnostic analysis (FMEDA);[6]

e) lifetime estimation;

f) V-model of systems engineering;[13]

g) process decision program chart (PDPC).[38][40][5]

10.4.5.9 Reliability deployment related uses

Reliability deployment tools can be used to investigate risks related to hazards, consumer and environmental safety, toxicology, security, data protection and vulnerability.

10.4.5.9.1 Regulatory, environment, and sustainability deployment

Regulatory, environmental, and sustainability issues can be deployed.

10.4.5.9.1.1 Regulatory deployment

Organizations that are highly regulated are constrained by governmental and professional bodies and QFD studies can be adapted for these.

EXAMPLE Table 42 shows how QFD is used to help drive continuous operational improvement and customer focused target-setting, Their power generation division (PGD-FPL) business services provides management with consistent, yearly, performance trending benchmarks both internally and externally against available industry peer groups across key operating metrics: safety, availability, reliability, generating efficiency (heat rate), non-fuel operations and management cost (¢/kWh and $/kW), productivity, emission rates, non-operated coal plants, and experience curves.[12]

Table 42 — Assuring customer satisfaction, improvement, cost reduction, and regulatory compliance at Florida Power & Light

FPL Business Services QFD Matrix					
QFD linkage	**XXX Function**	**Customer(s)**	**Customer satisfaction expectations**		
			Accuracy	**Timeliness**	**Outcome results**
Quality	Performance Benchmarking	Management, regulators, investors, ratepayers	X	X	Fleet performance Improvements
Cost	Financial analyses (NPVs, EDMs) and budgets	Project leaders, plants, management, ratepayers	X	X	Cost savings

Table 42 *(continued)*

FPL Business Services QFD Matrix					
QFD linkage	XXX Function	Customer(s)	Customer satisfaction expectations		
			Accuracy	Timeliness	Outcome results
Process/ Production	Routine regulatory analysis and reporting	FPL regulatory accounting, external regulators	X	X	Regulatory compliance and performance rewards
Project/ Task Mgt.	Rate case/discovery / due diligence disclosure	Internal: Witnesses and management External: Regulators, shareholders and ratepayers	X	X	Regulatory compliance and fair ROE outcomes

10.4.5.9.1.2 Responding to existing challenges

In response to changing regulatory changes, QFD helps producers avoid tradeoffs in customer satisfaction and instead protect and enhance customer satisfaction. Reverse QFD in 10.4.3.5.1.2 can be used to analyse and mitigate the impact of regulatory changes on customer satisfaction.

EXAMPLE A manufacturer of an aerosol product was forced to abandon CFCs as a propellant. QFD helped them formulate a new product that did not compromise the consumer experience.[36]

10.4.5.9.1.3 Proactively addressing challenges

Deforestation, diminishing biodiversity, acid rain, ozone layer depletion, global warming, and human population growth are concerns of product developers. These concerns influence at the corporate policy level,[10] project level, customer level, product level, system level, component level, materials level, build level, and process level. QFD can be used for sustainable solutions that require significant innovation and departure from traditional designs, and this can be done before design decisions are made, so that appropriate resourcing can be planned.[46]

10.4.5.9.1.4 Sustainable business growth

The evolution 7-QFD tools have been used to help organizations adapt and grow.[40] The integrated tools are as follows:

a) Blue ocean strategy (Bos-QFD) which is discussed in ISO 16355-2;

b) Statistical methods (Stat-QFD) which is discussed in design of experiments in ISO 16355-6 and ISO 16355-7;

c) Quality assurance (QA-QFD) which is assuring quality in the early stages of product development using quality deployment which is discussed in 10.4.2;

d) Job and business function QFD (Jobs-QFD) covers both integration of organizational functions in a new product development system[39] and well as specific job details[33] which is discussed in ISO/TR 16355-8;

e) Taguchi methods and TRIZ (TT-QFD) looks at the design optimization methods of Genichi Taguchi discussed in ISO 16355-6 and ISO 16355-7, and TRIZ discussed in 10.4.3.4;

f) Relational database (Rdb-QFD) to acquire, archive, and retrieve organizational knowledge which is discussed in 9.3.7;

g) Sustainability (Sus-QFD) to create sustainable quality management systems that promote business growth, such as ISO 9001:2015.

10.4.5.9.2 Safety deployment

Safety concerns can be deployed.

10.4.5.9.2.1 General

Safety Deployment focuses on user safety, production safety, materials safety, toxicology, hygiene and sanitation, environmental safety and sustainability. In new product development, safety requirements can be dictated by a regulatory agency department at a governmental level or an internal department responsible for product liability, safety claims on packaging, liaising with regulatory agencies, and internal safety issues related to work in both offices and plants. While most of these activities reflect a verification or validation approach such as by inspection, reporting, training and other means, QFD offers an opportunity to build safety in by design, using both the modern and comprehensive QFD tools.

10.4.5.9.2.2 Maximum value table

When modern Blitz QFD® is used, the maximum value table can include columns related to user safety, product safety, materials safety, process safety, and other areas of concern.

EXAMPLE 1 Table 43 shows information related to patient safety with an air filter used in a continuous positive airway pressure (CPAP) machine used to aid people with sleep apnea. The highest priority customer need is to not get ill at the diagnostic centre and the filter is used to filter out viruses and bacteria (product functional requirements column) with 99,999 % efficiency (performance targets column). There is patient risk of infection from microbes (safety column) at the diagnostic centre such as tuberculosis and hepatitis (clinical risk column) as well as a risk of filter debris entering the patient's lungs. Suppliers of filer media must be inspected periodically for pinholes and tears in the media (supply chain column) and the in-house assembly process must ensure sterility and no human contact (sterility column).

Table 43 — Maximum value table with columns for safety factors in a medical filter

	Solution Concept				Manufacturing	
Customer Needs	Product Requirements	Performance Targets/ Quality Metrics CTQs	Reliability/ Safety/ Risk	Testing/ Validation/ Regulatory/ Clinical Risk	Supply Chain	Sterility
I don't catch any disease while at center.	bactierial and viral filtering	ease of filter insertion and removal, filter particle size 0,3 microns or larger, # filters, 99,99+% viral efficiency, 99,999% bacterial efficiency, fit standard CPAP tubing inlet/outlet: 22 mm I.D. x 15 mm I.D./22 mm O.D, Dead space 42 ml	risk of filter material entering airflow (foam crumbles, fibers shed), Cellulose-based filter media can become a fertile breeding ground for microbes. MERV 8 pre-filters are treated with an EPA registered, broad-spectrum anti-microbial designed to inhibit microbial growth and protect the integrity of the filter media.	HEPA class 13 (>99,97), Tested against Mycobacterium tuberculosis, Hepatitis C, HIV, Serratia marcescens, Staphylococcus aureus, Bacillus subtilis, and MS-2 coliphage. Institute of Environmental Sciences and Technology (IEST) and Underwriters Laboratories (UL) IEST-RP- CC021 "Testing HEPA and ULPA Media which governs requirements for the filter media IEST-RP-CC001 "HEPA and ULPA Filters", which governs overall filter construction and labeling requirements IEST-RP-CC034 "HEPA and ULPA Filter Leak Tests, which governs HEPA and ULPA filter penetration (leakage) tests Testing and certification to meet UL900 flammability requirements.	filter supplier plant inspected 2/year, receiving test on 2 units per 1000 for pinholes or tears.	filters sealed in pouches and not touched in factory

EXAMPLE 2 An electrical power utility communicates safety issues through safety bulletins. Green bulletins describe a new procedure, a safety or other enhancements such as mobile applications. Yellow bulletins communicate a near miss that did not result in an injury but could have. Red bulletins communicate injuries. For yellow and red bulletins, the name of the employee or the plant is not included. The purpose of the bulletin is to ensure any lessons learned are shared so the injury is not repeated at another location. Letters of Instruction are used to track compliance with new mandatory safety issues. Safety teams meet each week and the meeting minutes are distributed and posted on a safety website. Every two weeks, the safety team gives a leadership update to discuss new initiatives, plans and accomplishments. The safety team also conducts annual site safety assessments. This affords an opportunity to learn first-hand what safety concerns or issues are in the field. The safety team participates in periodic safety surveys of all employees to get their feedback.

10.4.5.9.2.3 L-matrices

Similar to failure modes, safety concerns can be identified and prioritized using L-matrices such as customer needs-safety matrix, functional requirements-safety matrix, function-safety matrix, component-safety matrix, equipment-safety matrix, and process-safety matrix. The high priority safety items are investigated and proactive and corrective actions are taken.

EXAMPLE Table 44 shows a portion of a matrix used to identify safety risks with explosive munitions. Customer safety needs include operator handling, survivability of environmental conditions, detonation failures, electromagnetic pulses (EMP), and other conditions. Product characteristics include thermal, chemical, and mechanical characteristics such as thermal stability, ignition temperature, and others[43].

Table 44 — Customer needs-product characteristics L-matrix for munitions safety

				Thermal & Chemical Characteristics							Physical & Mechanical Characteristics			
Customer Needs			Customer Importance	Thermal stability (DCS, STANAG-4515	Thermal stability @ 75 deg C (TB-700)	Ignition temp (e.g. Woods metal bath), (Mil Std-650)	Thermal conductivity	Coefficient of thermal expansion	Simultaneous planning and development	Melting point	Viscosity assessment	Density	Hydroscopic properties	Irreversible growth characteristics (Mil Std-1751)
Operational Performance (0,0675)	Effectiveness (0,300)	Penetrator performance	0,100									○		◔
		Blast/frag effects	0,200									◔		◔
	IM survivability (0,100)	Withstand being in a fire - fast cookoff	0,017	○		○	○	◔						
		Withstand being in a fire - slow cookoff	0,017											
		Withstand bullet and fragment impact	0,034											
		Withstand sympathetic detonation conditions	0,033											
	Safety (0,100)	Rough handling	0,025											
		Weapon firing/hot tube	0,050	●		●	◔	●						
		EMP/lightening	0,025											
	Reliability	Controlled storage	0,025	○				●						
		Uncontrolled storage	0,025	○				●						

● = extremely strong relationship
◔ = moderately strong relationship
○ = weak relationship

10.4.5.9.3 Security deployment

Security concerns can be deployed.

10.4.5.9.3.1 Organizational information

Security deployment of organizational information includes protection of intellectual property, trade secrets, classified information, communications, and other unauthorized uses.

10.4.5.9.3.2 Personal information

Security deployment of personal information includes protection of identity, financial information, health records, and related information, communications, and other unauthorized uses.

10.4.5.9.3.3 Systems

Security deployment of systems includes unauthorized use or access of a system, including, but not limited to computer operating systems, device operating systems such as industrial equipment, medical devices, automobiles, and others.

10.4.6 Lifestyle and emotional quality deployment

Lifestyle and emotional quality deployment focuses on non-functional requirements such as aesthetics, attraction, and the emotional value of feeling good about oneself and looking good in the eyes of others whose opinion are esteemed. While this can begin during the concept development level, it is applicable best at the component level after the functional design is optimized. This is discussed in ISO/TR 16355-8.

10.5 Transferring deployment sets by levels

QFD deployments can flow down to different levels of design.

10.5.1 General

In addition to the deployments of dimensions of design (displayed vertically in Figure 3), QFD can also be conducted at the levels of design (displayed horizontally). A matrix or table occurs where a design dimension and a design level intersect. Not every deployment is required for every project. The layout of the deployments, which charts to use, and in what sequence can be tailored to the organization's product development process.

10.5.2 Function deployment

Function deployment examines the relationships between function and quality, technology, cost, reliability, and other dimensions. Function deployment can also be used to examine modularization and interfaces Function deployment details are in 10.4.2.3, 10.4.2.4, 10.4.4.3, and 10.4.5.7.

10.5.3 New concept engineering and deployment

New concept deployment examines the relationships between functional requirements and new design concepts and their reliability. Based upon the priority and design target levels, both existing solutions and new technology concepts can be explored. Helpful activities include innovation, invention, product generation strategic portfolio analysis, concept hybridization, modularization, concept selection, feasibility studies, resource planning (project management), intellectual property (patent screen, and patent of inventions), technology risk, robust design, design optimization and parameter design. New concept deployment details are in 10.4.3.7.2.4 and 10.4.5.6.

10.5.4 Parts deployment

Parts deployment examines the relationships between component parts and quality, technology, cost, and reliability. Deployments for service and software can be different, and can also refer to components. This is discussed in ISO/TR 16355-8.

10.5.5 Manufacturing and process deployments

Manufacturing and process deployments examine the relationships between manufacturing, production, or other build and implementation methods and equipment and quality, technology, cost, and reliability. This can support agile, lean, and world class manufacturing activities. Deployments for service and software can be different. This is discussed in ISO/TR 16355-8.

10.5.6 Project work or task management

Project work or task management concerns related to managing resources, skills, tools and testing, cost, milestone and prototypes schedules, risks, changes to scope and schedule, and other areas of project management.[45][57] This is discussed in ISO/TR 16355-8.

11 Design optimization

Design optimization is discussed on ISO 16355-6 and ISO 16355-7.

Annex A
(informative)

Theory of Inventive Problem Solving (TRIZ)

A.1 Overview

This annex contains the definitions of classical TRIZ engineering parameters and inventive principles, along with the tables of contradictions. They are used as follows.

a) Define your engineering conflict using Altshuller's engineering parameters (A.2). Find both the parameter to be improved and the parameter at risk of degradation. If there are multiple parameters, they can be analyzed separately.

b) Look up the parameter number to be improved and degraded in the appropriate table of contradictions in A.3.

c) In the intersecting cells in the table of contradictions, are one or more numbers that refer to the inventive principles that are defined in A.4. These inventive principles can be explored for solutions to the subject problem.

A.2 Altshuller's 39 classical engineering parameters (TRIZ)

1) Weight of moving object
2) Weight of non-moving object
3) Length of moving object
4) Length of non-moving object
5) Area of moving object
6) Area of nonmoving object
7) Volume of moving object
8) Volume of non-moving object
9) Speed
10) Force
11) Tension and pressure
12) Shape
13) Stability of object
14) Strength
15) Durability of moving object
16) Durability of non-moving object
17) Temperature
18) Brightness
19) Energy spent by moving object
20) Energy spent by non-moving object
21) Power
22) Waste of energy
23) Waste of substance
24) Loss of information
25) Waste of time
26) Amount of substance
27) Reliability
28) Accuracy of measurement
29) Accuracy of manufacturing
30) Harmful factors acting on object
31) Harmful side effects
32) Manufacturability
33) Convenience of use
34) Repairability
35) Adaptability
36) Complexity of device
37) Complexity of control
38) Level of automation
39) Productivity

A.3 TRIZ classical tables of contradictions

A.3.1 Improve parameters 1-10 degrade parameters 1-10

	Parameter degraded / Parameter to improve	Weight of moving object	Weight of nonmoving object	Length of moving object	Length of nonmoving object	Area of moving object	Area of nonmoving object	Volume of moving object	Volume of nonmoving object	Speed	Force
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**Weight of moving object**		-	15, 8, 29,34	-	29, 17, 38, 34	-	29, 2, 40, 28	-	2, 8, 15, 38	8, 10, 18, 37
2	**Weight of nonmoving object**	-		-	10, 1, 29, 35	-	35, 30, 13, 2	-	5, 35, 14, 2	-	8, 10, 19, 35
3	**Length of moving object**	8, 15, 29, 34	-		-	15, 17, 4	-	7, 17, 4, 35	-	13, 4, 8	17, 10, 4
4	**Length of nonmoving object**		35, 28, 40, 29	-		-	17, 7, 10, 40	-	35, 8, 2,14	-	28, 10
5	**Area of moving object**	2, 17, 29, 4	-	14, 15, 18, 4	-		-	7, 14, 17, 4		29, 30, 4, 34	19, 30, 35, 2
6	**Area of nonmoving object**	-	30, 2, 14, 18	-	26, 7, 9, 39	-		-		-	1, 18, 35, 36
7	**Volume of moving object**	2, 26, 29, 40	-	1, 7, 4, 35	-	1, 7, 4, 17	-		-	29, 4, 38, 34	15, 35, 36, 37
8	**Volume of nonmoving object**	-	35, 10, 19, 14	19, 14	35, 8, 2, 14	-		-		-	2, 18, 37
9	**Speed**	2, 28, 13, 38	-	13, 14, 8	-	29, 30, 34	-	7, 29, 34	-		13, 28, 15, 19
10	**Force**	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12	

A.3.2 Improve parameters 11-20, degrade parameters 1-10

Parameter to improve \ Parameter degraded		Weight of moving object	Weight of nonmoving object	Length of moving object	Length of nonmoving object	Area of moving object	Area of nonmoving object	Volume of moving object	Volume of nonmoving object	Speed	Force
		1	2	3	4	5	6	7	8	9	10
11	Tension, pressure	10, 36, 37, 40	13, 29, 10, 18	35, 10, 36	35, 1, 14, 16	10, 15, 36, 28	10, 15, 36, 37	6, 35, 10	35, 24	6, 35, 36	36, 35, 21
12	Shape	8, 10, 29, 40	15, 10, 26, 3	29, 34, 5, 4	13, 14, 10, 7	5, 34, 4, 10		14, 4, 15, 22	7, 2, 35	35, 15, 34, 18	35, 10, 37, 40
13	Stability of object	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37	2, 11, 13	39	28, 10, 19, 39	34, 28, 35, 40	33, 15, 28, 18	10, 35, 21, 16
14	Strength	1, 8, 40, 15	40, 26, 27, 1	1, 15, 8, 35	15, 14, 28, 26	3, 34, 40, 29	9, 40, 28	10, 15, 14, 7	9, 14, 17, 15	8, 13, 26, 14	10, 18, 3, 14
15	Durability of moving object	19, 5, 34, 31	-	2, 19, 9	-	3, 17, 19	-	10, 2, 19, 30	-	3, 35, 5	19, 2, 16
16	Durability of nonmoving object	-	6, 27, 19, 16	-	1, 40, 35	-		-	35, 34, 38	-	
17	Temperature	36,22, 6, 38	22, 35, 32	15, 19, 9	15, 19, 9	3, 35, 39, 18	35, 38	34, 39, 40, 18	35, 6, 4	2, 28, 36, 30	35, 10, 3, 21
18	Brightness	19, 1, 32	2, 35, 32	19, 32, 16		19, 32, 26		2, 13, 10		10, 13, 19	26, 19, 6
19	Energy spent by moving object	12,18 28,31	-	12, 28	-	15, 19, 25	-	35, 13, 18	-	8, 35, 35	16, 26, 21, 2
20	Energy spent by nonmoving object	-	19, 9, 6, 27	-		-		-		-	36, 37

A.3.3 Improve parameters 21-30, degrade parameters 1-10

	Parameter degraded / Parameter to improve	Weight of moving object	Weight of nonmoving object	Length of moving object	Length of nonmoving object	Area of moving object	Area of nonmoving object	Volume of moving object	Volume of nonmoving object	Speed
		1	2	3	4	5	6	7	8	9
21	Power	12,18 28,31 38, 31	19, 26, 17, 27	1, 10, 35, 37		19, 38	17, 32, 13, 38	35, 6, 38	30, 6, 25	15, 35, 2
22	Waste of energy	15, 6, 19, 28	19, 6, 18, 9	7, 2, 6, 13	6, 38, 7	15, 26, 17, 30	17, 7, 30, 18	7, 18, 23	7	16, 35, 38
23	Waste of substance	35, 6, 23, 40	35, 6, 22, 32	14, 29, 10, 39	10, 28,24	35, 2, 10, 31	10, 18, 39, 31	1, 29, 30, 36	3, 39, 18, 31	10, 13, 28, 38
24	Loss of Information	10, 24, 35	10, 35, 5	1, 26	26	30, 26	30, 16		2, 22	26, 32
25	Waste of Time	10, 20, 37, 35	10, 20, 26, 5	15, 2, 29	30, 24, 14, 5	26, 4, 5, 16	10, 35, 17, 4	2, 5, 34, 10	35, 16, 32, 18	
26	Amount of substance	35, 6, 18, 31	27, 26, 18, 35	29, 14, 35, 18		15, 14, 29	2, 18, 40, 4	15, 20, 29		35, 29, 34, 28
27	Reliability	3, 8, 10, 40	3, 10, 8, 28	15, 9, 14, 4	15, 29, 28, 11	17, 10, 14, 16	32, 35, 40, 4	3, 10, 14, 24	2, 35, 24	21, 35, 11, 28
28	Accuracy of measurement	32, 35, 26, 28	28, 35, 25, 26	28, 26, 5, 16	32, 28, 3, 16	26, 28, 32, 3	26, 28, 32, 3	32, 13, 6		28, 13, 32, 24
29	Accuracy of manufacturing	28, 32, 13, 18	28, 35, 27, 9	10, 28, 29, 37	2, 32, 10	28, 33, 29, 32	2, 29, 18, 36	32, 23, 2	25, 10, 35	10, 28, 32
30	Harmful factors acting on object	22, 21, 27, 39	2, 22, 13, 24	17, 1, 39, 4	1, 18	22, 1, 33, 28	27, 2, 39, 35	22, 23, 37, 35	34, 39, 19, 27	21, 22, 35, 28

A.3.4 Improve parameters 31-39, degrade parameters 1-10

	Parameter degraded / Parameter to improve	Weight of moving object	Weight of nonmoving object	Length of moving object	Length of nonmoving object	Area of moving object	Area of nonmoving object	Volume of moving object	Volume of nonmoving object	Speed	Force
		1	2	3	4	5	6	7	8	9	10
31	Harmful side effects	12,18 28,31 15, 39	35, 22, 1, 39	17, 15, 16, 22		17, 2, 18, 39	22, 1, 40	17, 2, 40	30, 18, 35, 4	35, 28, 3, 23	35, 28, 1, 40
32	Manufacturability	28, 29, 15, 16	1, 27, 36, 13	1, 29, 13, 17	15, 17, 27	13, 1, 26, 12	16, 40	13, 29, 1, 40	35	35, 13, 8, 1	35, 12
33	Convenience of use	25, 2, 13, 15	6, 13, 1, 25	1, 17, 13, 12		1, 17, 13, 16	18, 16, 15, 39	1, 16, 35, 15	4, 18, 39, 31	18, 13, 34	28, 13 35
34	Repairability	2, 27 35, 11	2, 27, 35, 11	1, 28, 10, 25	3, 18, 31	15, 13, 32	16, 25	25, 2, 35, 11	1	34, 9	1, 11, 10
35	Adaptability	1, 6, 15, 8	19, 15, 29, 16	35, 1, 29, 2	1, 35, 16	35, 30, 29, 7	15, 16	15, 35, 29		35, 10, 14	15, 17, 20
36	Complexity of device	26, 30, 34, 36	2, 26, 35, 39	1, 19, 26, 24	26	14, 1, 13, 16	6, 36	34, 26, 6	1, 16	34, 10, 28	26, 16
37	Complexity of control	27, 26, 28, 13	6, 13, 28, 1	16, 17, 26, 24	26	2, 13, 18, 17	2, 39, 30, 16	29, 1, 4, 16	2, 18, 26, 31	3, 4, 16, 35	30, 28, 40, 19
38	Level of automation	28, 26, 18, 35	28, 26, 35, 10	14, 13, 17, 28	23	17, 14, 13		35, 13, 16		28, 10	2, 35
39	Productivity	35, 26, 24, 37	28, 27, 15, 3	18, 4, 28, 38	30, 7, 14, 26	10, 26, 34, 31	10, 35, 17, 7	2, 6, 34, 10	35, 37, 10, 2		28, 15, 10, 36

A.3.5 Improve parameters 1-10, degrade parameters 11-20

Parameter to improve / Parameter degraded		Tension, pressure	Shape	Stability of object	Strength	Durability of moving object	Durability of nonmoving object	Temperature	Brightness	Energy spent by moving object	Energy spent by nonmoving object
		11	12	13	14	15	16	17	18	19	20
1	Weight of moving object	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39	28, 27, 18, 40	5, 34, 31, 35	-	6, 29, 4, 38	19, 1, 32	35, 12, 34, 31	-
2	Weight of nonmoving object	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40	28, 2, 10, 27	-	2, 27, 19, 6	28, 19, 32, 22	19, 32, 35	-	18, 19, 28, 1
3	Length of moving object	1, 8, 35	1, 8, 10, 29	1, 8, 15, 34	8, 35, 29, 34	19	-	10, 15, 19	32	8, 35, 24	-
4	Length of nonmoving object	1, 14, 35	13, 14, 15, 7	39, 37, 35	15, 14, 28, 26	-	1, 10, 35	3, 35, 38, 18	3, 25	-	
5	Area of moving object	10, 15, 36, 28	5, 34, 29, 4	11, 2, 13, 39	3, 15, 40, 14	6, 3	-	2, 15, 16	15, 32, 19, 13	19, 32	-
6	Area of nonmoving object	10, 15, 36, 37		2, 38	40	-	2, 10, 19, 30	35, 39, 38		-	
7	Volume of moving object	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39	9, 14, 15, 7	6, 35, 4	-	34, 39, 10, 18	2, 13, 10	35	-
8	Volume of nonmoving object	24, 35	7, 2, 35	34, 28, 35, 40	9, 14, 17, 15	-	35, 34, 38	35, 6, 4		-	
9	Speed	6, 18, 38, 40	35, 15, 18, 34	28, 33, 1, 18	8, 3, 26, 14	3, 19, 35, 5	-	28, 30, 36, 2	10, 13, 19	8, 15, 35, 38	-
10	Force	18, 21, 11	10, 35, 40, 34	35, 10, 21	35, 10, 14, 27	19, 2		35, 10, 21	-	19, 17, 10	1, 16, 36, 37

A.3.6 Improve parameters 11-20, degrade parameters 11-20

Parameter to improve \ Parameter degraded		Tension, pressure	Shape	Stability of object	Strength	Durability of moving object	Durability of nonmoving object	Temperature	Brightness	Energy spent by moving object	Energy spent by nonmoving object
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
11	**Tension, pressure**		35, 4, 15, 10	35, 33, 2, 40	9, 18, 3, 40	19, 3, 27		35, 39, 19, 2	-	14, 24, 10, 37	
12	**Shape**	34, 15, 10, 14		33, 1, 18, 4	30, 14, 10, 40	14, 26, 9, 25		22, 14, 19, 32	13, 15, 32	2, 6, 34, 14	
13	**Stability of object**	2, 35, 40	22, 1, 18, 4		17, 9, 15	13, 27, 10, 35	39, 3, 35, 23	35, 1, 32	32, 3, 27, 16	13, 19	27, 4, 29, 18
14	**Strength**	10, 3, 18, 40	10, 30, 35, 40	13, 17, 35		27, 3, 26		30, 10, 40	35, 19	19, 35, 10	35
15	**Durability of moving object**	19, 3, 27	14, 26, 28, 25	13, 3, 35	27, 3, 10		-	19, 35, 39	2, 19, 4, 35	28, 6, 35, 18	
16	**Durability of nonmoving object**			39, 3, 35, 23		-		19, 18, 36, 40		-	
17	**Temperature**	35, 39, 19, 2	14, 22, 19, 32	1, 35, 32	10, 30, 22, 40	19, 13, 39	19, 18, 36, 40		32, 30, 21, 16	19, 15, 3, 17	
18	**Brightness**		32, 30	32, 3, 27	35, 19	2, 19, 6		32, 35, 19		32, 1, 19	32, 35, 1, 15
19	**Energy spent by moving object**	12,18 28,31 25	12, 2, 29	19, 13, 17, 24	5, 19, 9, 35	28, 35, 6, 18	-	19, 24, 3, 14	2, 15, 19		-
20	**Energy spent by nonmoving object**			27, 4, 29, 18	35				19, 2, 35, 32	-	

A.3.7 Improve parameters 21-30, degrade parameters 11-20

Parameter to improve \ Parameter degraded		Tension, pressure	Shape	Stability of object	Strength	Durability of moving object	Durability of nonmoving object	Temperature	Brightness	Energy spent by moving object	Energy spent by nonmoving object
		11	12	13	14	15	16	17	18	19	20
21	Power	12,18 28,31 35	29, 14, 2, 40	35, 32, 15, 31	26, 10, 28	19, 35, 10, 38	16	2, 14, 17, 25	16, 6, 19	16, 6, 19, 37	
22	Waste of energy			14, 2, 39, 6	26			19, 38, 7	1, 13, 32, 15		
23	Waste of substance	3, 36, 37, 10	29, 35, 3, 5	2, 14, 30, 40	35, 28, 31, 40	28, 27, 3, 18	27, 16, 18, 38	21, 36, 39, 31	1, 6, 13	35, 18, 24, 5	28, 27, 12, 31
24	Loss of Information					10	10		19		
25	Waste of Time	37, 36,4	4, 10, 34, 17	35, 3, 22, 5	29, 3, 28, 18	20, 10, 28, 18	28, 20, 10, 16	35, 29, 21, 18	1, 19, 26, 17	35, 38, 19, 18	1
26	Amount of substance	10, 36, 14, 3	35, 14	15, 2, 17, 40	14, 35, 34, 10	3, 35, 10, 40	3, 35, 31	3, 17, 39		34, 29, 16, 18	3, 35, 31
27	Reliability	10, 24, 35, 19	35, 1, 16, 11		11, 28	2, 35, 3, 25	34, 27, 6, 40	3, 35, 10	11, 32, 13	21, 11, 27, 19	36, 23
28	Accuracy of measurement	6, 28, 32	6, 28, 32	32, 35, 13	28, 6, 32	28, 6, 32	10, 26, 24	6, 19, 28, 24	6, 1, 32	3, 6, 32	
29	Accuracy of manufacturing	3, 35	32, 30, 40	30, 18	3, 27	3, 27, 40		19, 26	3, 32	32, 2	
30	Harmful factors acting on object	22, 2, 37	22, 1, 3, 35	35, 24, 30, 18	18, 35, 37, 1	22, 15, 33, 28	17, 1, 40, 33	22, 33, 35, 2	1, 19, 32, 13	1, 24, 6, 27	10, 2, 22, 37

A.3.8 Improve parameters 31-39, degrade parameters 11-20

Parameter to improve \ Parameter degraded		Tension, pressure	Shape	Stability of object	Strength	Durability of moving object	Durability of nonmoving object	Temperature	Brightness	Energy spent by moving object	Energy spent by nonmoving object
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
31	**Harmful side effects**	12,18 28,31 27, 18	35, 1	35, 40, 27, 39	15, 35, 22, 2	15, 22, 33, 31	21, 39, 16, 22	22, 35, 2, 24	19, 24, 39, 32	2, 35, 6	19, 22, 18
32	**Manufacturability**	35, 19, 1, 37	1, 28, 13, 27	11, 13, 1	1, 3, 10, 32	27, 1, 4	35, 16	27, 26, 18	28, 24, 27, 1	28, 26, 27, 1	1, 4
33	**Convenience of use**	2, 32, 12	15, 34, 29, 28	32, 35, 30	32, 40, 3, 28	29, 3, 8, 25	1, 16, 25	26, 27, 13	13, 17, 1, 24	1, 13, 24	
34	**Repairability**	13	1, 13, 2, 4	2, 35	11, 1, 2, 9	11, 29, 28, 27	1	4, 10	15, 1, 13	15, 1, 28, 16	
35	**Adaptability**	35, 16	15, 37, 1, 8	35, 30, 14	35, 3, 32, 6	13, 1, 35	2, 16	27, 2, 3, 35	6, 22, 26, 1	19, 35, 29, 13	
36	**Complexity of device**	19, 1, 35	29, 13, 28, 15	2, 22, 17, 19	2, 13, 28	10, 4, 28, 15		2, 17, 13	24, 17, 13	27, 2, 29, 28	
37	**Complexity of control**	35, 36, 37, 32	27, 13, 1, 39	11, 22, 39, 30	27, 3, 15, 28	19, 29, 39, 25	25, 34, 6, 35	3, 27, 35, 16	2, 24, 26	35, 38	19, 35, 16
38	**Level of automation**	13, 35	15, 32, 1, 13	18, 1	25, 13	6, 9		26, 2, 19	8, 32, 19	2, 32, 13	
39	**Productivity**	10, 37, 14	14, 10, 34, 40	35, 3, 22, 39	29, 28, 10, 18	35, 10, 2, 18	20, 10, 16, 38	35, 21, 28, 10	26, 17, 19, 1	35, 10, 38, 19	1

A.3.9 Improve parameters 1-10, degrade parameters 21-30

Parameter to improve \ Parameter degraded		Power	Waste of energy	Waste of substance	Loss of Information	Waste of Time	Amount of substance	Reliability	Accuracy of measurement	Accuracy of manufacturing	Harmful factors acting on object
		21	22	23	24	25	26	27	28	29	30
1	Weight of moving object	12, 36, 18, 31	6, 2, 34, 19	5, 35, 3, 31	10, 24, 35	10, 35, 20, 28	3, 26, 18, 31	1, 3, 11, 27	28, 27, 35, 26	28, 35, 26, 18	22, 21, 18, 27
2	Weight of nonmoving object	15, 19, 18, 15	18, 19, 28, 15	5, 8, 13, 30	10, 15, 35	10, 20, 35, 26	19, 6, 18, 26	10, 28, 8, 3	18, 26, 28	10, 1, 35, 17	2, 19, 22, 37
3	Length of moving object	1, 35	7, 2, 35, 39	4, 29, 23, 10	1, 24	15, 2, 29	29, 35	10, 14, 29, 40	28, 32, 4	10, 28, 29, 37	1, 15, 17, 24
4	Length of nonmoving object	12, 8	6, 28	10, 28, 24, 35	24, 26,	30, 29, 14		15, 29, 28	32, 28, 3	2, 32, 10	1, 18
5	Area of moving object	19, 10, 32, 18	15, 17, 30, 26	10, 35, 2, 39	30, 26	26, 4	29, 30, 6, 13	29, 9	26, 28, 32, 3	2, 32	22, 33, 28, 1
6	Area of nonmoving object	17, 32	17, 7, 30	10, 14, 18, 39	30, 16	10, 35, 4, 18	2, 18, 40, 4	32, 35, 40, 4	26, 28, 32, 3	2, 29, 18, 36	27, 2, 39, 35
7	Volume of moving object	35, 6, 13, 18	7, 15, 13, 16	36, 39, 34, 10	2, 22	2, 6, 34, 10	29, 30, 7	14, 1, 40, 11	26, 26, 28	25, 28, 2, 16	22, 21, 27, 35
8	Volume of nonmoving object	30, 6		10, 39, 35, 34		35, 16, 32 18	35, 3	2, 35, 16		35, 10, 25	34, 39, 19, 27
9	Speed	19, 35, 38, 2	14, 20, 19, 35	10, 13, 28, 38	13, 26		10, 19, 29, 38	11, 35, 27, 28	28, 32, 1, 24	10, 28, 32, 25	1, 28, 35, 23
10	Force	19, 35, 18, 37	14, 15	8, 35, 40, 5		10, 37, 36	14, 29, 18, 36	3, 35, 13, 21	35, 10, 23, 24	28, 29, 37, 36	1, 35, 40, 18

A.3.10 Improve parameters 11-20, degrade parameters 21-30

Parameter to improve \ Parameter degraded		Power	Waste of energy	Waste of substance	Loss of Information	Waste of Time	Amount of substance	Reliability	Accuracy of measurement	Accuracy of manufacturing	Harmful factors acting on object
		21	22	23	24	25	26	27	28	29	30
11	Tension, pressure	10, 35, 14	2, 36, 25	10, 36, 3, 37		37, 36, 4	10, 14, 36	10, 13, 19, 35	6, 28, 25	3, 35	22, 2, 37
12	Shape	4, 6, 2	14	35, 29, 3, 5		14, 10, 34, 17	36, 22	10, 40, 16	28, 32, 1	32, 30, 40	22, 1, 2, 35
13	Stability of object	32, 35, 27, 31	14, 2, 39, 6	2, 14, 30, 40		35, 27	15, 32, 35		13	18	35, 24, 30, 18
14	Strength	10, 26, 35, 28	35	35, 28, 31, 40		29, 3, 28, 10	29, 10, 27	11, 3	3, 27, 16	3, 27	18, 35, 37, 1
15	Durability of moving object	19, 10, 35, 38		28, 27, 3, 18	10	20, 10, 28, 18	3, 35, 10, 40	11, 2, 13	3	3, 27, 16, 40	22, 15, 33, 28
16	Durability of nonmoving object	16		27, 16, 18, 38	10	28, 20, 10, 16	3, 35, 31	34, 27, 6, 40	10, 26, 24		17, 1, 40, 33
17	Temperature	2, 14, 17, 25	21, 17, 35, 38	21, 36, 29, 31		35, 28, 21, 18	3, 17, 30, 39	19, 35, 3, 10	32, 19, 24	24	22, 33, 35, 2
18	Brightness	32	13, 16, 1, 6	13, 1	1, 6	19, 1, 26, 17	1, 19		11, 15, 32	3, 32	15, 19
19	Energy spent by moving object	12,18 28,31 37, 18	12, 22, 15, 24	35, 24, 18, 5		35, 38, 19, 18	34, 23, 16, 18	19, 21, 11, 27	3, 1, 32		1, 35, 6, 27
20	Energy spent by nonmoving object			28, 27, 18, 31			3, 35, 31	10, 36, 23			10, 2, 22, 37

A.3.11 Improve parameters 21-30, degrade parameters 21-30

Parameter to improve \ Parameter degraded		Power 21	Waste of energy 22	Waste of substance 23	Loss of Information 24	Waste of Time 25	Amount of substance 26	Reliability 27	Accuracy of measurement 28	Accuracy of manufacturing 29	Harmful factors acting on object 30
21	Power	12,18 28,31	10, 35, 38	28, 27, 18, 38	10, 19	35, 20, 10, 6	4, 34, 19	19, 24, 26, 31	32, 15, 2	32, 2	19, 22, 31, 2
22	Waste of energy	3, 38		35, 27, 2, 37	19, 10	10, 18, 32, 7	7, 18, 25	11, 10, 35	32		21, 22, 35, 2
23	Waste of substance	28, 27, 18, 38	35, 27, 2, 31			15, 18, 35, 10	6, 3, 10, 24	10, 29, 39, 35	16, 34, 31, 28	35, 10, 24, 31	33, 22, 30, 40
24	Loss of Information	10, 19	19, 10			24, 26, 28, 32	24, 28, 35	10, 28, 23			22, 10, 1
25	Waste of Time	35, 20, 10, 6	10, 5, 18, 32	35, 18, 10, 39	24, 26, 28, 32		35, 38, 18, 16	10, 30, 4	24, 34, 28, 32	24, 26, 28, 18	35, 18, 34
26	Amount of substance	35	7, 18, 25	6, 3, 10, 24	24, 28, 35	35, 38, 18, 16		18, 3, 28, 40	13, 2, 28	33, 30	35, 33, 29, 31
27	Reliability	21, 11, 26, 31	10, 11, 35	10, 35, 29, 39	10, 28	10, 30, 4	21, 28, 40, 3		32, 3, 11, 23	11, 32, 1	27, 35, 2, 40
28	Accuracy of measurement	3, 6, 32	26, 32, 27	10, 16, 31, 28		24, 34, 28, 32	2, 6, 32	5, 11, 1, 23			28, 24, 22, 26
29	Accuracy of manufacturing	32, 2	13, 32, 2	35, 31, 10, 24		32, 26, 28, 18	32, 30	11, 32, 1			26, 28, 10, 36
30	Harmful factors acting on object	19, 22, 31, 2	21, 22, 35, 2	33, 22, 19, 40	22, 10, 2	35, 18, 34	35, 33, 29, 31	27, 24, 2, 40	28, 33, 23, 26	26, 28, 10, 18	

A.3.12 Improve parameters 31-39, degrade parameters 21-30

Parameter to improve \ Parameter degraded		Power	Waste of energy	Waste of substance	Loss of Information	Waste of Time	Amount of substance	Reliability	Accuracy of measurement	Accuracy of manufacturing	Harmful factors acting on object
		21	22	23	24	25	26	27	28	29	30
31	Harmful side effects	12,18 28,31 18	21, 35, 2, 22	10, 1, 34	10, 21, 29	1, 22	3, 24, 39, 1	24, 2, 40, 39	3, 33, 26	4, 17, 34, 26	
32	Manufacturability	27, 1, 12, 24	19, 35	15, 34, 33	32, 24, 18, 16	35, 28, 34, 4	35, 23, 1, 24		1, 35, 12, 18		24, 2
33	Convenience of use	35, 34, 2, 10	2, 19, 13	28, 32, 2, 24	4, 10, 27, 22	4, 28, 10, 34	12, 35	17, 27, 8, 40	25, 13, 2, 34	1, 32, 35, 23	2, 25, 28, 39
34	Repairability	15, 10, 32, 2	15, 1, 32, 19	2, 35, 34, 27		32, 1, 10, 25	2, 28, 10, 25	11, 10, 1, 16	10, 2, 13	25, 10	35, 10, 2, 16
35	Adaptability	19, 1, 29	18, 15, 1	15, 10, 2, 13		35, 28	3, 35, 15	35, 13, 8, 24	35, 5, 1, 10		35, 11, 32, 31
36	Complexity of device	20, 19, 30, 34	10, 35, 13, 2	35, 10, 28, 29		6, 29	13, 3, 27, 10	13, 35, 1	2, 26, 10, 34	26, 24, 32	22, 19, 29, 40
37	Complexity of control	18, 1, 16, 10	35, 3, 15, 19	1, 18, 10, 24	35, 33, 27, 22	18, 28, 32, 9	3, 27, 29, 18	27, 40, 28, 8	26, 24, 32, 28		22, 19, 29, 28
38	Level of automation	28, 2, 27	23, 28	35, 10, 18, 5	35, 33	24, 28, 35, 30	35, 13	11, 27, 32	28, 26, 10, 34	28, 26, 18, 23	2, 33
39	Productivity	35, 20, 10	28, 10, 29, 35	28, 10, 35, 23	13, 15, 23		35, 38	1, 35, 10, 38	1, 10, 34, 28	18, 10, 32, 1	22, 35, 13, 24

A.3.13 Improve parameters 1-10, degrade parameters 31-39

Parameter to improve \ Parameter degraded		Harmful side effects	Manufacturability	Convenience of use	Repairability	Adaptability	Complexity of device	Complexity of control	Level of automation	Productivity
		31	32	33	34	35	36	37	38	39
1	Weight of moving object	22, 35, 31, 39	27, 28, 1, 36	35, 3, 2, 24	2, 27, 28, 11	29, 5, 15, 8	26, 30, 36, 34	28, 29, 26, 32	26, 35 18, 19	35, 3, 24, 37
2	Weight of nonmoving object	35, 22, 1, 39	28, 1, 9	6, 13, 1, 32	2, 27, 28, 11	19, 15, 29	1, 10, 26, 39	25, 28, 17, 15	2, 26, 35	1, 28, 15, 35
3	Length of moving object	17, 15	1, 29, 17	15, 29, 35, 4	1, 28, 10	14, 15, 1, 16	1, 19, 26, 24	35, 1, 26, 24	17, 24, 26, 16	14, 4, 28, 29
4	Length of nonmoving object		15, 17, 27	2, 25	3	1, 35	1, 26	26		30, 14, 7, 26
5	Area of moving object	17, 2, 18, 39	13, 1, 26, 24	15, 17, 13, 16	15, 13, 10, 1	15, 30	14, 1, 13	2, 36, 26, 18	14, 30, 28, 23	10, 26, 34, 2
6	Area of nonmoving object	22, 1, 40	40, 16	16, 4	16	15, 16	1, 18, 36	2, 35, 30, 18	23	10, 15, 17, 7
7	Volume of moving object	17, 2, 40, 1	29, 1, 40	15, 13, 30, 12	10	15, 29	26, 1	29, 26, 4	35, 34, 16, 24	10, 6, 2, 34
8	Volume of nonmoving object	30, 18, 35, 4	35		1		1, 31	2, 17, 26		35, 37, 10, 2
9	Speed	2, 24, 35, 21	35, 13, 8, 1	32, 28, 13, 12	34, 2, 28, 27	15, 10, 26	10, 28, 4, 34	3, 34, 27, 16	10, 18	
10	Force	13, 3, 36, 24	15, 37, 18, 1	1, 28, 3, 25	15, 1, 11	15, 17, 18, 20	26, 35, 10, 18	36, 37, 10, 19	2, 35	3, 28, 35, 37

A.3.14 Improve parameters 11-20, degrade parameters 31-39

Parameter to improve \ Parameter degraded		Harmful side effects	Manufacturability	Convenience of use	Repairability	Adaptability	Complexity of device	Complexity of control	Level of automation	Productivity
		31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**
11	**Tension, pressure**	2, 33, 27, 18	1, 35, 16	11	2	35	19, 1, 35	2, 36, 37	35, 24	10, 14, 35, 37
12	**Shape**	35, 1	1, 32, 17, 28	32, 15, 26	2, 13, 1	1, 15, 29	16, 29, 1, 28	15, 13, 39	15, 1, 32	17, 26, 34, 10
13	**Stability of object**	35, 40, 27, 39	35, 19	32, 35, 30	2, 35, 10, 16	35, 30, 34, 2	2, 35, 22, 26	35, 22, 39, 23	1, 8, 35	23, 35, 40, 3
14	**Strength**	15, 35, 22, 2	11, 3, 10, 32	32, 40, 25, 2	27, 11, 3	15, 3, 32	2, 13, 25, 28	27, 3, 15, 40	15	29, 35, 10, 14
15	Durability of moving **object**	21, 39, 16, 22	27, 1, 4	12, 27	29, 10, 27	1, 35, 13	10, 4, 29, 15	19, 29, 39, 35	6, 10	35, 17, 14, 19
16	**Durability of nonmoving object**	22	35, 10	1	1	2		25, 34, 6, 35	1	20, 10, 16, 38
17	Temperature	22, 35, 2, 24	26, 27	26, 27	4, 10, 16	2, 18, 27	2, 17, 16	3, 27, 35, 31	26, 2, 19, 16	15, 28, 35
18	**Brightness**	35, 19, 32, 39	19, 35, 28, 26	28, 26, 19	15, 17, 13, 16	15, 1, 1, 19	6, 32, 13	32, 15	2, 26, 10	2, 25, 16
19	**Energy spent by moving object**	12,18 28,31 2, 35, 6	28, 26, 30	19, 35	1, 15, 17, 28	15, 17, 13, 16	2, 29, 27, 28	35, 38	32, 2	12, 28, 35
20	**Energy spent by nonmoving object**	19, 22, 18	1, 4					19, 35, 16, 25		1, 6

A.3.15 Improve parameters 21-30, degrade parameters 31-39

Parameter to improve \ Parameter degraded		Harmful side effects	Manufacturability	Convenience of use	Repairability	Adaptability	Complexity of device	Complexity of control	Level of automation	Productivity
		31	32	33	34	35	36	37	38	39
21	Power	12,18 28,31 18	26, 10, 34	26, 35, 10	35, 2, 10, 34	19, 17, 34	20, 19, 30, 34	19, 35, 16	28, 2, 17	28, 35, 34
22	Waste of energy	21, 35, 2, 22		35, 32, 1	2, 19		7, 23	35, 3, 15, 23	2	28, 10, 29, 35
23	Waste of substance	10, 1, 34, 29	15, 34, 33	32, 28, 2, 24	2, 35, 34, 27	15, 10, 2	35, 10, 28, 24	35, 18, 10, 13	35, 10, 18	28, 35, 10, 23
24	Loss of Information	10, 21, 22	32	27, 22				35, 33	35	13, 23, 15
25	Waste of Time	35, 22, 18, 39	35, 28, 34, 4	4, 28, 10, 34	32, 1, 10	35, 28	6, 29	18, 28, 32, 10	24, 28, 35, 30	
26	Amount of substance	3, 35, 40, 39	29, 1, 35, 27	35, 29, 25, 10	2, 32, 10, 25	15, 3, 29	3, 13, 27, 10	3, 27, 29, 18	8, 35	13, 29, 3, 27
27	Reliability	35, 2, 40, 26		27, 17, 40	1, 11	13, 35, 8, 24	13, 35, 1	27, 40, 28	11, 13, 27	1, 35, 29, 38
28	Accuracy of measurement	3, 33, 39, 10	6, 35, 25, 18	1, 13, 17, 34	1, 32, 13, 11	13, 35, 2	27, 35, 10, 34	26, 24, 32, 28	28, 2, 10, 34	10, 34, 28, 32
29	Accuracy of manufacturing	4, 17, 34, 26		1, 32, 35, 23	25, 10		26, 2, 18		26, 28, 18, 23	10, 18, 32, 39
30	Harmful factors acting on object		24, 35, 2	2, 25, 28, 39	35, 10, 2	35, 11, 22, 31	22, 19, 29, 40	22, 19, 29, 40	33, 3, 34	22, 35, 13, 24

A.3.16 Improve parameters 31-39, degrade parameters 31-39

Parameter to improve \ Parameter degraded		Harmful side effects	Manufacturability	Convenience of use	Repairability	Adaptability	Complexity of device	Complexity of control	Level of automation	Productivity
		31	32	33	34	35	36	37	38	39
31	Harmful side effects	12,18 28,31					19, 1, 31	2, 21, 27, 1	2	22, 35, 18, 39
32	Manufacturability			2, 5, 13, 16	35, 1, 11, 9	2, 13, 15	27, 26, 1	6, 28, 11, 1	8, 28, 1	35, 1, 10, 28
33	Convenience of use		2, 5, 12		12, 26, 1, 32	15, 34, 1, 16	32, 26, 12, 17		1, 34, 12, 3	15, 1, 28
34	Repairability		1, 35, 11, 10	1, 12, 26, 15		7, 1, 4, 16	35, 1, 13, 11		34, 35, 7, 13	1, 32, 10
35	Adaptability		1, 13, 31	15, 34, 1, 16	1, 16, 7, 4		15, 29, 37, 28	1	27, 34, 35	35, 28, 6, 37
36	Complexity of device	19, 1	27, 26, 1, 13	27, 9, 26, 24	1, 13	29, 15, 28, 37		15, 10, 37, 28	15, 1, 24	12, 17, 28
37	Complexity of control	2, 21	5, 28, 11, 29	2, 5	12, 26	1, 15	15, 10, 37, 28		34, 21	35, 18
38	Level of automation	2	1, 26, 13	1, 12, 34, 3	1, 35, 13	27, 4, 1, 35	15, 24, 10	34, 27, 25		5, 12, 35, 26
39	Productivity	35, 22, 18, 39	35, 28, 2, 24	1, 28, 7, 10	1, 32, 10, 25	1, 35, 28, 37	12, 17, 28, 24	35, 18, 27, 2	5, 12, 35, 26	

A.4 TRIZ 40 classical inventive principles

1) Segmentation
2) Extraction
3) Local quality
4) Asymmetry
5) Combining
6) Universality
7) Nesting
8) Counterweight
9) Prior counter-action
10) Prior action
11) Cushion in advance
12) Equipotentiality
13) Inversion
14) Spheroidality
15) Dynamicity
16) Partial or overdone action
17) Moving to a new dimension
18) Mechanical vibration
19) Periodic action
20) Continuity of a useful action
21) Rushing through
22) Convert harm into benefit
23) Feedback
24) Mediator
25) Self-service
26) Copying
27) Inexpensive, short-lived object
28) Replacement of a mechanical system
29) Pneumatic or hydraulic construction,
30) Flexible membranes or thin film
31) Use of porous material
32) Changing the colour
33) Homogeneity
34) Rejecting and regenerating parts
35) Transformation of the physical and chemical states of an object
36) Phase transformation
37) Thermal expansion
38) Use strong oxidizers
39) Inert environment
40) Composite materials

Annex B
(informative)

Cross-reference between ISO 16355 and JIS Q 9025:2003(e)

B.1 Overview

The purpose of this annex is to supplement ISO 16355-5 by referencing the Japanese standard JIS Q 9025:2003, the first standard on QFD. JIS Q 9025:2003 is helpful for understanding the QFD concept.

NOTE 1 The Japanese Standards Association (JSA) published and translated into English the first standard on QFD titled JIS Q 9025:2003 "Performance improvement of management systems — Guidelines for quality function deployment."

NOTE 2 This cross-reference includes both directions of ISO-JIS and JIS-ISO. Also, relevant tables and flowcharts are referenced.

B.2 ISO 16355 (all parts) to JIS Q 9025:2003(e) cross reference

ISO 16355-1:2015		JIS Q 9025:2003	
0	Introduction	0	Introduction
0	Introduction	0.1	General
1	Scope	1	Scope
2	Normative references	2	Normative reference
3	Terms and definitions	3	Terms and definitions
3	Terms and definitions	3.1	Terms related to quality function deployment
3	Terms and definitions	3.2	Terms related to quality
3.1	Quality function deployment (QFD)	3.1.6	Quality function deployment (QFD)
3.2	Voice of the customer	3.1.12	Voice of the customer
3.3	Customer need	3.1.13	Required quality
4	Basic concepts of QFD	4	Basic concepts
4.1	Theory and principles of QFD	4.1	General
4.1	Theory and principles of QFD	4.3	Principles of quality function deployment
4.1	Theory and principles of QFD	7.1	Application guide, Objective
4.1 c)	Listen to the voice of the customer	4.2 a)	Customer focus
4.1 f)	Improve internal communications through transformation	3.1.1	Transformation
4.2	QFD use of the word function	3.1.11	Job function deployment
5	Integration of QFD and product development methods	0.4	Compatibility with other management systems
5	Integration of QFD and product development methods	9	Related methods

5.1	QFD support for product development methods	4.2	Quality function deployment in quality management
5.1	QFD support for product development methods	9.1	Related methods, General
5.2	Organization of the QFD flow	4.2 e)	Secure quality assurance
6	Types of QFD projects	4.2 d)	Development management
6.1	Types of QFD projects, General	7	Application guide
6.1	Types of QFD projects, General	7.2	Frame corresponding to objective
6.1 f)	Document and preserve market and technical knowledge	8.3	Quality function deployment using information technology
7	QFD team membership	4.2 b)	Participation of people
7	QFD team membership	8.2	Formation of the team
8	QFD voices	8	Introduction and application to organizations
8.1	Voice of business	8.1	Introduction of quality function deployment
8.2.9	Sources of VOC and VOS	9.2 a)	Questionnaire survey
9	Structuring information sets	3.1.3	Deployment table
9	Structuring information sets	4.3 d)	Principle of consolidation and breakdown
12	Translation of one information set into another	4.3 e)	Principle of transformation
12.1	Translation of one information set into another, General	3.1.2	Deployment
12	Translation of one information set into another	4.3 c)	Principle of multi-dimensional development and visualization
13.1	Transfer of prioritization	3.1.4	Matrix
13.1	Transfer of prioritization	3.1.5	Correlation strength
13.5	Transferring deployment sets by dimensions	4.2 f)	Multilateral evaluation
13.5.2	Quality deployment	3.1.7	Quality deployment
13.5.3	Quality deployment, Applicable tools and methods	9.2	Relevant methods in quality deployment
13.5.4	Technology deployment	3.1.8	Engineering deployment
13.5.5	Technology deployment, Applicable tools and methods	9.3	Relevant methods in engineering deployment
13.5.6	Cost deployment	3.1.9	Cost deployment
13.5.7	Technology deployment, Applicable tools and methods	9.4	Relevant methods in cost deployment
13.5.8	Reliability deployment	3.1.10	Reliability deployment
13.5.9 a)	Fault tree analysis	9.5 a)	FTA
13.5.9 b)	Failure mode and effects analysis	9.5 b)	FMEA
13.5.9	Reliability deployment, Applicable tools and methods	9.5	Relevant methods in reliability deployment
13.5.5 e)	Reviewed dendrogram	9.3 b)	Reviewed dendrogram
13.5.5 f)	Super Pugh concept selection with AHP	9.3 a)	Comparison or proposals

13.6	Transferring deployment sets by levels	4.3 a)	Principle of deployment
15	Design optimization	9.2 c)	Quality engineering
16	Prototyping, testing, and validation	9.2 b)	Test planning method
16.2 g)	Prototyping, testing, and validation, Applicable tools and methods	9.5 c)	Design review
Bibliography	Reference [127] to [131]	0.2	Consistency with other standards
Reference [35]	7 Product planning tools	9.2 d)	Product planning method
ISO 16355-2:2017			
9.1.2.7.2	Balanced scorecard	9.4 b)	Balanced scorecard
ISO 16355-4:2017			
9.1.3	Information contained in VOC and VOS	8.4	Information configuration
9.1.3.2	Cost	8.4 j)	Cost
9.1.3.3	Customer needs	3.1.13	required quality
9.1.3.3	Customer needs	8.4 a)	Voice of the consumer
9.1.3.4	Functional requirements	8.4 b)	Engineering characteristics
9.1.3.5	Function	8.4 c)	Product function
9.1.3.6	Technology	8.4 h)	Technology
9.1.3.7	Reliability or failure mode	8.4k)	Failure mode
9.1.3.8	Subsystem or component	8.4 e)	Parts and components
9.1.3.8	Subsystem or component	8.4 f)	Mechanisms
9.1.3.9	Material	8.4 d)	Materials used
9.1.3.11	Process	8.4 n)	Job functions
9.1.3.13	Manufacturing or build methods	8.4 l)	Manufacturing methods
9.1.3.14	Measurement methods	8.4 m)	Measurement method
9.1.3.15	Quality	8.4 o)	Assurance items
9.2	Translating VOC and VOS into customer needs	5.4.1 b)	Transformation into required quality
9.2.3	Cause-to-effect diagram	4.3 b)	Principle of segmentation and integration
9.2.5	Sources of VOC or VOS	5.4.1 a)	Gathering “voice of the customer”
10	Structuring information sets	5.4.1 c)	Creation of required quality deployment table
10.3	Hierarchy diagram	5.2.1	Deployment table
10.3.1	Hierarchy diagram, General	3.2.1	Required quality deployment table
10.3.2	Steps to make hierarchy diagram	Annex 1 3 a)	Create required quality deployment table
11	Prioritization	5.4.1 d)	Calculation of order of importance in required quality
12.2	Quality planning table	3.2.4	Quality of planning
12.2	Quality planning table	5.3 d)	Quality planning table
12.2	Quality planning table (QPT)	5.4.1	Required quality and quality of planning
12.2 c)	Competition clause	3.2.6	Ratio of level improvement

12.2 c)	QPT competition clause	5.4.1 e)	Comparative analysis
12.2 c)	QPT competition clause	5.4.1 f)	Establishment of quality of planning
12.2 c)	QPT competition clause	5.4.1 g)	Calculation of the rate of improvement
12.2 d)	Selling point	3.2.7	Selling point
12.2 d)	QPT selling point	5.4.1 h)	Establishment of selling point
12.2 f)	Unadjusted customer need priority	3.2.8	Unadjusted weight
12.2 f)	Adjusted customer need priority	3.2.9	Adjusted weight of required quality
12.2 f)	QPT global weights	5.4.1 i)	Calculation of unadjusted weight and adjusted weight of required quality
Table 12	Weighted quality planning table	Annex 5 Table 1	Example of quality of planning chart
Table 4	Customer needs hierarchy diagram	Annex 2 Table 1	Example of required quality deployment table
ISO 16355-5:2017			
9.3	L-Matrices	5.2	Deployment table and matrix
9.3	L-Matrices	5.2.2	Matrix
9.3.6	House of quality	5.1	Quality table, General
9.3.6	House of quality	5.4	Quality table creation procedure
9.3.6	House of quality	Annex 1 1 a)	Create quality table
9.3.6	House of quality	Annex 1 3 c)	Create required quality-quality characteristics matrix
9.3.6.2	Information in the house of quality	5.3	Composition of the quality table
9.3.6.2 a)	Customer needs hierarchy	5.3 a)	Required quality deployment table
9.3.6.2 b)	Functional requirements hierarchy	5.3 b)	Quality characteristic deployment table
9.3.6.2 c)	Matrix	5.3 c)	Matrix
9.3.6.2 d)	Quantify row information	5.3 d)	Quality planning table
9.3.6.2 e)	Design planning table	5.3 e)	Design quality table
9.3.6.2 f)	Functional requirements correlation matrix	5.3 f)	Quality characteristic correlation table
9.3.6.2.2	Functional requirements hierarchy	3.2.2	Quality characteristic deployment table
9.3.6.2.2	Columns of the house of quality	5.4.2 a)	Identify quality characteristics
9.3.6.2.2	Functional requirements hierarchy	5.4.2 b)	Create quality characteristic deployment table
9.3.6.2.2	Functional requirements hierarchy	Annex 1 2 c)	Create quality characteristics deployment table
9.3.6.2.2	Functional requirements hierarchy	Annex 1 3 b)	Create quality characteristics deployment table
9.3.6.2.3	Matrix	3.2.3	Quality table
9.3.6.2.3	Matrix	3.2.5	Quality of design
9.3.6.2.3	Matrix	5.4.2 c)	Create matrix for required quality deployment table and quality characteristic deployment table

10.2	Transfer of prioritization	5.2.3	Transformation in level of importance
10.2.1	Quantify strength of relationships in the matrix	5.4.2 d)	Enter correlations
10.2.3	Calculate the column weights	5.4.2 e)	Transform weight
10.2.4.2	Independent distribution	5.2.3 a)	Independent rating method
10.2.4.4	Proportional distribution	5.2.3 b)	Proportional distribution method
10.3.4.1	Design planning table information for the house of quality	5.4.2	Quality table and design quality
10.3.4.3	Unweighted design planning table	5.4.2 f)	Conduct comparative analysis
10.3.4.3	Unweighted design planning table	5.4.2 g)	Establish quality of design
10.3.4.5	Weighted design planning table	3.2.10	Quality characteristic weight
10.4	Transferring deployment sets by dimensions and levels	6	Quality function deployment
10.4.1	Deployment sets	6.1	Quality function deployment, General
10.4.1.2 a)	Improve performance of new or existing product	7.2 a)	Existing product assembly
10.4.1.2 e)	Regulatory deployment	7.2 g)	Environment-compliant design
10.4.2	Quality deployment	6.2	Quality deployment
10.4.2.1.1	Quality deployment, Objective	6.2.1	Quality deployment, Objective
10.4.2.1.2	Quality deployment, Composition	6.2.2	Quality deployment, Composition
10.4.2.3.2 a)	Value analysis (VA) and value engineering (VE)	9.6 a)	Value analysis (VA) and value engineering (VE)
10.4.2.3.3	Building the function tree	Annex 1 2 b)	Create function deployment table
10.4.2.4.3	Functional requirements-function matrix	Annex 1 2 f)	Create quality characteristics-function matrix
10.4.2.4.3 d)	Transfer priorities of functional requirements to functions	Annex 1 2 i)	Transform QC weight-function weight
10.4.3	Technology deployment	6.3	Engineering deployment
10.4.3	Technology deployment	Annex 1 3	Engineering deployment
10.4.3.1	Technology deployment, General	4.2 c)	Early detection of technological issues
10.4.3.1.1	Technology deployment, Objective	6.3.1	Engineering deployment, Objective
10.4.3.1.2	Technology deployment, Composition	6.3.2	Engineering deployment, Composition
10.4.3.2	Assessing technology readiness	Annex 1 3 a)	Identify criteria for bottlenecks
10.4.3.3	Needs to seeds technology development	8.4 g)	Seeds
10.4.3.4.1	Revealing technical contradictions	Annex 1 3 b)	Identify parts and technology bottlenecks
10.4.3.6.3	Structuring concepts	Annex 1 1 b)	Create subsystem deployment table
10.4.3.6.3	Structuring concepts	Annex 1 1 c)	Create unit/parts deployment table
10.4.3.6.3	Structuring concepts	Annex 1 2 d)	Create mechanism deployment table

10.4.3.6	Develop system, subsystem concepts	7.2 e)	Concept planning
10.4.3.7.1	Agile development	7.2 c)	Software
10.4.3.7.2	Selecting concepts using QFD criteria	Annex 1 1 e)	Create quality characteristics-subsystem matrix
10.4.3.7.2	Selecting concepts using Pugh and super Pugh methods	Annex 1 3 c)	Review bottleneck alternative solutions
10.4.3.8.2	Resolving engineering bottlenecks	3.1.14	Bottleneck engineering (BNE)
10.4.3.8.2	Resolving engineering bottlenecks	8.4 i)	Bottleneck engineering
10.4.4	Cost deployment	6.4	Cost deployment
10.4.4	Cost deployment	Annex 1 2	Cost deployment
10.4.4.1.1	Cost deployment, Objective	6.4.1	Cost deployment, Objective
10.4.4.1.2	Cost deployment, Composition	6.4.2	Cost deployment, Composition
10.4.4.2	Target cost estimation	Annex 1 2 a)	Establish target cost
10.4.4.3.3	Building the function-system/subsystem matrix	Annex 1 2 g)	Create function-mechanism matrix
10.4.4.5	Design-to-cost analysis	9.4 a)	Cost planning
10.4.5	Reliability deployment	6.5	Reliability deployment
10.4.5	Reliability deployment	Annex 1 3	Reliability deployment
10.4.5.1.1	Reliability deployment, Objective	6.5.1	Reliability deployment, Objective
10.4.5.1.2	Reliability deployment, Composition	6.5.2	Reliability deployment, Composition
10.4.5.4	Fault tree analysis	Annex 1 3 e)	Conduct FTA on assurance items
10.4.5.5	Customer needs-failure mode matrix	Annex 1 3 d)	Identify assurance items from key required quality
10.4.5.6	Functional requirements-failure mode matrix	Annex 1 3 d)	Identify assurance items from key quality characteristics
Figure 6	Hierarchy diagram of functional requirements	Annex 3 Table 1	Example of quality characteristic deployment table
Figure 13	Building the fault tree	Annex 1 3 f)	Show FTA diagram
Table 3	Customer needs-functional requirements matrix (house of quality)	Annex 4 Table 1	Example of quality table
Table 5	Customer needs-functional requirements matrix (house of quality), weighted	Annex 6 Table 1	Example of transforming order of importance
ISO 16355-8:2017			
9.3	Functional requirements-components matrix	7.2 f)	Parts
9.3.2	Components hierarchy diagram	Annex 1 1 d)	Create parts deployment table

9.3.2 b)	Components hierarchy diagram	Annex 1 2 e)	Create parts deployment table
9.5.2	Building the function-component matrix	Annex 1 2 h)	Create function-parts matrix
9.6.2	Building the subsystem-components matrix	Annex 1 1 f)	Create subsystem-unit/parts matrix
9.6.2	Building the subsystem-components matrix	Annex 1 1 g)	Create unit/parts-parts matrix
9.6.2 d)	Transfer priorities of subsystems to components	Annex 1 2 i)	Transform mechanism weight-part weight
9.6.2 e)	Allocate target cost of subsystems to components	Annex 1 2 j)	Allocate target cost to each weight
9.6.2 f)	Identify components that are problematic to quality and cost	Annex 1 2 k)	Identify cost bottlenecks
9.7.2	Building the component-failure mode matrix	Annex 1 3 g)	Create FT-unit deployment matrix
9.7.2	Building the component-failure mode matrix	Annex 1 3 h)	Create FT-part matrix
9.8	Component failure mode and effects analysis (FMEA)	Annex 1 3 i)	FMEA of components and reliability bottlenecks
9.9	Quality assurance table	3.1.15	quality assurance (QA) table
9.9.2	Building the QA table	Annex 1 1 l)	Create QA chart
10	Statistical analysis of customers' evaluations of products	9.2 e)	Multivariate analysis
11	Testing, validation, design review, and prototyping	7.3	Use in design review
11.4 a)	Planning stage design review	7.3 a)	Quality function deployment in design review in the planning stage
11.4 b)	Prototype drawing and preproduction stage design review	7.3 b)	Quality function deployment in design review in the prototype drawing production stage
11.4 c)	Production stage design review	7.3 c)	Quality function deployment in design review at completion of mass-production prototype
12.1.5	Project work or task management	7.2 b)	Service
13	Build and process planning	Annex 1 1	Subsystem and process deployment based on quality deployment
13.2	Quality control process planning table	Annex 1 1 k)	Create process-process element matrix
13.3	Quality control table for component production and assembly	Annex 1 1 j)	Create process element deployment table
13.5.1	QC process table based work standard	7.2 d)	Production goods
13.5.1	QC process table based work standard	Annex 1 1 l)	Create QC process chart
13.5.2.2	Building the functional requirements-process matrix	Annex 1 1 i)	Create quality characteristics-process matrix
13.5.2.2 b)	Process steps	Annex 1 1 h)	Create process deployment table

20	Quality assurance network diagram	6.6	Job function deployment table
20	Quality assurance network	9.6 b)	Quality assurance system diagram
20	Quality assurance network	Annex 1 5	Quality function deployment as management system
20.1	Quality assurance network diagram, Objective	6.6.1	Job function deployment table, Objective
20.1	Quality assurance network, objective, note	Annex 1 5 d)	Create job function-quality assurance items matrix
20.2	Quality assurance network diagram, Composition	6.6.2	Job function deployment table, Composition
20.2	Quality assurance network, Composition	9.6	Relevant methods in job function deployment
20.2	Quality assurance network, Composition	9.6 c)	Quality assurance activity chart
20.2	Quality assurance network, Composition	Annex 1 5 a)	Identify job functions for assuring quality
20.2	Quality assurance network, Composition	Annex 1 5 b)	Create job function deployment table
20.2	Quality assurance network, Composition	Annex 1 5 c)	Identify product quality assurance items
Figure 8	Quality assurance network diagram	Annex 1 5 e)	Create list of quality assurance items and quality assurance system diagram
Table 20	QA table	Annex 7 Table 1	Example of QA chart
Table 30	QC process table	Annex 8 Table 1	Example of QC process chart

B.3 JIS Q 9025:2003(e) to ISO 16355 (all parts) cross reference

JIS Q 9025		ISO 16355 (all parts)		
0	Introduction	ISO 16355-1:2015	0	Introduction
0.1	General	ISO 16355-1:2015	0	Introduction
0.2	Consistency with other standards	ISO 16355-1:2015	Bibliography	[127] to [131]
0.3	Relationship with JIS Q 9000 family	—	—	—
0.4	Compatibility with other management systems	ISO 16355-1:2015	5	Integration of QFD and product development methods
1	Scope	ISO 16355-1:2015	1	Scope
2	Normative reference	ISO 16355-1:2015	2	Normative references
3	Terms and definitions	ISO 16355-1:2015	3	Terms and definitions
3.1	Terms related to quality function deployment	ISO 16355-1:2015	3	Terms and definitions
3.1.1	Transformation	ISO 16355-1:2015	4.1 f)	Improve internal communications through transformation

3.1.2	Deployment	ISO 16355-1:2015	12.1	Translation of one information set into another, General
3.1.3	Deployment table	ISO 16355-1:2015	9	Structuring information sets
3.1.4	Matrix	ISO 16355-1:2015	13.1	Transfer of prioritization
3.1.5	Correlation strength	ISO 16355-1:2015	13.1	Transfer of prioritization
3.1.6	Quality function deployment (QFD)	ISO 16355-1:2015	3.1	Quality function deployment (QFD)
3.1.7	Quality deployment	ISO 16355-1:2015	13.5.2	Quality deployment
3.1.8	Engineering deployment	ISO 16355-1:2015	13.5.4	Technology deployment
3.1.9	Cost deployment	ISO 16355-1:2015	13.5.6	Cost deployment
3.1.10	Reliability deployment	ISO 16355-1:2015	13.5.8	Reliability deployment
3.1.11	Job function deployment	ISO 16355-1:2015	4.2	QFD use of the word function
3.1.12	Voice of the customer	ISO 16355-1:2015	3.2	Voice of the customer
3.1.13	Required quality	ISO 16355-1:2015	3.3	Customer needs
3.1.13	Required quality	ISO 16355-4:2017	9.1.3.3	Customer needs
3.1.14	Bottleneck engineering (BNE)	ISO 16355-5:2017	10.4.3.8.2	Resolving engineering bottlenecks
3.1.15	Quality assurance (QA) table	ISO 16355-8:2017	9.9	Quality assurance table
3.2	Terms related to quality	ISO 16355-1:2015	3	Terms and definitions
3.2.1	Required quality deployment table	ISO 16355-4:2017	10.3.1	Hierarchy diagram, General
3.2.2	Quality characteristic deployment table	ISO 16355-5:2017	9.3.6.2.2	Functional requirements hierarchy
3.2.3	Quality table	ISO 16355-5:2017	9.3.6.2.3	Matrix
3.2.4	Quality of planning	ISO 16355-4:2017	12.2	Quality planning table
3.2.5	Quality of design	ISO 16355-5:2017	9.3.6.2.3	Matrix
3.2.6	Ratio of level improvement	ISO 16355-4:2017	12.2 3)	Competition clause
3.2.7	Selling point	ISO 16355-4:2017	12.2 4)	Selling point
3.2.8	Unadjusted weight	ISO 16355-4:2017	12.2 6)	Unadjusted customer need priority
3.2.9	Adjusted weight of required quality	ISO 16355-4:2017	12.2 6)	Adjusted customer need priority
3.2.10	Quality characteristic weight	ISO 16355-5:2017	10.3.4.5	Weighted design planning table
4	Basic concepts	ISO 16355-1:2015	4	Basic concepts of QFD
4.1	General	ISO 16355-1:2015	4.1	Theory and principles of QFD
4.2	Quality function deployment in quality management	ISO 16355-1:2015	5.1	QFD support for product development methods
4.2 a)	Customer focus	ISO 16355-1:2015	4.1 c)	Listen to the voice of the customer
4.2 b)	Participation of people	ISO 16355-1:2015	7	QFD team membership

4.2 c)	Early detection of technological issues	ISO 16355-5:2017	10.4.3.1	Technology deployment, General
4.2 d)	Development management	ISO 16355-1:2015	6	Types of QFD projects
4.2 e)	Secure quality assurance	ISO 16355-1:2015	5.2	Organization of the QFD flow
4.2 f)	Multilateral evaluation	ISO 16355-1:2015	13.5	Transferring deployment sets by dimensions
4.3	Principles of quality function deployment	ISO 16355-1:2015	4.1	Theory and principles of QFD
4.3 a)	Principle of deployment	ISO 16355-1:2015	13.6	Transferring deployment sets by levels
4.3 b)	Principle of segmentation and integration	ISO 16355-4:2017	9.2.3	Cause-to-effect diagram
4.3 c)	Principle of multi-dimensional development and visualization	ISO 16355-1:2015	12	Translation of one information set into another
4.3 d)	Principle of consolidation and breakdown	ISO 16355-1:2015	9	Structuring information sets
4.3 e)	Principle of transformation	ISO 16355-1:2015	12	Translation of one information set into another
5.1	Quality table, General	ISO 16355-5:2017	9.3.6	House of quality
5.2	Deployment table and matrix	ISO 16355-5:2017	9.3	L-Matrices
5.2.1	Deployment table	ISO 16355-4:2017	10.3	Hierarchy diagram
5.2.2	Matrix	ISO 16355-5:2017	9.3	L-Matrices
5.2.3	Transformation in level of importance	ISO 16355-5:2017	10.2	Transfer of prioritization
5.2.3 a)	Independent rating method	ISO 16355-5:2017	10.2.4.2	Independent distribution
5.2.3 b)	Proportional distribution method	ISO 16355-5:2017	10.2.4.4	Proportional distribution
5.3	Composition of the quality table	ISO 16355-5:2017	9.3.6.2	Information in the house of quality
5.3 a)	Required quality deployment table	ISO 16355-5:2017	9.3.6.2 a)	Customer needs hierarchy
5.3 b)	Quality characteristic deployment table	ISO 16355-5:2017	9.3.6.2 b)	Functional requirements hierarchy
5.3 c)	Matrix	ISO 16355-5:2017	9.3.6.2 c)	Matrix
5.3 d)	Quality planning table	ISO 16355-5:2017	9.3.6.2 d)	Quality planning table
5.3 d)	Quality planning table	ISO 16355-5:2017	10.3.2	Quantify row information
5.3 e)	Design quality table	ISO 16355-5:2017	9.3.6.2 e)	Design planning table
5.3 f)	Quality characteristic correlation table	ISO 16355-5:2017	9.3.6.2 f)	Functional requirements correlation matrix
5.4	Quality table creation procedure	ISO 16355-5:2017	9.3.6	House of quality
5.4.1	Required quality and quality of planning	ISO 16355-4:2017	12.2	Quality planning table (QPT)
5.4.1 a)	Gathering “voice of the customer”	ISO 16355-2:2017	9.2.5	Sources of VOC or VOS

5.4.1 b)	Transformation into required quality	ISO 16355-4:2017	9.2	Translating VOC and VOS into customer needs
5.4.1 c)	Creation of required quality deployment table	ISO 16355-4:2017	10	Structuring information sets
5.4.1 d)	Calculation of order of importance in required quality	ISO 16355-4:2017	11	Prioritization
5.4.1 e)	Comparative analysis	ISO 16355-4:2017	12.2 c)	QPT competition clause
5.4.1 f)	Establishment of quality of planning	ISO 16355-4:2017	12.2 c)	QPT competition clause
5.4.1 g)	Calculation of the rate of improvement	ISO 16355-4:2017	12.2 c)	QPT competition clause
5.4.1 h)	Establishment of selling point	ISO 16355-4:2017	12.2 d)	QPT selling point
5.4.1 i)	Calculation of unadjusted weight and adjusted weight of required quality	ISO 16355-4:2017	12.2 f)	QPT global weights
5.4.2	Quality table and design quality	ISO 16355-5:2017	10.3.4.1	Design planning table information for the house of quality
5.4.2 a)	Identify quality characteristics	ISO 16355-5:2017	9.3.6.2.2	Columns of the house of quality
5.4.2 b)	Create quality characteristic deployment table	ISO 16355-5:2017	9.3.6.2.2	Functional requirements hierarchy
5.4.2 c)	Create matrix for required quality deployment table and quality characteristic deployment table	ISO 16355-5:2017	9.3.6.2.3	Matrix
5.4.2 d)	Enter correlations	ISO 16355-5:2017	10.2.1	Quantify strength of relationships in the matrix
5.4.2 e)	Transform weight	ISO 16355-5:2017	10.2.3	Calculate the column weights
5.4.2 f)	Conduct comparative analysis	ISO 16355-5:2017	10.3.4.3	Unweighted design planning table
5.4.2 g)	Establish quality of design	ISO 16355-5:2017	10.3.4.3	Unweighted design planning table
6	Quality function deployment	ISO 16355-5:2017	10.4	Transferring deployment sets by dimensions and levels
6.1	Quality function deployment, General	ISO 16355-5:2017	10.4.1	Deployment sets
6.2	Quality deployment	ISO 16355-5:2017	10.4.2	Quality deployment
6.2.1	Quality deployment, Objective	ISO 16355-5:2017	10.4.2.1.1	Quality deployment, Objective
6.2.2	Quality deployment, Composition	ISO 16355-5:2017	10.4.2.1.2	Quality deployment, Composition
6.3	Engineering deployment	ISO 16355-5:2017	10.4.3	Technology deployment
6.3.1	Engineering deployment, Objective	ISO 16355-5:2017	10.4.3.1.1	Technology deployment, Objective
6.3.2	Engineering deployment, Composition	ISO 16355-5:2017	10.4.3.1.2	Technology deployment, Composition
6.4	Cost deployment	ISO 16355-5:2017	10.4.4	Cost deployment

6.4.1	Cost deployment, Objective	ISO 16355-5:2017	10.4.4.1.1	Cost deployment, Objective
6.4.2	Cost deployment, Composition	ISO 16355-5:2017	10.4.4.1.2	Cost deployment, Composition
6.5	Reliability deployment	ISO 16355-5:2017	10.4.5	Reliability deployment
6.5.1	Reliability deployment, Objective	ISO 16355-5:2017	10.4.5.1.1	Reliability deployment, Objective
6.5.2	Reliability deployment, Composition	ISO 16355-5:2017	10.4.5.1.2	Reliability deployment, Composition
6.6	Job function deployment table	ISO 16355-8:2017	20	Quality assurance network diagram
6.6.1	Job function deployment table, Objective	ISO 16355-8:2017	20.1	Quality assurance network diagram, Objective
6.6.2	Job function deployment table, Composition	ISO 16355-8:2017	20.2	Quality assurance network diagram, Composition
7	Application guide	ISO 16355-1:2015	6.1	Types of QFD projects, General
7.1	Application guide, Objective	ISO 16355-1:2015	4.1	Theory and principles of QFD
7.2	Frame corresponding to objective	ISO 16355-1:2015	6.1	Types of QFD projects, General
7.2 a)	Existing product assembly	ISO 16355-5:2017	10.4.1.2 a)	Improve performance of new or existing product
7.2 b)	Service	ISO 16355-8:2017	12.1.5	Project work or task management
7.2 c)	Software	ISO 16355-5:2017	10.4.3.7.1.1	Agile development
7.2 d)	Production goods	ISO 16355-8:2017	13.5.1	QC process table based work standard
7.2 e)	Concept planning	ISO 16355-5:2017	10.4.3.6	Develop system, subsystem concepts
7.2 f)	Parts	ISO 16355-8:2017	9.3	Functional requirements-components matrix
7.2 g)	Environment-compliant design	ISO 16355-5:2017	10.4.1.2 e)	Regulatory deployment
7.3	Use in design review	ISO 16355-8:2017	11	Testing, validation, design review, and prototyping
7.3 a)	Quality function deployment in design review in the planning stage	ISO 16355-8:2017	11.4 a)	Planning stage design review
7.3 b)	Quality function deployment in design review in the prototype drawing production stage	ISO 16355-8:2017	11.4 b)	Prototype drawing and pre-production stage design review
7.3 c)	Quality function deployment in design review at completion of mass-production prototype	ISO 16355-8:2017	11.4 c)	Production stage design review
8	Introduction and application to organizations	ISO 16355-1:2015	8	QFD voices
8.1	Introduction of quality function deployment	ISO 16355-1:2015	8.1	Voice of business

8.2	Formation of the team	ISO 16355-1:2015	7	QFD team membership
8.3	Quality function deployment using information technology	ISO 16355-1:2015	6.1 f)	Document and preserve market and technical knowledge
8.4	Information configuration	ISO 16355-4:2017	9.1.3	Information contained in VOC and VOS
8.4 a)	Voice of the consumer	ISO 16355-4:2017	9.1.3.3	Customer needs
8.4 b)	Engineering characteristics	ISO 16355-4:2017	9.1.3.4	Functional requirements
8.4 c)	Product function	ISO 16355-4:2017	9.1.3.5	Function
8.4 d)	Materials used	ISO 16355-4:2017	9.1.3.9	Material
8.4 e)	Parts and components	ISO 16355-4:2017	9.1.3.8	Subsystem or component
8.4 f)	Mechanisms	ISO 16355-4:2017	9.1.3.8	Subsystem or component
8.4 g)	Seeds	ISO 16355-5:2017	10.4.3.3	Needs to seeds technology development
8.4 h)	Technology	ISO 16355-4:2017	9.1.3.6	Technology
8.4 i)	Bottleneck engineering	ISO 16355-5:2017	10.4.3.8.2	Resolving engineering bottlenecks
8.4 j)	Cost	ISO 16355-4:2017	9.1.3.2	Cost
8.4k)	Failure mode	ISO 16355-4:2017	9.1.3.7	Reliability or failure mode
8.4 l)	Manufacturing methods	ISO 16355-4:2017	9.1.3.13	Manufacturing or build methods
8.4 m)	Measurement method	ISO 16355-4:2017	9.1.3.14	Measurement methods
8.4 n)	Job functions	ISO 16355-4:2017	9.1.3.11	Process
8.4 o)	Assurance items	ISO 16355-4:2017	9.1.3.15	Quality
9	Related methods	ISO 16355-1:2015	5	Integration of QFD and product development methods
9.1	Related methods, General	ISO 16355-1:2015	5.1	QFD support for product development methods
9.2	Relevant methods in quality deployment	ISO 16355-1:2015	13.5.3	Quality deployment, Applicable tools and methods
9.2 a)	Questionnaire survey	ISO 16355-1:2015	8.2.9	Sources of VOC and VOS
9.2 b)	Test planning method	ISO 16355-1:2015	16	Prototyping, testing, and validation
9.2 c)	Quality engineering	ISO 16355-1:2015	15	Design optimization
9.2 d)	Product planning method	ISO 16355-1:2015	Reference [35]	7 Product planning tools
9.2 e)	Multivariate analysis	ISO 16355-8:2017	10	Statistical analysis of customers' evaluations of products
9.3	Relevant methods in engineering deployment	ISO 16355-1:2015	13.5.5	Technology deployment, Applicable tools and methods

9.3 a)	Comparison or proposals	ISO 16355-1:2015	13.5.5 f)	Super Pugh concept selection with AHP
9.3 b)	Reviewed dendrogram	ISO 16355-1:2015	13.5.5 e)	Reviewed dendrogram
9.4	Relevant methods in cost deployment	ISO 16355-1:2015	13.5.7	Technology deployment, Applicable tools and methods
9.4 a)	Cost planning	ISO 16355-5:2017	10.4.4.5	Design-to-cost analysis
9.4 b)	Balanced scorecard	ISO 16355-2:2017	9.1.2.7.2	Balanced scorecard
9.5	Relevant methods in reliability deployment	ISO 16355-1:2015	13.5.9	Reliability deployment, Applicable tools and methods
9.5 a)	FTA	ISO 16355-1:2015	13.5.9.a)	Fault tree analysis
9.5 b)	FMEA	ISO 16355-1:2015	13.5.9.b)	Failure mode and effects analysis
9.5 c)	Design review	ISO 16355-1:2015	16.2 g)	Prototyping, testing, and validation, Applicable tools and methods
9.6	Relevant methods in job function deployment	ISO 16355-8:2017	20.2	Quality assurance network, Composition
9.6 a)	Value analysis (VA) and value engineering (VE)	ISO 16355-5:2017	10.4.2.3.2 a)	Value analysis (VA) and value engineering (VE)
9.6 b)	Quality assurance system diagram	ISO 16355-8:2017	20	Quality assurance network
9.6 c)	Quality assurance activity chart	ISO 16355-8:2017	20.2	Quality assurance network, Composition
Annex 1 1	Subsystem and process deployment based on quality deployment	ISO 16355-8:2017	13	Build and process planning
Annex 1 1 a)	Create quality table	ISO 16355-5:2017	9.3.6	House of quality
Annex 1 1 b)	Create subsystem deployment table	ISO 16355-5:2017	10.4.3.6.3	Structuring concepts
Annex 1 1 c)	Create unit/parts deployment table	ISO 16355-5:2017	10.4.3.6.3	Structuring concepts
Annex 1 1 d)	Create parts deployment table	ISO 16355-8:2017	9.3.2	Components hierarchy diagram
Annex 1 1 e)	Create quality characteristics-subsystem matrix	ISO 16355-5:2017	10.4.3.7.2.4	Selecting concepts using QFD criteria
Annex 1 1 f)	Create subsystem-unit/parts matrix	ISO 16355-8:2017	9.6.2	Building the subsystem-components matrix
Annex 1 1 g)	Create unit/parts-parts matrix	ISO 16355-8:2017	9.6.2	Building the subsystem-components matrix
Annex 1 1 h)	Create process deployment table	ISO 16355-8:2017	13.5.2.2 2)	process steps
Annex 1 1 i)	Create quality characteristics-process matrix	ISO 16355-8:2017	13.5.2.2	Building the functional requirements-process matrix
Annex 1 1 j)	Create process element deployment table	ISO 16355-8:2017	13.3	Quality control table for component production and assembly

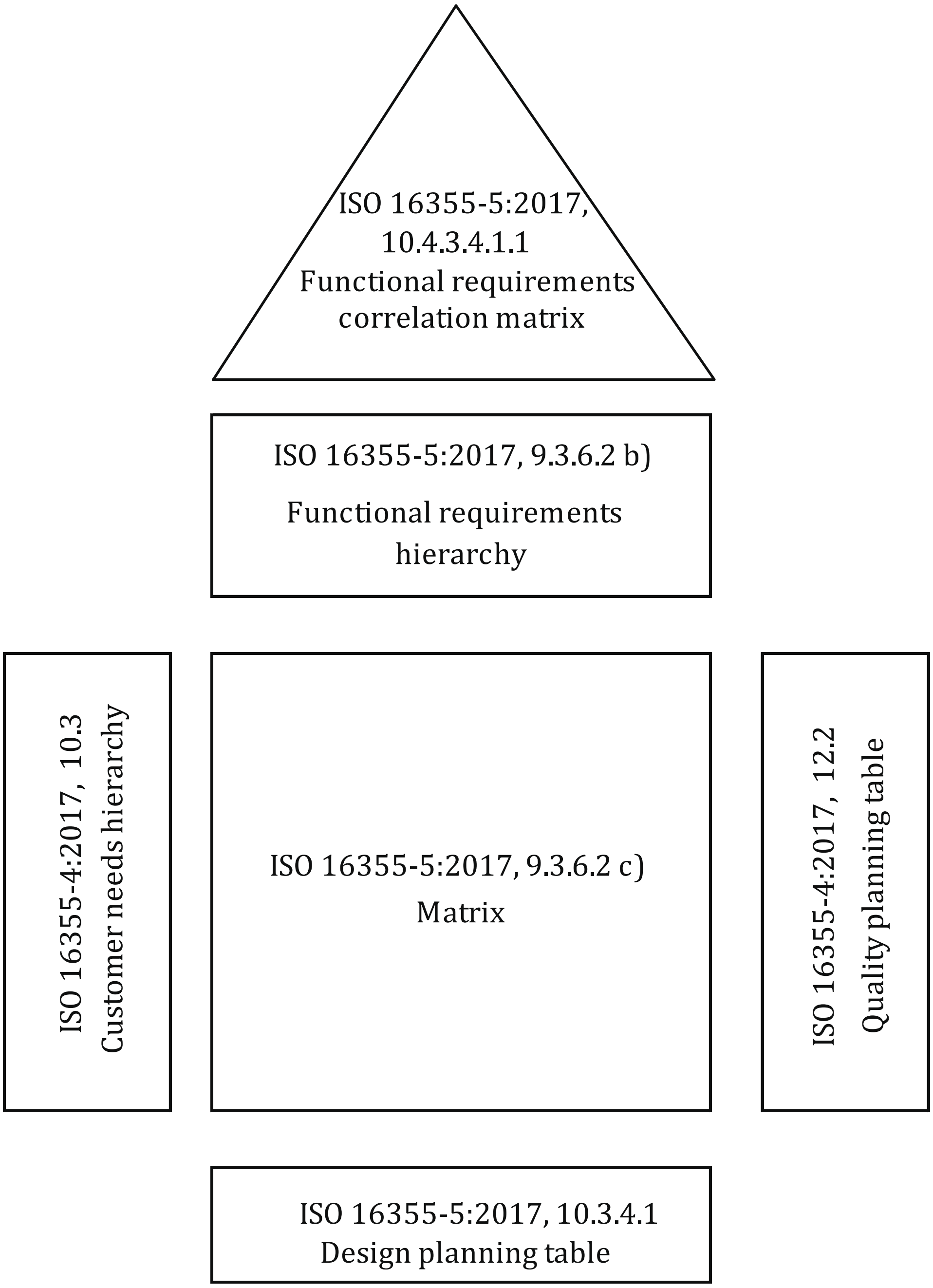
Annex 1 1 k)	Create process-process element matrix	ISO 16355-8:2017	13.2	Quality control process planning table
Annex 1 1 l)	Create QA chart	ISO 16355-8:2017	9.9.2	Building the QA table
Annex 1 1 l)	Create QC process chart	ISO 16355-8:2017	13.5.1	QC process table based work standard
Annex 1 2	Cost deployment	ISO 16355-5:2017	10.4.4	Cost deployment
Annex 1 2 a)	Establish target cost	ISO 16355-5:2017	10.4.4.2	Target cost estimation
Annex 1 2 b)	Create function deployment table	ISO 16355-5:2017	10.4.2.3.3	Building the function tree
Annex 1 2 c)	Create quality characteristics deployment table	ISO 16355-5:2017	9.3.6.2.2	Functional requirements hierarchy
Annex 1 2 d)	Create mechanism deployment table	ISO 16355-5:2017	10.4.3.6.3	Structuring concepts
Annex 1 2 e)	Create parts deployment table	ISO 16355-8:2017	9.3.2 b)	Components hierarchy diagram
Annex 1 2 f)	Create quality characteristics-function matrix	ISO 16355-5:2017	10.4.2.4.3	Functional requirements-function matrix
Annex 1 2 g)	Create function-mechanism matrix	ISO 16355-5:2017	10.4.4.3.3	Building the function-system/subsystem matrix
Annex 1 2 h)	Create function-parts matrix	ISO 16355-8:2017	9.5.2	Building the function-component matrix
Annex 1 2 i)	Transform QC weight-function weight	ISO 16355-5:2017	10.4.2.4.3 4)	Transfer priorities of functional requirements to functions
Annex 1 2 i)	Transform mechanism weight-part weight	ISO 16355-8:2017	9.6.2 4)	Transfer priorities of subsystems to components
Annex 1 2 j)	Allocate target cost to each weight	ISO 16355-8:2017	9.6.2 5)	Allocate target cost of subsystems to components
Annex 1 2 k)	Identify cost bottlenecks	ISO 16355-8:2017	9.6.2 6)	Identify components that are problematic to quality and cost
Annex 1 3	Engineering deployment	ISO 16355-5:2017	10.4.3	Technology deployment
Annex 1 3 a)	Identify criteria for bottlenecks	ISO 16355-5:2017	10.4.3.2	Assessing technology readiness
Annex 1 3 b)	Identify parts and technology bottlenecks	ISO 16355-5:2017	10.4.3.4.1	Revealing technical contradictions
Annex 1 3 c)	Review bottleneck alternative solutions	ISO 16355-5:2017	10.4.3.7.2	Selecting concepts using Pugh and super Pugh methods
Annex 1 3	Reliability deployment	ISO 16355-5:2017	10.4.5	Reliability deployment
Annex 1 3 a)	Create required quality deployment table	ISO 16355-4:2017	10.3.2	Steps to make hierarchy diagram

Annex 1 3 b)	Create quality characteristics deployment table	ISO 16355-5:2017	9.3.6.2.2	Functional requirements hierarchy
Annex 1 3 c)	Create required quality-quality characteristics matrix	ISO 16355-5:2017	9.3.6	House of quality
Annex 1 3 d)	Identify assurance items from key required quality	ISO 16355-5:2017	10.4.5.5	Customer needs-failure mode matrix
Annex 1 3 d)	Identify assurance items from key quality characteristics	ISO 16355-5:2017	10.4.5.6	Functional requirements-failure mode matrix
Annex 1 3 e)	Conduct FTA on assurance items	ISO 16355-5:2017	10.4.5.4	Fault tree analysis
Annex 1 3 f)	Show FTA diagram	ISO 16355-5:2017	Figure 13	Building the fault tree
Annex 1 3 g)	Create FT-unit deployment matrix	ISO 16355-8:2017	9.7.2	Building the component-failure mode matrix
Annex 1 3 h)	Create FT-part matrix	ISO 16355-8:2017	9.7.2	Building the component-failure mode matrix
Annex 1 3 i)	FMEA of components and reliability bottlenecks	ISO 16355-8:2017	9.8	Component failure mode and effects analysis (FMEA)
Annex 1 5	Quality function deployment as management system	ISO 16355-8:2017	20	Quality assurance network
Annex 1 5 a)	Identify job functions for assuring quality	ISO 16355-8:2017	20.2	Quality assurance network, Composition
Annex 1 5 b)	Create job function deployment table	ISO 16355-8:2017	20.2	Quality assurance network, Composition
Annex 1 5 c)	Identify product quality assurance items	ISO 16355-8:2017	20.2	Quality assurance network, Composition
Annex 1 5 d)	Create job function-quality assurance items matrix	ISO 16355-8:2017	20.1	Quality assurance network, objective, note
Annex 1 5 e)	Create list of quality assurance items and quality assurance system diagram	ISO 16355-8:2017	Figure 8	Quality assurance network diagram
Annex 2 Table 1	Example of required quality deployment table	ISO 16355-4:2017	Table 4	Customer needs hierarchy diagram
Annex 3 Table 1	Example of quality characteristic deployment table	ISO 16355-5:2017	Figure 6	Hierarchy diagram of functional requirements
Annex 4 Table 1	Example of quality table	ISO 16355-5:2017	Table 3	Customer needs-functional requirements matrix (house of quality)
Annex 5 Table 1	Example of quality of planning chart	ISO 16355-4:2017	Table 12	Weighted quality planning table

Annex 6 Table 1	Example of transforming order of importance	ISO 16355-5:2017	Table 5	Customer needs-functional requirements matrix (house of quality), weighted
Annex 7 Table 1	Example of QA chart	ISO 16355-8:2017	Table 20	QA table
Annex 8 Table 1	Example of QC process chart	ISO 16355-8:2017	Table 30	QC process table

B.4 JIS Q 9025:2003(e) figures and tables with ISO cross references

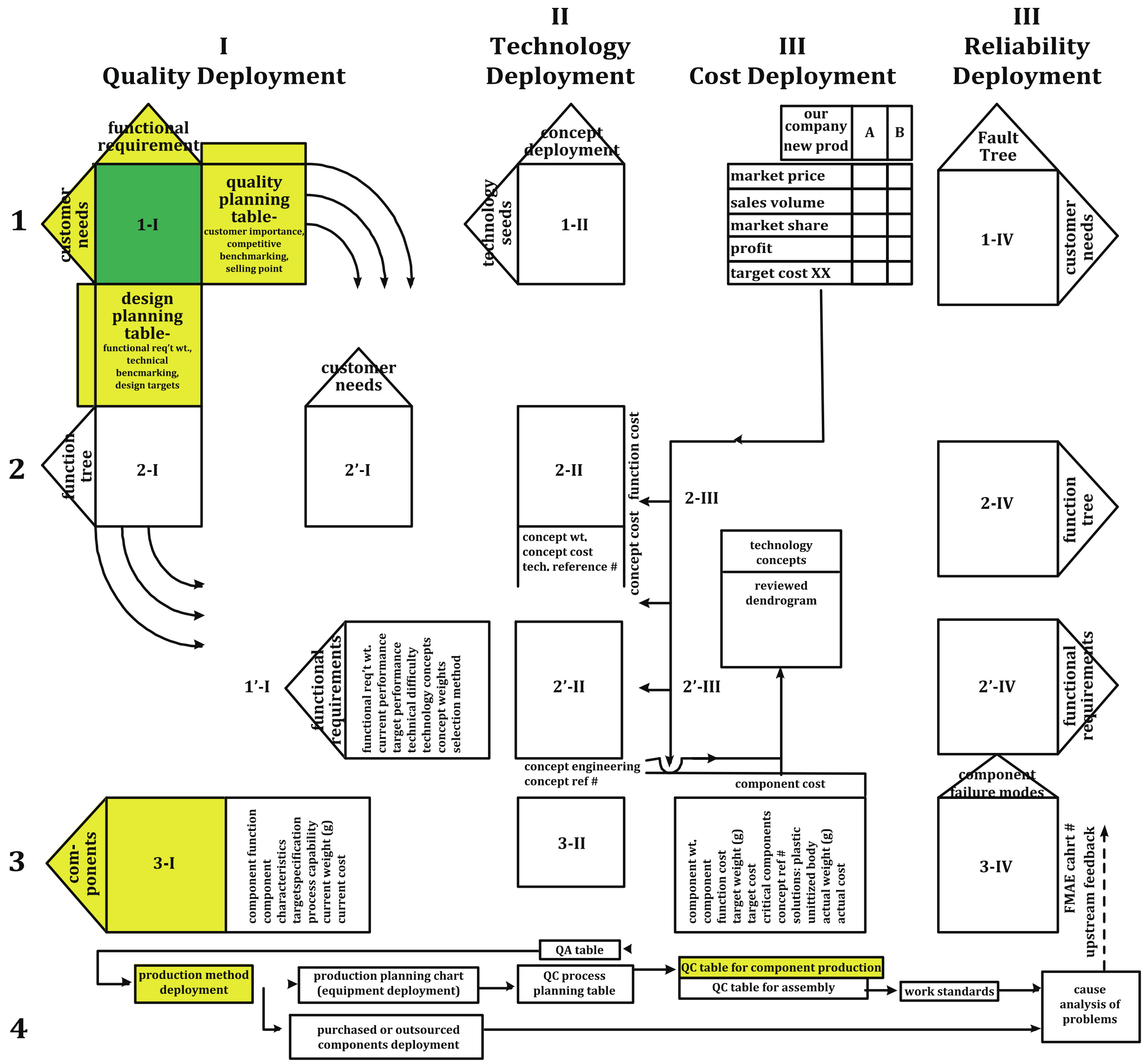
B.4.1 Composition of a quality table



NOTE Source: JIS Q 9025, Figure 1.

Figure B.1 — Composition of a quality table

B.4.2 Total concept chart of quality function deployment

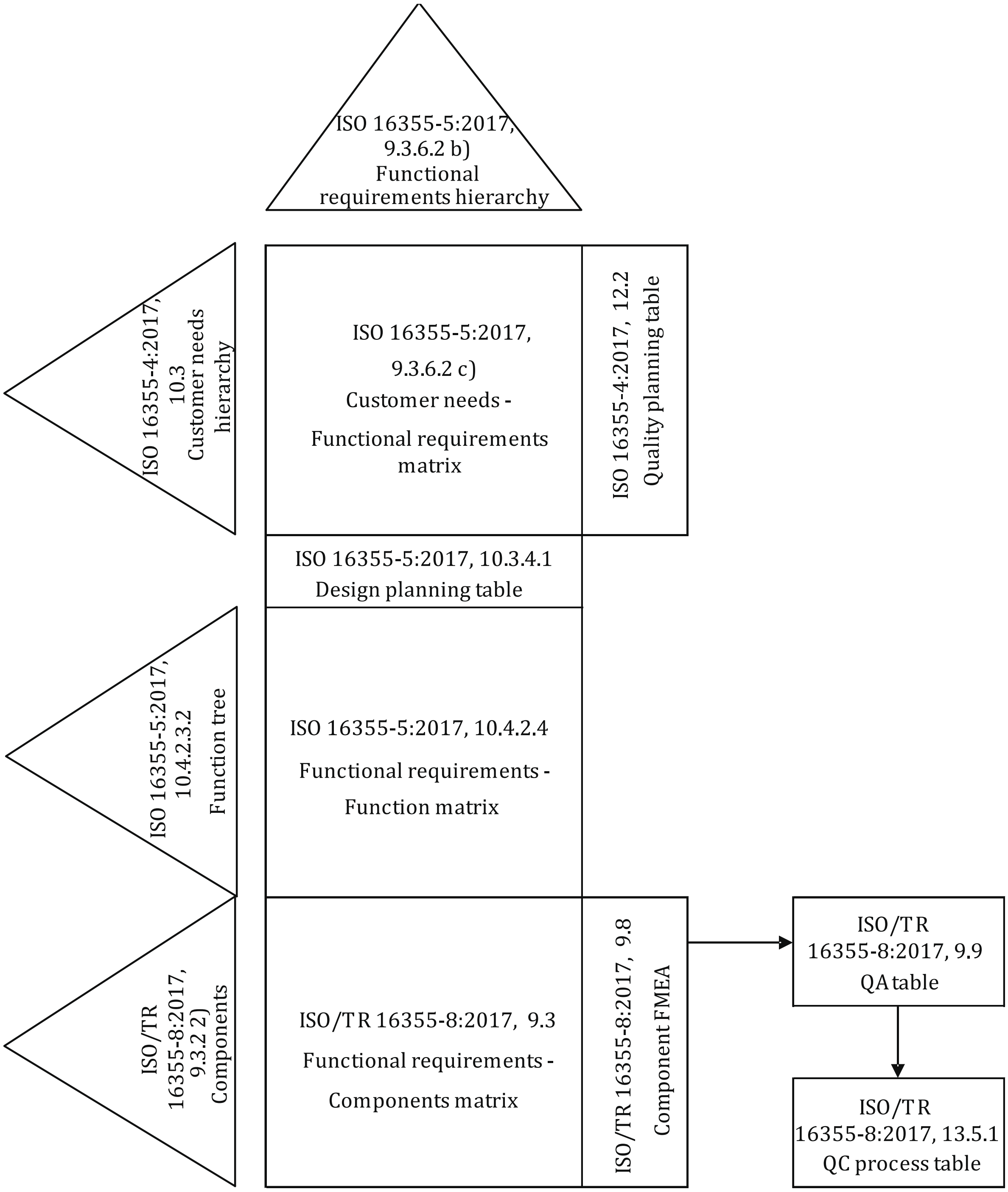


NOTE 1 See Figure 3 for Key Table.

NOTE 2 Source: JIS Q 9025, Figure 2.

Figure B.2 — Total concept chart of quality function deployment

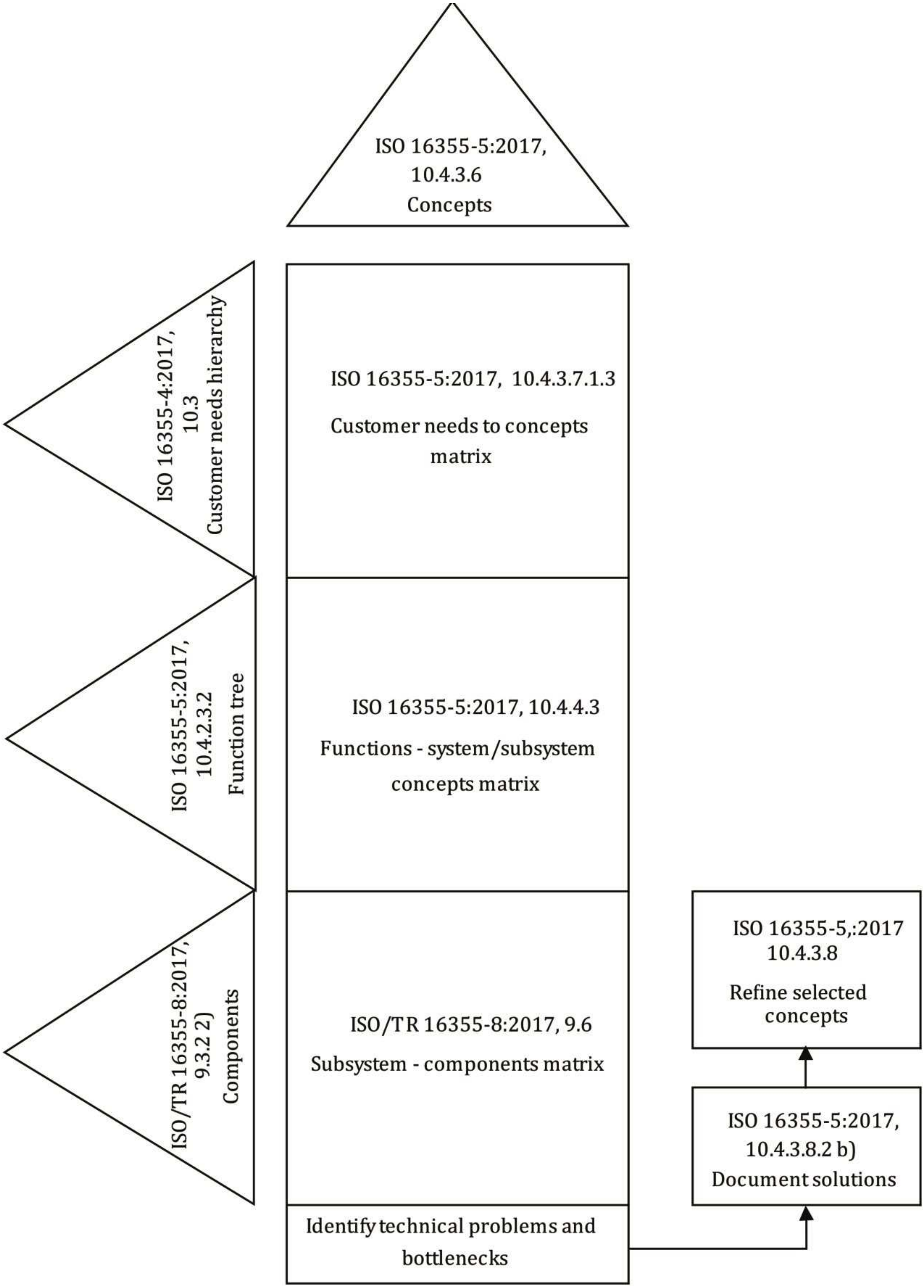
B.4.3 Composition chart of quality deployment (example)



NOTE Source: JIS Q 9025, Figure 3.

Figure B.3 — Composition chart of quality deployment (example)

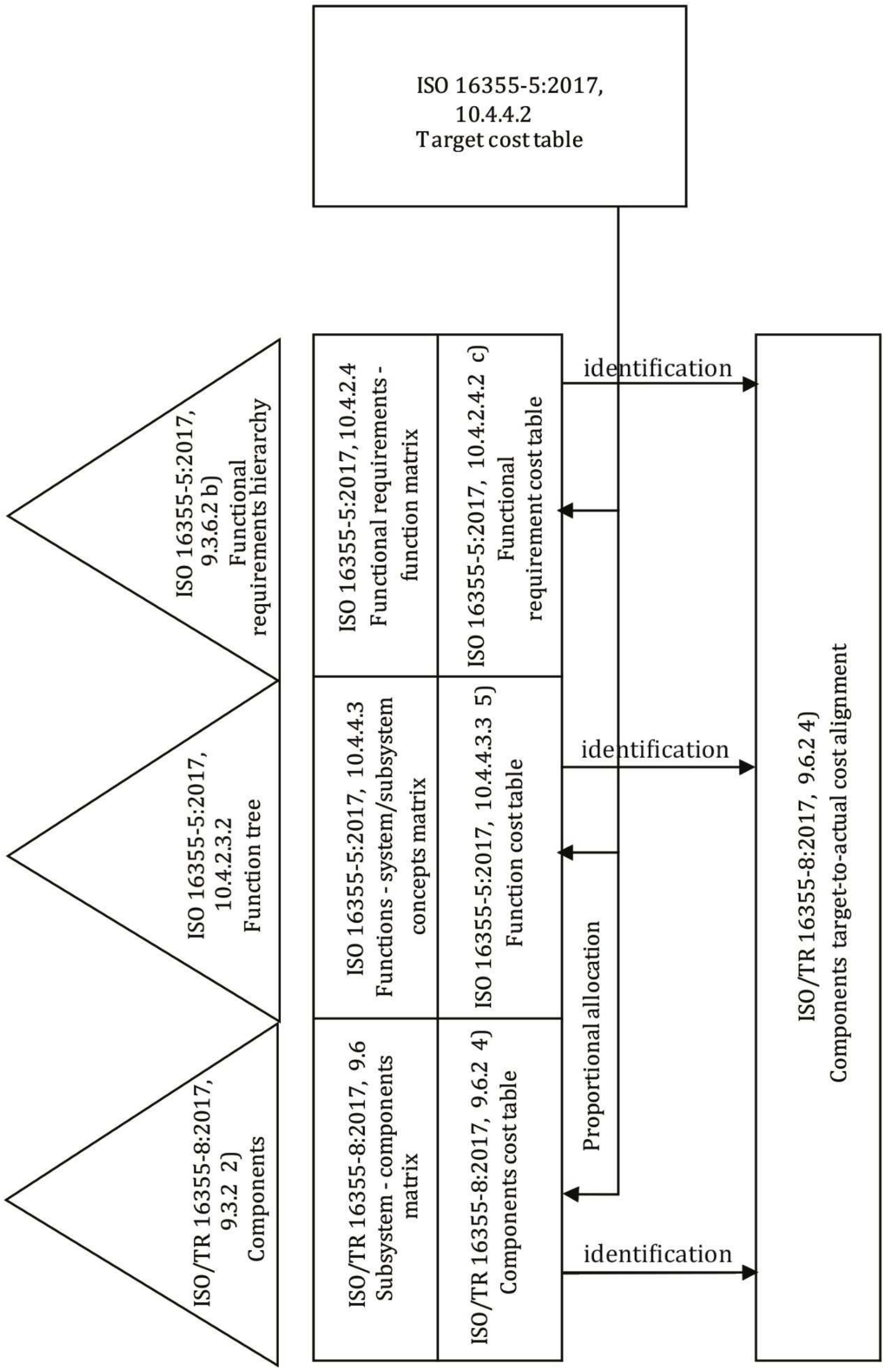
B.4.4 Composition chart of engineering deployment (example)



NOTE Source: JIS Q 9025, Figure 4.

Figure B.4 — Composition chart of engineering deployment (example)

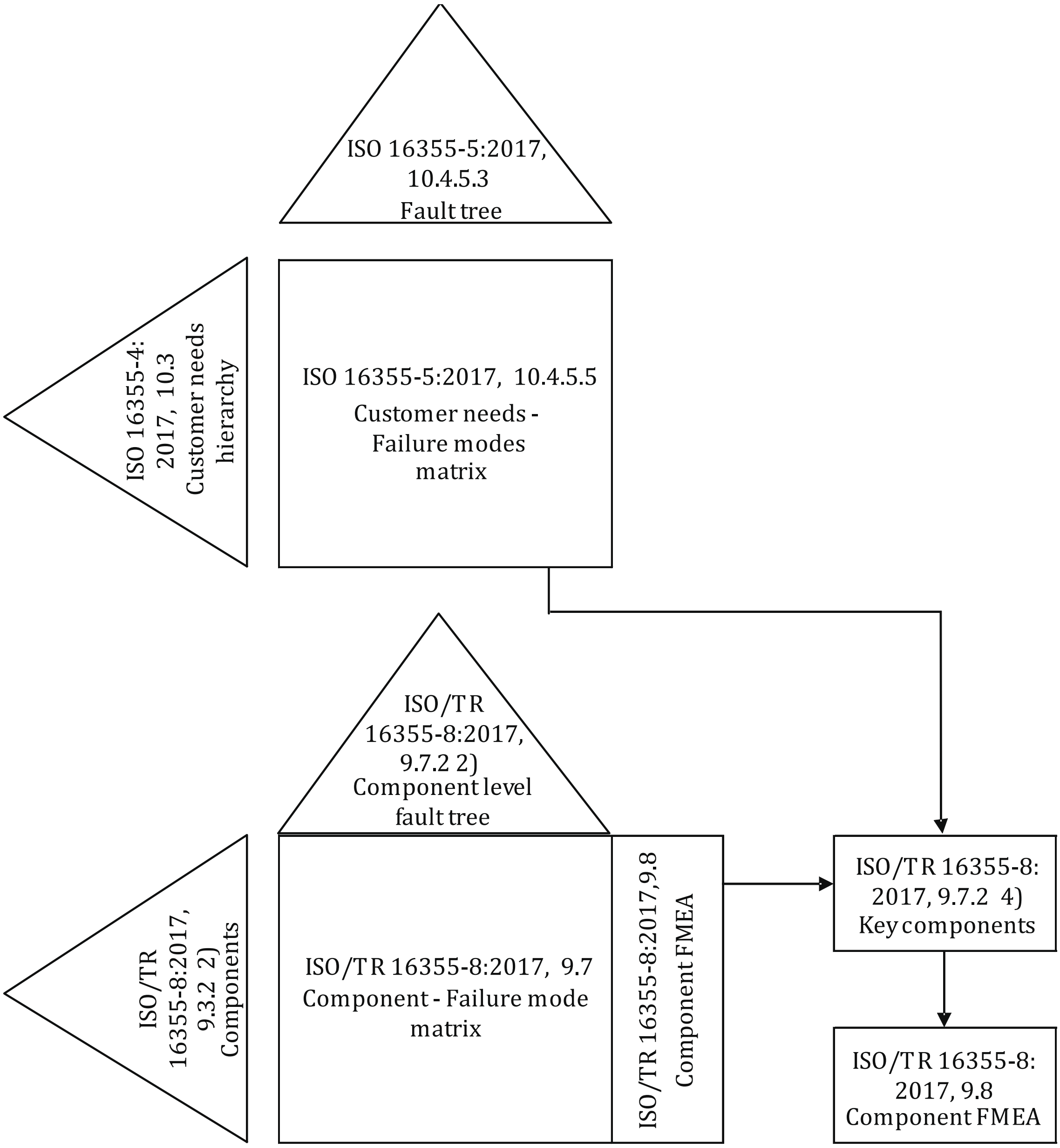
B.4.5 Composition chart of cost deployment (example)



NOTE Source: JIS Q 9025, Figure 5.

Figure B.5 — Composition chart of cost deployment (example)

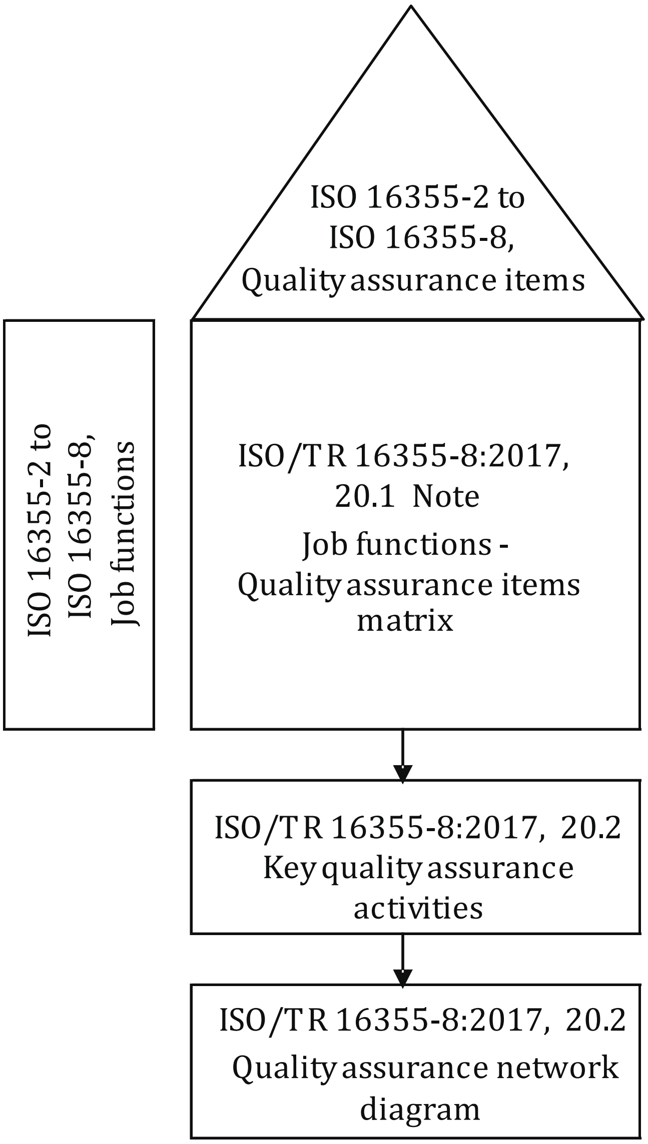
B.4.6 Composition chart of reliability deployment (example)



NOTE Source: JIS Q 9025, Figure 6.

Figure B.6 — Composition chart of reliability deployment (example)

B.4.7 Composition chart of job function deployment (example)



NOTE Source: JIS Q 9025, Figure 7.

Figure B.7 — Composition chart of job function deployment (example)

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4) Under preparation.

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