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

Part 4: Analysis of non-quantitative and quantitative Voice of Customer and Voice of Stakeholder

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National foreword

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

Part 4: Analysis of non-quantitative and quantitative Voice of Customer and Voice of Stakeholder

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

Partie 4: Analyse du retour client (Voice of Customer) ou du retour des parties prenantes (Voice of stakholders) quantitatif et non-quantitatif

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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 the 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 should 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, and 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 have found that these improvements make QFD easier and faster to use. The methods and tools shown and referenced in this document represent decades of improvements to QFD; the list is neither exhaustive nor exclusive. Users should 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.

INTERNATIONAL STANDARD ISO 16355-4:2017(E)

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

Part 4: Analysis of non-quantitative and quantitative Voice of Customer and Voice of Stakeholder

1 Scope

This document describes the analysis of the voice of the customer (VOC) and the voice of the stakeholder (VOS). These include translation of VOC and VOS into true customer needs, prioritization of these needs, and competitive benchmarking of alternatives from the customer's perspective. This document also provides recommendations on the use of the applicable tools and methods.

Users of this document include all organization functions necessary to ensure customer satisfaction, including business planning, marketing, sales, research and development (R and 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 the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 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 Basic concepts of QFD

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

5 Integration of VOC and VOS analysis 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 product development with VOC and VOS analysis

5.2.1 Organization of the VOC and VOS analysis

The flow of VOC and VOS analysis 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.

5.2.2 Outline of VOC and VOS analysis

Figure 1 illustrates the organization of the clauses of this document. Here is an outline of the specific steps and their respective clause numbers. Further in the document, each clause describes the step and suggests applicable methods and tools with guidance that can be used to accomplish the step.

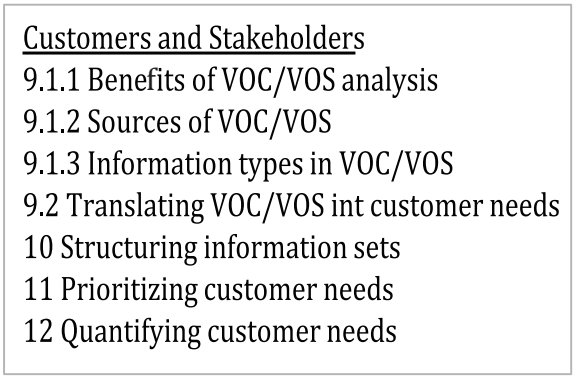

Figure 1 — VOC and VOS analysis outline

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.

7 VOC and VOS analysis team membership

7.1 VOC and VOS analysis 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.

7.4 VOC and VOS analysis team leadership

VOC and VOS analysis teams can be led by members of business functions such as sales, marketing, market research, customer service, customer support, and others with firsthand knowledge or contact with customers and stakeholders.

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

8 Seven management and planning tools

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

9 Analysis of the voice of customer (VOC) or voice of stakeholder (VOS)

9.1 General

9.1.1 Benefits of VOC and VOS analysis

The benefits of VOC and VOS analysis include the following.

a) Simplify complex statements into single issue statements.

EXAMPLE A VOC can state that the process should be "quick and easy," but are both equally important? The VOC should be simplified into "quick" and "easy" so that the customer can prioritize more precisely.

b) Discover unspoken or latent customer or stakeholder needs.

EXAMPLE A VOC can state that the customer wishes to tag photographs with meta information. It is reasonable to conclude that the customer can also with to tag videos, music and audio, and other types of non-text information for ease of retrieval.

c) Improve accuracy of prioritizing which customer needs matter most.

Accurate prioritization requires having subject matter knowledge. Generally, customers have more knowledge about their needs than about solutions. Similarly, producers have more knowledge about solutions than customers. So, if VOC or VOS is about a solution, translating it into a need first helps customers prioritize more accurately.

EXAMPLE A VOC for web access states account should have no more than one screen to login, and should have high security. Both are product functions of ease of access and user account security. Translating these into customer needs, these could mean "I can login quickly just to check on my bank balance while at the register", and "my money is safe when making online payments." Depending on the use case, there would be different priorities, and it would be more accurate for customers to prioritize these statements as needs rather than as product functions.

d) Quantify current and hoped for levels of satisfaction.

EXAMPLE A customer buying a laptop computer can more easily state a desire to store twice as many photographs as now, rather than needing a 500 GB hard drive.

e) Benchmark alternatives.

EXAMPLE A customer can more easily relate to how many photos can be stored on one laptop vs another model.

f) Identify selling points.

EXAMPLE Sales promotion and labelling can point to photo storage capacity instead of hard drive size.

g) Keep from arriving at solutions too quickly.

EXAMPLE If solutions are identified before key stakeholder needs have been clarified, then the ability to reconfigure the solution to satisfy missing needs can be precluded. As an example, in information and communications technology (ICT) solution designs, key information access needs can be blocked if extreme information security measures have been committed too early in the solution design. Similarly, if information access needs are translated into solutions independently of consideration of security needs, then solution security vulnerabilities can be introduced that are difficult or costly to address during solution development.

h) Assure solutions are complete.

This ensures consistent quality in the solutions developed later in the product development process.

EXAMPLE A VOC for an industrial vehicle is for a 2,8 m lift height. What the customer forgets to mention is that the loads typically weigh 250 kg and at that height would cause the vehicle to tip. By translating this product specification into a customer need of "I can maximize the footprint of the storage facility," the QFD team was able to determine other product specifications related to centre of gravity, swing arc, mast diameter, and others missing from the original VOC.

i) Greater solution options.

EXAMPLE A VOC for hot coffee translated into "It is cold outside and I want to feel warm." The QFD team identified other solutions for feeling warm, such as alcohol and spice.

j) Predict satisfaction with different solutions.

EXAMPLE A VOC for greater maneuverability of a farm tractor was more clearly understood when translated into customer needs related to the soil type and travel speed. These identified different turning radii that could later be tested in the field.

9.1.2 Sources of VOC and VOS

ISO 16355-2 and ISO 16355-3 identify potential sources of VOC and VOS that include, but are not limited to, the following:

a) customer process model things-gone-right and things-gone-wrong;

b) customer gemba table clarified items;

c) customer support and help systems;

d) customer supplied specifications;

e) focus groups;

f) social media;

g) free response questionnaires;

h) interviews;

i) customer satisfaction surveys and sampling surveys;

j) lead user analysis;

k) warranty returns, scrap, maintenance records, unplanned field failures, and complaints;

l) sales, maintenance, and technical visit reports;

m) ethnographies;

n) continuous QFD and collaborative QFD;

o) design thinking;

p) conference papers, reports, and journals;

q) market research;

r) big data;

s) gender mainstreaming analysis.

9.1.3 Information contained in VOC and VOS

9.1.3.1 General

VOC and VOS is raw, unprocessed information from the customer or stakeholder. It often includes complaints, needs, functional requirements, performance specifications and targets, solutions, components, materials, activities, information, and other customer or stakeholder statements. The following are examples of different statements or narratives in VOC and VOS. These vary according to the product, service, information technology, or process, but the following are common.

NOTE To be most useful, these can be sorted, analysed, structured, quantified, and prioritized by key customers.

9.1.3.2 Customer or stakeholder use

Information related to customer or stakeholder segment or attributes, modes or environment of use or use case.

EXAMPLE Customer is certified or chartered public accountant working on end-of-year financial statements. Some tax law changes have not been published.

9.1.3.3 Customer needs

The benefit to a customer from having their problem solved, their opportunity enabled, their image (to oneself or to others) enhanced, or being advanced to a more desirable state. Customer needs should be positively stated if possible, and independent of the product.

NOTE A customers need explains why a customer wants something, not what a product does.

EXAMPLE I must ensure my client follows all applicable tax codes. I must ensure all applicable tax forms are filed on time.

9.1.3.4 Functional requirements

Inherent performance of the product or an action that the product must be able to accomplish. The manner in which the product accomplishes the action is not part of the functional requirement.

NOTE 1 Can be expressed as a capability.

NOTE 2 Some QFD texts call this a quality element or substitute quality characteristic.

EXAMPLE Tax reporting software must be up-to-date within 24 h of changes. Tax reporting software must flag for tax preparer all applicable changes in tax code since last filing for client.

9.1.3.5 Function

Specific statement of what needs to be done, expressed as a verb plus noun (English), without specifying how to accomplish it. Can be mechanical, human, or software.

EXAMPLE Support weight.

9.1.3.6 Technology

A specific way to enable a function.

EXAMPLE For the function transfer data, technologies include Ethernet, Bluetooth, Wi-Fi, 4G.

9.1.3.7 Reliability or failure mode

Function or performance expected life, or inability to meet that expected life.

EXAMPLE Product shall have mean time between failures (MTBF) of 1 000 h.

9.1.3.8 Subsystem or component

A part of the product.

EXAMPLE Product filter is replaceable.

9.1.3.9 Material

What the product is made from.

EXAMPLE Stainless steel.

9.1.3.10 Test or regulation

Must meet or pass a test or regulatory requirement.

EXAMPLE 1 Must meet TG-53 and TG-101 regulations.

EXAMPLE 2 Perform routine regulatory analysis and reporting.

9.1.3.11 Process

Steps, jobs, and tasks the product engages.

EXAMPLE 1 Exposed areas shall be treated with corrosion resistant coating.

EXAMPLE 2 Provide management with consistent, yearly, performance trending benchmarks both internally and externally against available industry peer groups across key operating metrics.

9.1.3.12 Cost

Monies associated with selling price, indirect expenses such as facilities, administration, and equipment, and direct expenses associated with labour, components (purchased or internally sourced), energy, disposal.

EXAMPLE Target price = € 17.

9.1.3.13 Manufacturing or build methods

Equipment, facilities, methodologies, and techniques concerning how the product is to be made.

EXAMPLE Sonic welding instead of adhesive.

9.1.3.14 Measurement methods

Methods, equipment, gauges, templates, and their maintenance.

EXAMPLE Must use coordinate measuring machine (CMM) on 1 m concrete base.

9.1.3.15 Quality

Quality assurance, quality control, inspection, and problem solving methods and skills.

EXAMPLE Must follow APQP (advanced product quality planning) phases.

9.1.3.16 Schedule

Time associated with development, build, or launch durations, milestones, and deadlines.

EXAMPLE Start of production by second quarter of 2020.

9.1.3.17 Support

Post-purchase on-site or off-site advice or supplies related to installation, troubleshooting, upgrades, supplies, and related activities.

EXAMPLE Telephone support 24/7 in local language.

9.2 Translating VOC and VOS into customer needs

9.2.1 General

QFD project teams constrained by resources, budget, and time should focus their efforts where they matter most to the customer. The customer, not the QFD team, should determine these priorities whenever possible. To get accurate priorities, VOC should be translated into an information set about which the customer has greater domain knowledge – customer needs. To derive true customer needs, identify and separate customer from product related from the customer or stakeholder.

NOTE 1 Clear separation of needs and product can lead to more flexibility and innovation in finding appropriate solutions for the customers and stakeholders.

NOTE 2 Some VOC and VOS are already customer needs. They do not need to be translated, but they can be simplified to single issues, which improves the accuracy of the prioritization.

NOTE 3 Some QFD studies interchange the terms customer needs and customer benefits.

NOTE 4 Some QFD studies interchange the terms product and features.

9.2.2 Verbal translation

When the VOC or VOS is about the product, verbally translate back to the underlying need that explains why the customer made that statement.

EXAMPLE In a visit to a supplier of brake components, a customer mentions that the assembly area is extremely hot and humid. This VOC can be examined as follows.

a) Convert negative statement of too hot and humid into air conditioned clean room (process conditions).

b) Air conditioned room reduces perspiration contamination from workers (process failure).

c) Perspiration damages the stainless steel surface (material).

d) Of the brake cylinder (component).

e) An undamaged surface improves its corrosion resistance (durability).

f) Corrosion resistance improves the service life (reliability).

g) Reliability ensures required compressing of brake fluid (function).

h) In an emergency (customer use case), reliable compressing makes the vehicle stop smoothly (customer need).

9.2.3 Cause-to-effect diagram

Early QFD studies used a cause-to-effect diagram to show the relationship between product and needs. [10] Product features cause a need to be fulfilled. So, if the VOC or VOS statement is about product, service, software, or process characteristics, then the statement is a causal factor. The diagram can help the QFD team determine what effects result if the cause is fulfilled. Essentially, the process is a

positive cause-and-effect diagram, where proper product design produces a positive effect: a satisfied customer need. This is the fundamental concept to translate VOC and VOS into customer needs.

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 and effect-to-cause, which is explained later in ISO 16355-5. Note that the arrows point from the causal factor to the effects.

NOTE 2 The causal factors can also relate with each other. Understanding these relationships can improve the translation into customer needs.

EXAMPLE In this example, a customer enters a café requesting a hot cup of coffee. Parsing the VOC into each phrase, Figure 2 illustrates the translation of the word hot. The word hot describes the product coffee so it is a causal factor. Then, ask the customer why they want hot coffee. The responses are the desirable effects of I am cold and want to feel warm, I am tense and want to feel relaxed, I feel dehydrated and want to feel steamy, and I feel rushed and want to sip slowly for a long time.

NOTE 1 It is possible to meet the customer VOC with a cup of coffee that is 99 °C. However, it would be too hot to drink so the above benefits would be delayed. The product meets the stated VOC but fail to provide the sought-after benefits.

NOTE 2 If the customer need is to feel warm, there are other technical solutions besides temperature, such as alcohol (Irish coffee), spice (capsicum, curry), a squeezable cup that provides exercise, and others. By understanding the true customer need, there are more options for the design team to consider.

NOTE 3 Additional diagrams can be made for “cup” and “coffee.”

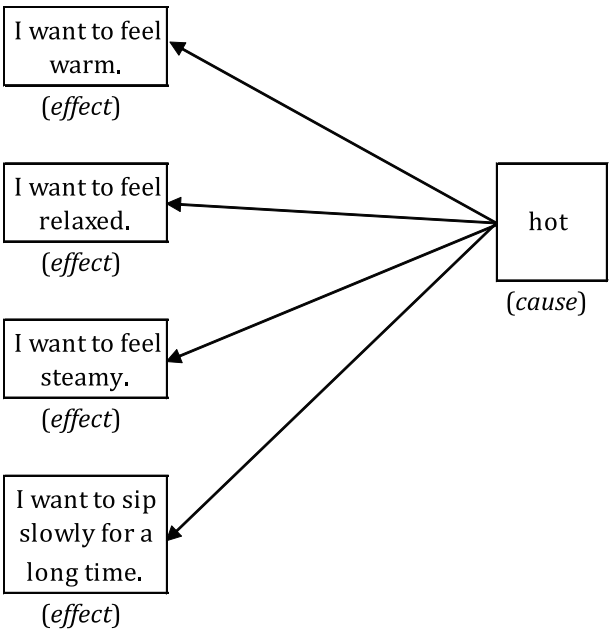

Figure 2 — VOC/VOS translation for a café using cause-to-effect diagram

9.2.4 Customer voice table

Either the verbal translation or the cause-to-effect diagram can be displayed in a spreadsheet or customer voice table. The translation process is the same; take the VOC or VOS and uncover the underlying customer needs.

EXAMPLE 1 Table 1 is an example of a simple customer voice table for a breakfast service kiosk in an airport.[8] The left portion of the table captures VOC narratives from a business traveller market segment trying to decide what to eat for breakfast and if they have enough time. First the QFD team determines if the VOC narrative is a customer need or a product requirement. The first VOC narrative of "do you have anything more interesting than plain bagels" (a type of bread) is a product requirement so the broken line indicates that his should be copied to the product side of the table on the right. Variety is not a specific design requirement but rather a broader functional requirement, it is entered into that column. Following the solid lines, the functional requirement is translated back into the underlying benefits in the customer needs column. The logic here is that if there are more varieties, the customer can get a taste they like, make a healthy choice, and get an appealing choice.

Table 1 — Customer voice table for airport food kiosk

	Customer			Product	
Segment	**Customer task**	**VOC narrative**	**Customer needs**	**Functional requirements**	**Design requirements**
Business travelers	Decide whether to order bagel	"Do you have anything more interesting than plain bagels?" <# varieties>	I can get a taste I like	more than plain bagels - # varieties	
			I can make a healthy choice		
			I can make an appealing choice		
		"Can you toast my bagel?" <# heating options>	I get the best breakfast today	Even, golden brown color <bagel color>	"Can you toast my bagel?" <# heating options>
	Decide if enough time to eat	I want food that's fast to buy <time to be served>	I must get to my plane on time	fast time to buy - time to be served	
		Late. Don't know if I can get food and make plane	I can make it to next meal	I want something that will sustain me <glycemic index>	

EXAMPLE 2 In Table 2 from the development of a financial services customer relationship management (CRM) system, the section of the customer voice table (CVT) for the end customer segment of interest is used to structure the translation of VOC and VOS statements that are characteristics and capabilities, supporting functional and non-functional, and process and organizational change requirements into customer needs.[13] This is a critical capability for the QFD team as it establishes a coherent solution-wide view of which key stakeholder needs are implied by solution functions and the way the solution should deliver those functions.

Table 2 — Customer voice table for CRM information system

Customer		Solution requirements			
Customer segment	**Needs**	**Characteristics amd capabilities**	**Functional (FR) (architecture & software)**	**Non-Functional (N-FR) (URPS)**	**Process / org. change**
Customer - Private - US Professional - 30 to 40 age group (20%)	Customer needs service information presented clearly in way they can compare	Service Information easy to access and compare	Presents information in standard format. Allows service info. To be compared.	Usability: Easy for customer to compare service profile description. Service Catalogue Flexible Presentation of services **Supportability**: Supports customer enquiries in all countries/ languages. Service Catalogue configuration Controlled centrally.	Service Description Standards Comparison with other Providers evaluated
	Customer only has to put in their information once	Single point of entry of customer information - available at all subsequent stages	Customer Data Information Object - accessible at all (C,R)	Usability: Customer only puts in one set of identification data, doesn't repeat this time or subsequent visits	Process Standardisation across Business Units - Customer Data Capture
	Customer taken quickly to appropriate area for new services	Menu Hierarchy allows customer to identify their reason for contact early.	Reason for Enquiry at top level of menu	Easy for Customer to clarify why visiting the site.	Cutomer segment preferences for strucure of menu identified.

NOTE 1 Later in the QFD process, customers are asked to prioritize their needs. If a VOC or VOS is mistranslated, it probably receives a low priority and is not acted upon. Should it receive a high priority, then the QFD team has uncovered an unspoken, latent requirement with a potential for competitive differentiation.

NOTE 2 If useful, more detailed columns can be added to the right portion of the table to classify narratives relating to components, materials, processes, and similar information categories shown in 9.2.2.

10 Structuring information sets

10.1 General

To obtain accurate, unbiased, and unambiguous prioritization and quantification, and to reduce the effort of both customers and team members to obtain this, information should be organized into a logical structure. Structuring should be done by members of the group that own the information set and have greater domain knowledge. Customer needs should be structured by the customer.

10.2 Affinity diagram

10.2.1 General

When there are many customer needs, an affinity diagram can be used to manage them. The affinity diagram allows customers to group their needs in a way that makes sense to them. This diagram is built bottom-up so that first, the cards are grouped according to a shared affinity determined by the customers and then descriptive header cards are created to describe the each card group's common theme. The customer needs affinity diagram is built using the KJ™[1)] method developed by the Japanese anthropologist Kawakita Jiro (hence the name KJ) following these steps.

10.2.2 Steps to make an affinity diagram

The steps to create the diagram are as follows.

a) Write each customer need on a separate card.

b) Have customers silently group the cards where they make most sense.

1) KJ™ 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.

c) Label each group of cards with a description of their common theme.

EXAMPLE 1 Figure 3 shows a health insurance provider example. The customer is a company employer offering health insurance plans to its employees[3]. One group of customer needs, such as my employees, appreciate the benefits I provide them and keep my employees and their families healthy are grouped with the label employee satisfaction.

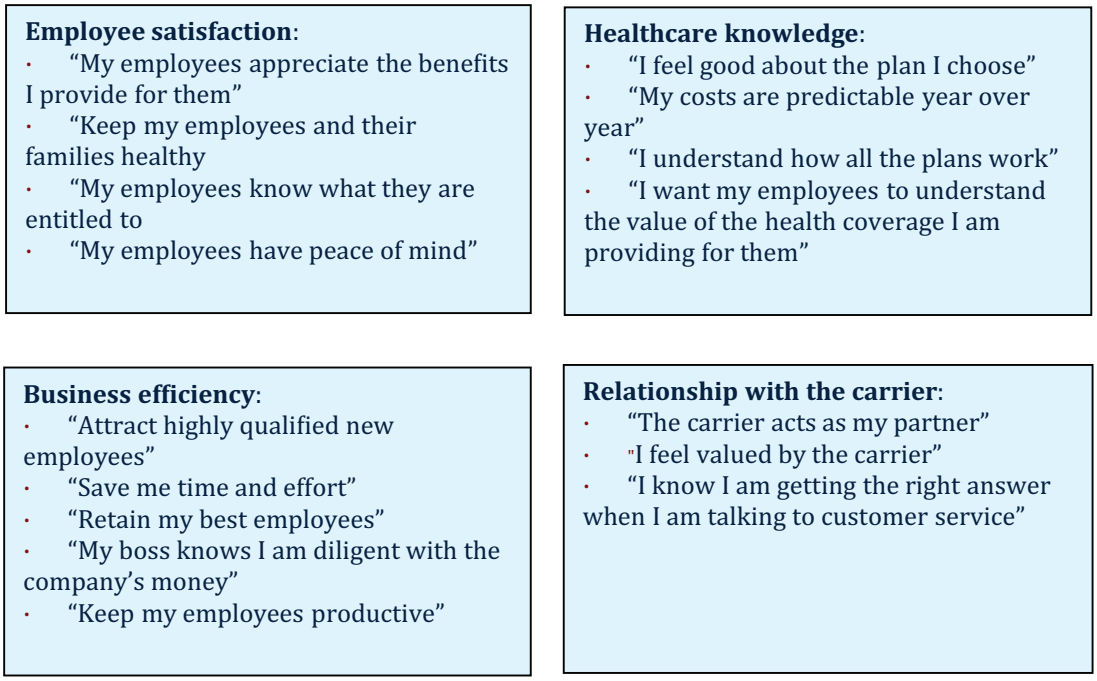

Figure 3 — Affinity diagram for health insurance provider

NOTE In QFD studies on internal business processes, group labels can already be established.

EXAMPLE 2 An electrical power generation utility uses the following group labels for internal operations:

a) safety — safe to use, safe for employees;

b) quality — free of errors, defects, and mistakes;

c) cost — value equals or exceeds price;

d) delivery — output received when needed;

e) public responsibility — accountable to communities served;

f) other factors commonly used in Six Sigma projects such as critical-to-quality (CTQ) or some other category of critical-to-x (CTX).

10.3 Hierarchy diagram

10.3.1 General

The customer needs hierarchy diagram is used to address any structural issues with the customer needs affinity diagram. This is important for finding unspoken or missing customer needs, as well as improving the accuracy and efficiency of the prioritization process. The hierarchy diagram is used to display and organize customer needs from very vague needs on the left to more specific, measurable needs on the right. Measurable needs can be confirmed during product development, as well as routinely monitored after the product goes to the customer to determine how well the actual product is performing against the customer needs.

Information set structuring should ensure that information groups are mutually exclusive and collectively exhaustive (MECE) to ensure no overlapping or missing elements. Overlapping or missing elements can reduce the accuracy of later analyses such as prioritization.

10.3.2 Steps to make a hierarchy diagram

The steps to create the diagram are as follows.

a) Rotate the affinity diagram counterclockwise 90°. This makes the following steps easier.

b) Starting from the left (called the primary level), confirm that the customer needs labels have the same level of abstraction; adjust if necessary.

c) Determine if there are any missing needs at that level of abstraction that should be added.

d) Repeat at each level to the right for the secondary and tertiary levels.

e) Review with customer, especially in business-to-business products and internal business process projects, to validate those customer needs are agreed upon by both customers and suppliers.

NOTE Needs can later deploy to contractual requirements formally detailing process output standards agreed upon by both parties. These are also known as specification limits or service level agreements (SLA) and usually include specific performance measures and targets

EXAMPLE Figure 4 is from the financial services company CRM development[13]. The hierarchy diagram of the customer and stakeholder needs shows three levels of the hierarchy: primary, secondary, and tertiary. A missing need from the prior customer voice table and affinity diagram analyses has been added during discussion with the customer.

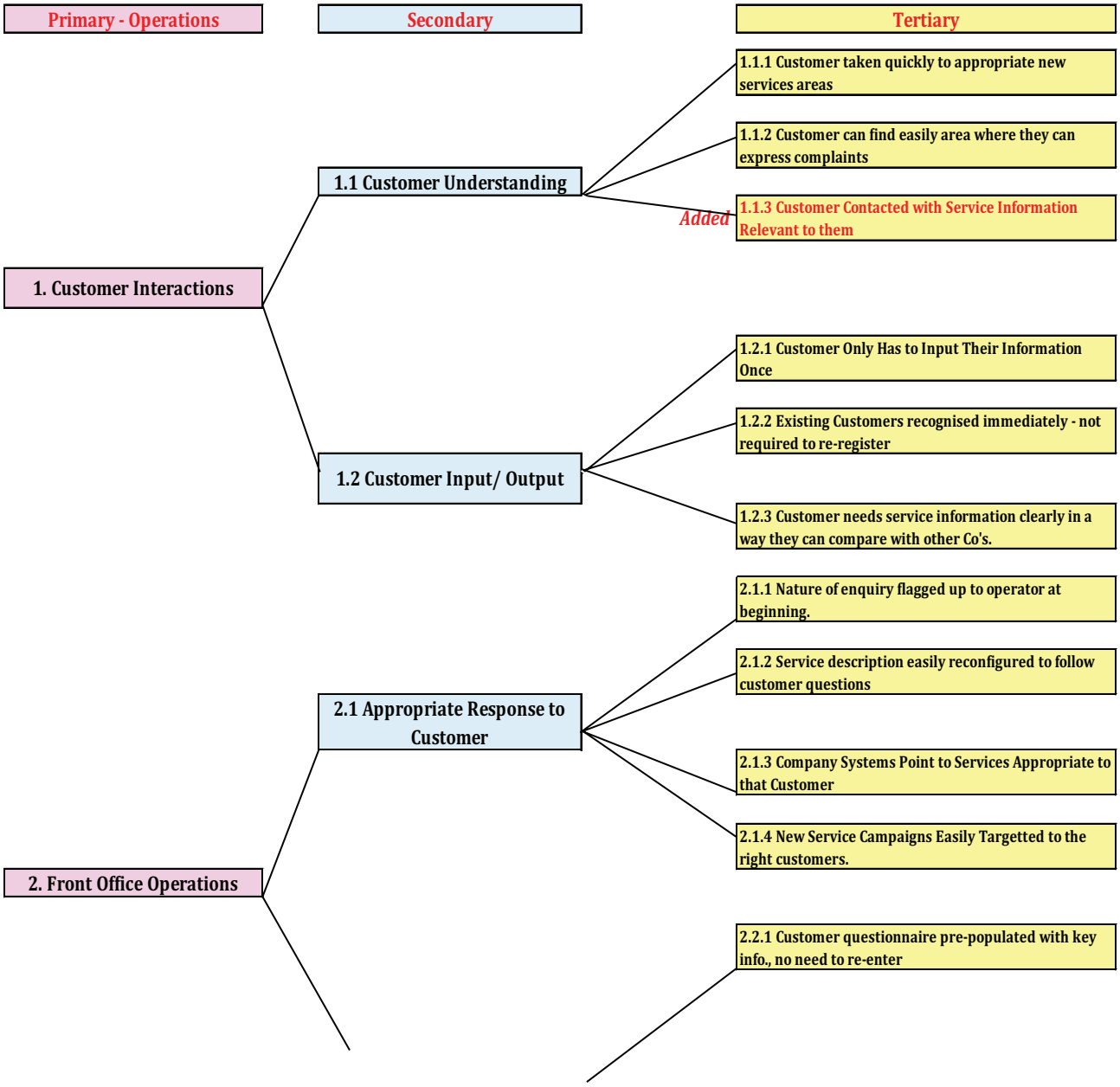

Figure 4 — Customer needs hierarchy diagram for CRM information system (partial)

11 Prioritization

11.1 General

In order to focus where maximum benefit to customers or stakeholders is provided with minimal effort by the QFD team, prioritization of the information set should not be neglected. Priorities should 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 should not be ignored.

NOTE 1 Prioritization is done by the group that "owns" the information. For example, customer needs are 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. AHP also gives customers a forced-choice, paired comparison model that yields more accurate results because they cannot say "everything is important." Finally, when applied to a hierarchy as explained below, the prioritization process is broken into smaller groups which is less fatiguing than presenting customers with a single, long list of needs to rate on an ordinal scale.

NOTE 3 Other statistical methods can be applied to prioritize customer needs, such as multiple correspondence analysis.

EXAMPLE 1 An example of an absolute ratio scale is distance. 2 km is twice the distance of 1 km. Thus, ratio scales values can be multiplied, as well as other mathematical functions.

NOTE 4 Ordinal scale values do not contain sufficient information to perform these mathematical functions properly. There are several problems: 1) 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 closer to equal as shown in Figure 5), 2) because of the inequality or ratios, ordinal scales tend to bias towards the higher values. Thus, ordinal scale values cannot be divided, nor can most other mathematical functions. 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.

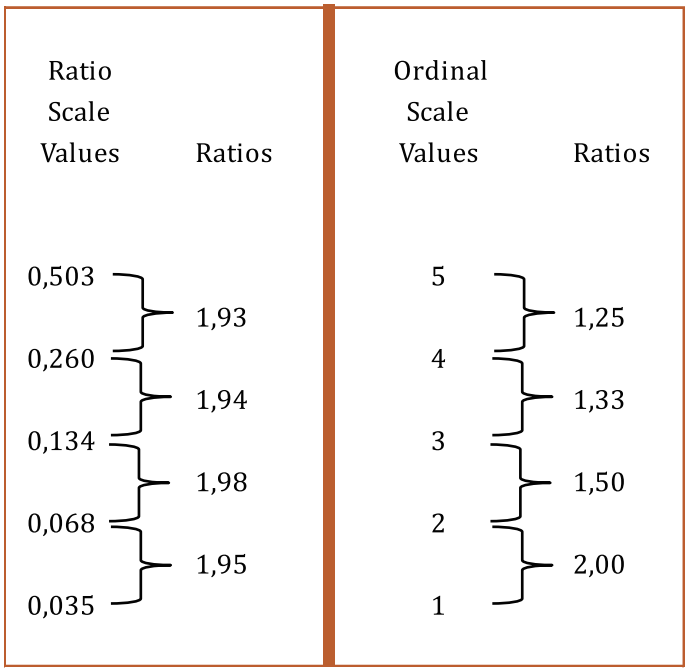

Figure 5 — Equality of ratio: ratio scale vs ordinal scale

EXAMPLE 2 An example of an ordinal scale are the Olympic medals: gold, silver, bronze for first, second, third place, respectively. While gold is better than silver, one cannot say that the athlete was two times better as the ordinal scale of first to second place might suggest. It depends on the event, the actual performance scores, times, and other factors.

NOTE 5 Those preferring 1 to 5 scale surveys can still survey with ordinal numbers. However, before any mathematical functions are performed, such as averaging, the responses should be converted to ratio scale, as shown in Figure 5. For example, if a customer need received 10 responses of 5 and 5 responses of 4, the ratio scale average would be $(10 \times 0{,}503 + 5 \times 0{,}26)/15 = 0{,}422$.

11.2 Applying AHP to customer needs

QFD asks the customer: are all needs equally important or are some more important than others? If one just hands the customer a list of needs, they are likely to dismiss the question with "they are all important." This is not helpful to a product realization team that must focus its limited resources. Classical QFD uses a five-point ordinal scale similar to a Likert scale so that customers can rate their

needs. Ordinal scales do not have defined intervals and contain sufficient information only for modal counts or median calculation. Without defined intervals, other QFD mathematical operations such as addition, multiplication, division, and averaging have no meaning. Ratio scale priorities do permit these operations. Modern QFD uses AHP to derive ratio scale priorities by having customers choose between pairs of needs and determine which of the pairs is more important and by how much. Customers are encouraged to rate using a verbal scale (equally important, moderately more important, strongly more important, very strongly more important, and extremely more important) which the QFD team then substitutes numbers (1, 3, 5, 7, 9, respectively) in a decision matrix. AHP calculates the eigenvector of the decision matrix to closely approximate the relative priorities of the customer needs. AHP is preferred to central tendency theorems as it can also report on judgment inconsistency (a > b, b > c, c > a); less than 10 % inconsistency is acceptable. Responses from multiple customers can be averaged using the geometric mean, which is then entered into cells of the decision matrix. AHP can be applied to the customer needs hierarchy.

NOTE It can be useful in some product upgrade projects to phrase the paired questions as which is "more important to improve" rather than which is "more important." "To improve" implies that the current state is insufficient while "important" says nothing about the current state. In QFD, important and insufficient is generally more urgent than important and sufficient.

11.3 Steps to AHP using a spreadsheet

The steps when using a spreadsheet are as follows.

a) Arrange the set of information to be prioritized (in this case, customer needs) so that the same information appears in both the rows and columns of a spreadsheet grid.

b) Ask the customer to compare the need in the row to the need in the column by first stating which is more important, the row or the column, and then how much more important using the verbal scale above. The corresponding number (1, 3, 5, 7, 9) is entered into the grid. If the row is more important, enter an integer; if the column is more important, enter a fraction. In the example in Table 3, the third column need "customer contacted with service information relevant to them" is moderately more important than the first row need of "customer taken quickly to appropriate new services areas"[13]. Thus, the fraction 1/3 is entered in the upper right cell of the decision grid, and a 3 is entered in the lower left.

NOTE 1 The diagonal of the grid where each need is compared to itself always contains 1. Values to the lower left of the diagonal are always the inverse of the cells in the upper right. There is no need to ask customers to score the diagonal or lower right, as these are computed from the responses to the upper right cells.

NOTE 2 Where there is more than one respondent and a consensus score cannot be reached, it is permitted to average the votes of the respondents for each cell. Since the scale goes from a minimum of 1/9 to a maximum of 9, the scale is nonlinear and the geometric average should be used instead of the arithmetic average. The geometric average is calculated as the nth root of the product of the votes, where n = the number of respondents.

c) The eigenvector can be approximated from the row average of the normalized columns (RANC). To normalize the columns of the response grid, sum each column and divide each cell by the column sum. Then sum each row of the normalized columns and average. This row average represents the ratio scale weight of each need relative to the others.

NOTE 3 Specialized AHP applications can automate these calculations.

Table 3 — Customer needs AHP for CRM information

1.1 Customer Understanding	1.1.1 Customer taken quickly to appropriate new services areas	1.1.2 Customer can find easily area where they can express complaints	1.1.3 Customer Contacted with Service Information Relevant to them	normalized columns			sum	row avg
1.1.1 Customer taken quickly to appropriate new services areas	1	1/2	1/3	0,167	0,143	0,182	0,491	**0,164**
1.1.2 Customer can find easily area where they can express complaints	2	1	1/2	0,333	0,286	0,273	0,892	**0,297**
1.1.3 Customer Contacted with Service Information Relevant to them	3	2	1	0,500	0,571	0,545	1,617	**0,539**
	6,000	3,500	1,833	1,000	1,000	1,000	3,000	1,000
							Inconsistency Ratio	**0,01**

11.4 AHP survey format for customer needs prioritization

In business-to-business products, it can be possible to get customer needs prioritization immediately following the gemba visit. In business-to-consumer products or cases where a larger number of responses are justified, a survey can be conducted by mail, by direct or telephone interview, or online. The customer needs hierarchy diagram in 10.3 should be used to construct the survey. First, survey the most abstract primary level customer needs with paired questions, and then survey each group of secondary branches under each primary. Then survey each group of tertiary branches under each secondary.

NOTE To prevent customer fatigue, first survey secondary branches under high priority primary needs and tertiary branches under high priority secondary needs.

EXAMPLE Figure 6 is an example of a survey mailed to 1 000 businesses that offered health insurance to their employees. In a prior mailing, the primary customer needs shown in Figure 3, the highest priority primary need was employee satisfaction[3]. This figure shows the four secondary branch customer needs of employee satisfaction. Four needs yields the six paired questions. Customers are instructed to select which of the paired questions is most important to improve and by how much, selecting the appropriate verbal expression from equal to extremely more important. The corresponding numbers given in 11.3 are entered into a spreadsheet or AHP software application as integers if the response is on the left side of the pair or the fraction is the response is on the right side of the pair. Multiple responses are averaged using the geometric mean, as explained above.

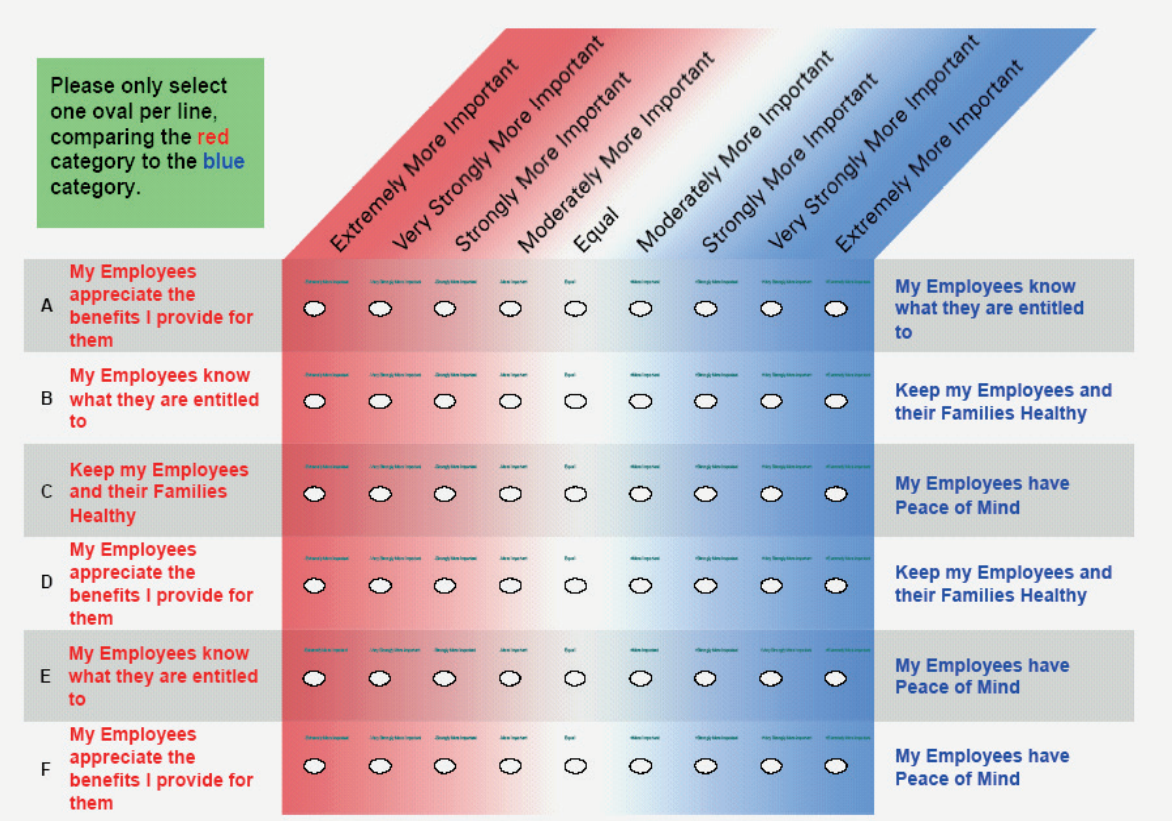

Figure 6 — AHP mailed survey of secondary branch customer needs for health insurance

11.5 Sample size for customer needs prioritization

Quantitative responses should have a sample size that the team believes represents the market they are trying to serve but also respects the time and cost of collecting those responses. Formula (1) calculates a sample size for large populations. QFD team members representing the marketing department can help determine which values to use:

$$n = pq\left(\frac{z}{e}\right)^2 \tag{1}$$

where

n is the sample size to be calculated;

p is the estimated proportion of a variable characteristic;

q is 1-p;

e is the margin of error tolerable (1 %, 2 %, 3 %, 4 %, 5 %);

z is the confidence level desired (if 90 %, then z = 1,64, 95 %, z = 1,96, 99 %, z = 2,58).

NOTE 1 In QFD, variable is likelihood that respondents represent target market segment, where most random case is 50 % to 50 %. The closer to 50-50, the larger the sample size.

NOTE 2 Margin of error is the difference between the sample mean and the population mean. Lower margin of error requires a larger sample size.

NOTE 3 Confidence level is related to standard deviation. Higher confidence levels requires a larger sample size.

EXAMPLE A medical device company has targeted large North American university hospitals in prior QFD steps. They believe that a design that works in this scenario is acceptable to other customers. Their marketing department creates an AHP to survey these hospital staff, and are about 90 % sure the respondents represent large North American university hospitals. Thus, there P = 90 % and q = 100 to 90 or 10 %. They are willing to tolerate a ±3 % margin of error and accept a confidence level of 95 %. Substituting these numbers into the following formula, their sample size of returned surveys should be 384.

(a) $$384 = 0,90 \times 0,10 \left(\frac{1,96}{0,03} \right)^2$$

If the marketing department is willing to tolerate a larger margin of error of ±5 % and lower confidence of 90 %, the sample size shrinks to 97 respondents as shown in the following formula.

b) $$97 = 0,90 \times 0,10 \left(\frac{1,64}{0,05} \right)^2$$

If the marketing department can narrow the respondents to ensure that 95 % represent the target market segment of large North American university hospitals, the sample size shrinks to 51 respondents as shown in the following formula.

c) $$51 = 0,95 \times 0,05 \left(\frac{1,64}{0,05} \right)^2$$

11.6 Applying AHP to a customer needs hierarchy

AHP can be applied directly to a hierarchy. A common use of AHP in QFD is help customers or stakeholders prioritize their needs. AHP helps because customers often find it difficult to give accurate priorities. When presented with a list of needs to be prioritized, customers can quickly tire of the process and start guessing just to get to the end. Since theses priorities drive later allocation of time, people, and money, QFD teams prefer more mathematical precision.

a) Starting with the most abstract level (primary) on the left of the hierarchy, create a pairwise comparison grid of only primary level customer needs. Calculate the priorities as explained in 11.3. This is called a local weight and sum to 100 %. This is shown in Figure 7[13].

b) Create a pairwise comparison grid of secondary level customer needs, separately for each primary need. Calculate the local weights, and then multiply by the weight of its primary parent to get a global weight. Repeat for all secondary level customer needs.

c) Create a pairwise comparison grid of tertiary level customer needs, separately for each secondary need. Calculate the local weights, and then multiply by the weight of its secondary parent to get a global weight. Repeat for all tertiary level customer needs

NOTE It is possible to save time by only calculating for high priority secondary and tertiary level need branches. In such a case, if only high priority needs are deployed further, renormalize the scores to 100 %.

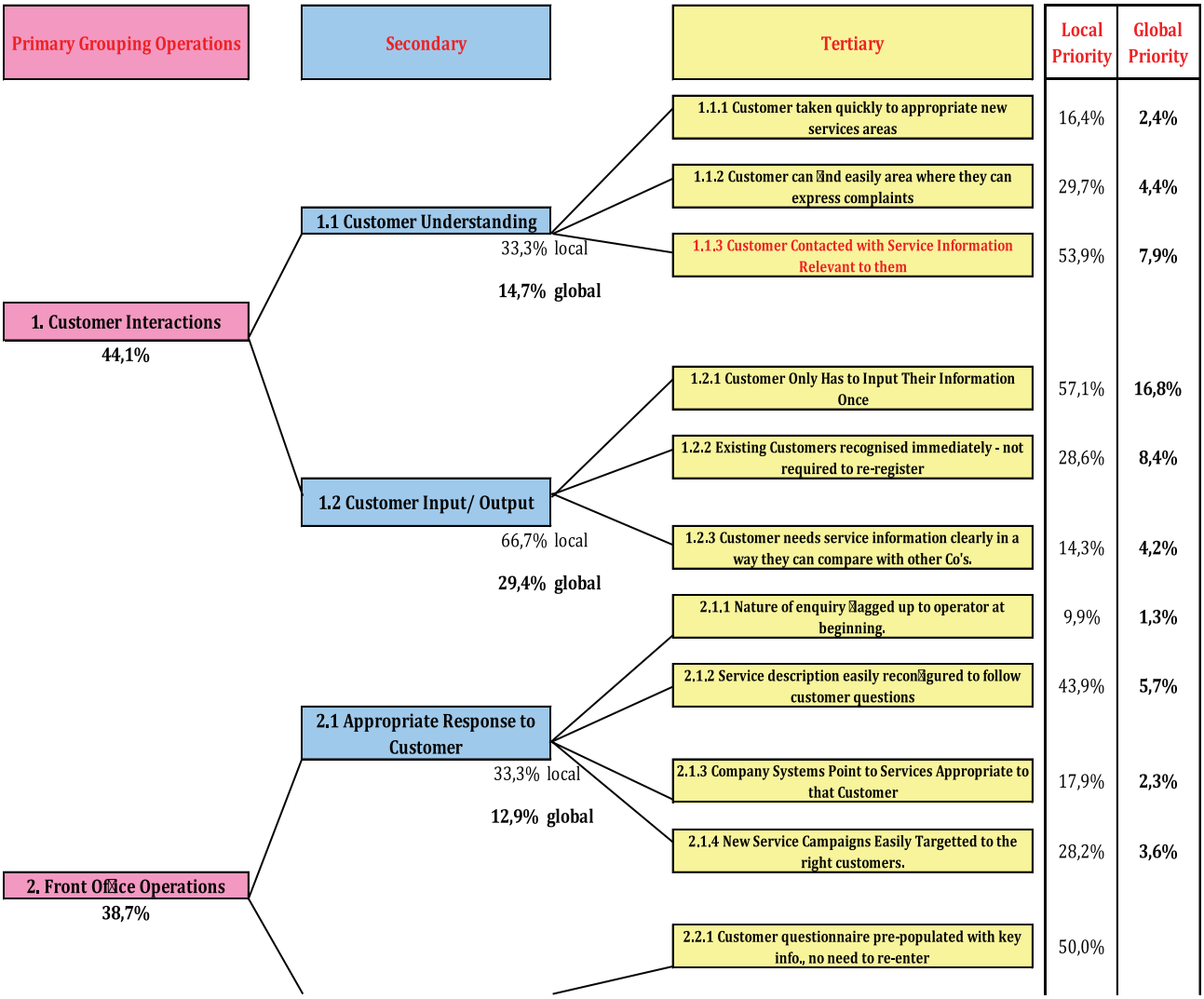

Figure 7 — Weighted customer needs hierarchy diagram for CRM information system (partial)

11.7 Analytic network process (ANP), fuzzy AHP, and fuzzy ANP

When customer needs or other types of information to be prioritized are not mutually exclusive but contain interactions, the ANP can be used instead of AHP[12][6]. Also, when discrete responses are difficult to obtain, fuzzy logic can be integrated into both the AHP and ANP methods Fuzzy AHP[7][4].

12 Quantification

12.1 General

Quantification of customer needs can include customer current and hoped-for satisfaction levels, customer scoring of the magnitude of current product and benchmarking competitive alternatives, and other factors that reflect customer value. Quantification of customer needs can also include minimum acceptance levels (below which there is no real benefit) and maximum thresholds (beyond which there is no additional benefit). Quantifications can be used as adjustments to recalculate customer needs priorities to reflect market opportunities and competitive threats.

12.2 Quality planning table

The quality planning table is used to capture customer perception of current and competitive product alternatives, propose an improvement target, and select potential selling points for later promotion. In classical QFD[1], these were scored with ordinal ratings but modern QFD can also accommodate more detailed information. Other types of information can be added. Since the effort to acquire competitive preferences can be great, it is recommended to begin with the highest priority customer needs. The quality planning can be weighted to adjust the customer need priorities. The modern quality planning table uses AHP to assess the satisfaction and competitive levels in ratio scale that permit the math calculations. Further, the adjustment categories themselves of customer importance, competitive improvement, and sales point can also be prioritized according the purpose of the project.

NOTE The information, current and hoped for measures, and competitive offerings come from the customers. Previous QFD analyses such as the customer process model and gemba visit table are opportunities to get this information directly from the customer at the time of use. Other sources of the information can be gathered in focus groups, surveys, and questionnaires. These are described in ISO 16355-2.

EXAMPLE 1 Table 4 shows the same information as the classical QFD but avoiding the ordinal scale numbers. Instead of a 1 to 5 ordinal rating, customers are encouraged to use a measurement that is meaningful to them. For the airport food service customer need of "I can make a healthy choice," the current, competitive, and hoped for plan describe the current food as junk, the desire for at least one healthy choice, and the competitor offering a protein bar. As in classical QFD, customers can also rate their level of satisfaction using the Likert verbal scale of very satisfied, satisfied, neutral (neither satisfied nor dissatisfied), dissatisfied, or very dissatisfied. The selling point also follows the classical QFD where the sales department member of the QFD team determines one major and two minor sales points to be exploited at the point of sale, in packaging, or in promotions. Finally, a parallel methodology developed by a Japanese quality expert, Noriaki Kano[5] is sometimes included in the quality planning table. While Kano's method tests for product features and the QFD study has not yet progressed to that point, it is still possible to predict whether a feature addressing a customer need is exciting to the customer or just meet a basic expectation.

Table 4 — Unweighted quality planning table for airport food kiosk

		information								
Customer		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	

EXAMPLE 2 Table 9 shows a fully weighted quality planning table but using AHP to calculate proper ratio scale weights. With a large number of customer needs, the information can be quantified and used to adjust the weights of the customer needs. Classical QFD asked customers to score satisfaction and benchmark competitive alternatives using a 1 to 5 ordinal scale. Verbal information such as in Table 4 can also be used. As in other QFD weightings, ordinal scale values do not support math functions like addition, subtraction, multiplication, or division. Ratio scales using AHP should be used.

a) According to the project goals determined earlier in the QFD project, it is possible that the customer priority, competitive benchmark, selling point, and Kano prediction are not equally contributing factors. For example, if there is no existing solution, then customer priority can be the most important factor. If a competitor has introduced a product before the company, then the competitive

benchmark can be the most important factor. If the company is launching a brand campaign, then selling point can be the most important factor. If the company is introducing a technology, then the Kano prediction can be the most important factor. Modern QFD allows weighting of these factors. In this example from the airport food service kiosk, an AHP paired comparison was done by the QFD team on these four factors yielding these factor priorities: customer priority: 57,3 %, competitive benchmark: 10,6 %, selling point: 5,9 %, and Kano potential: 26,2 %, as shown in Table 5.

b) Within each of the factors, the adjustments can be weighted using similar AHP paired comparisons. In the customer needs section, the previously calculated AHP priorities from the tertiary customer needs hierarchy in 11.6 are entered in the customer section. If a subset of the customer needs are used, they can be normalized to 100 % as a local priority. In this airport food kiosk example, the priority for "I can make a healthy choice" is 11,5 % but when the subset of needs is used, the normalized local priority is 19,3 %. However, since the customer factor has a priority of 57,3 %, one can multiply these to get a global priority of 19,3 × 57,3 = 11,0 %. These numbers are rounded to three decimal places.

Table 5 — AHP weighting of quality planning table adjustment factors

factors	Customer	Competition	Selling point	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**
Selling point	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**

c) In the competition section, the survey results of asking customers how satisfied they are on an ordinal scale of 1 to 5 with our current product (if any) and the competitors' products. In this example, only one competitor is shown. For the customer need of "I can make a healthy choice" the modal survey score for our current offering is a 2 and the competitor is a 3. Because these are ordinal scale survey responses, a mean value should not be used, but the mode (most frequent response) is appropriate. A target is planned to beat the competition and the QFD team, led by marketing, would like to see a future response after the new product launch of 4. In modern QFD, the QFD team can evaluate this improvement as moving from a level 2 (company's current level) to a level 4 (company plan) as being better than the competition. Four levels of improvement are used and a paired comparison AHP grid is used to calculate ratio scale values for each level, as shown in Table 6. In the example, "better" has a ratio scale value of 26,3 %. This is repeated for the other customer needs and the level-up values are normalized as local priorities. The local priority for "I can make a healthy choice" is then multiplied by the competition factor weight of 10,6 % to get a global priority of 46,7 × 10,6 = 5,0 %, rounded to three decimal places.

Table 6 — AHP weighting of competitor level-up

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**

d) The next factor is the selling point to focus product promotion. It is recommended that there be no more than three selling points to reduce the risk of confusing the customer. It is recommended that no more than one major and two minor selling points in point-of-sale signage, printed or online advertisements, or on-the-box promotions. The sales department member of the QFD team should guide this judgment by considering the importance to the customer, the competitive alternatives, and the planned improvement level. Modern QFD uses a paired comparison AHP grid is used to calculate ratio scale values for each selling point level as shown in Table 7. In the example, "minor selling point" has a ratio scale value of 26,0 %. This is repeated for the other customer needs and the selling point values are normalized as local priorities. The local priority for "I can make a healthy choice" is then multiplied by the sales factor weight of 5,9 % to get a global priority of 45,0 × 5,9 = 2,6 %, rounded to two decimal places.

Table 7 — AHP weighting of major, minor, or no selling point

Selling point	Major	Minor	No	*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**
No	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**

e) The Kano categories are an option. The details of this method and its integration into QFD is covered in ISO 16355-5. Since the Kano method is used to evaluate customer satisfaction with product function and performance, it is too early in the QFD process the use the method in full. However, it can be used to predict the potential Kano category of a solution to each customer need. The Kano categories result from a survey conducted during the solution concept development stage and depending on the responses, suggest whether the solution concept is exciting, desired, expected, neutral, or reverse. Modern QFD uses a paired comparison AHP grid to calculate ratio scale values for each Kano category according to the goals and scope of the project determined earlier in the QFD study. In some new technology projects, just meeting basic expectations can be judged by the QFD team as being a higher priority than exciting the customer. In this airport food kiosk example, exciting was judged most important as shown in Table 8. In the example, "I can make a healthy choice" is predicted by the QFD team to be expected by the target customer segment. This is repeated for the other customer needs and the Kano category values are normalized as local

priorities. The local priority for "I can make a healthy choice" is then multiplied by the Kano factor weight of 26,2 % to get a global priority of 14,4 × 26,2 = 3,8 %, rounded to three decimal places.

Table 8 — AHP weighting of Kano categories

Kano	Exciting	Desired	Expected	Neutral	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**
Neutral	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	**0,00**

f) The global weights for each customer need adjustment are then summed across to calculate the adjusted customer need priority on the right side of the weighted quality planning table. In the example, the sum of the global weights for "I can make a healthy choice" is 11,0 % + 5,0 % + 2,6 % + 3,8 % = 22,4 %. increasing the importance significantly.

NOTE The effort to make these adjustments can be considerable when there are many customer needs. If the time and cost of surveying customers and making these judgments is constrained, it is recommended to use either a small subset of high priority customer needs or use the unweighted quality planning table in Table 4.

Table 9 — Weighted quality planning table for airport food kiosk

	Adjusted CN Rank		2	1	3	4
	Adjusted Priority		19,3%	53,0%	14,6%	13,1%
Kano	Global Priority	26,2%	3,0%	11,4%	5,9%	5,9%
	Local Priority	Kano	11,6%	43,4%	22,5%	22,5%
	Kano Value		13,4%	50,3%	26,0%	26,0%
	Kano Potential Evaluation		Expected	Exciting	Desired	Desired
Sales	Global Priority	5,9%	1,2%	2,9%	1,2%	0,5%
	Local Priority	Sales	20,7%	50,2%	20,7%	8,4%
	Selling Point Value		26,0 %	63,3 %	26,0 %	10,6%
	Selling Point Evaluation		Minor	Major	Minor	No
Competition	Global Priority	10,6%	4,0 %	4,0 %	0,9 %	1,8 %
	Local Priority	Competition	37,3%	37,3%	8,1%	17,3%
	Level-up Value		26,3%	26,3%	5,7%	12,2%
	Improvement Level-up		Better	Better	Worse	Equal
Customer survey	target	satisfaction	4	5	3	5
	competitor		3	5	4	4
	current		2	4	5	5
Customer	Global Priority	57,3%	11,0%	34,7%	6,6%	4,9%
	Local Priority	Customer	19,3%	60,6%	11,6%	8,6%
	Priority		11,5%	36,1%	6,9%	5,1%
Customer Needs			I can make a healthy choice	I can get a taste I like	I can make an appealing choice	I can choose quickly
			1.1.1	1.1.2	1.1.3	1.1.4

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

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