BS ISO 16355-2:2017

BSI Standards Publication

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

Part 2: Non-quantitative approaches for the acquisition of voice of customer and voice of stakeholder

bsi.

National foreword

This British Standard is the UK implementation of ISO 16355-2:2017.

The UK participation in its preparation was entrusted to Technical Committee MS/6, Methodologies for business process improvement using statistical methods.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2017

ISBN 978 0 580 80497 7

ICS 03.120.30

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 February 2017.

Amendments/corrigenda issued since publication

Date	Text affected

BS ISO 16355-2:2017

INTERNATIONAL STANDARD

ISO 16355-2

First edition
2017-02

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

Part 2: Non-quantitative approaches for the acquisition of voice of customer and voice of stakeholder

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

Partie 2: Acquisition non quantitative du retour client (Voice of Customer) ou du retour des parties prenantes (Voice of stakholders)

Reference number
ISO 16355-2:2017(E)

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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).

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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 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 assure customer or stakeholder satisfaction and value with new and existing products by designing in, from different levels and different perspectives, the requirements that are most important to the customer or stakeholder. 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 lifecycle 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 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 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 16355-2:2017(E)

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

Part 2:
Non-quantitative approaches for the acquisition of voice of customer and voice of stakeholder

1 Scope

This document describes the non-quantitative approaches in the acquisition of voice of customer (VOC) and voice of stakeholder (VOS) and its purpose, and provides recommendations on the use of the applicable tools and methods. It is not a management system standard.

NOTE It does not provide requirements or guidelines for organizations to develop and systematically manage their policies, processes, and procedures in order to achieve specific objectives.

Users of this document include all organization functions necessary to assure customer satisfaction, including business planning, marketing, sales, research and development (R&D), engineering, information technology (IT), manufacturing, procurement, quality, production, service, packaging and logistics, support, testing, regulatory, 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, *Application of statistical and related methods to new technology and product development process — Part 1: General principles and perspectives of Quality Function Deployment (QFD)*

3 Terms and definitions

For the purposes of this document, the terms 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 non-quantitative voice of customer (VOC) and voice of stakeholder (VOS) acquisition with customer research methods

5.1 VOC and VOS acquisition support for market research methods for product development

Integration of non-quantitative VOC and VOS acquisition with customer research methods is both desirable and possible. Successful integration has been accomplished with market research, focus groups, ethnographies, use case, agile development, and other methods. This integration should be guided by an expert familiar with these methods.

NOTE 1 QFD can be integrated with other customer research methods.

NOTE 2 QFD can integrate tools and methods from different new product development processes. Conversely, different new product development processes can utilize QFD tools and methods.

NOTE 3 The applicable tools listed are not exhaustive. They are meant to illustrate tools that have been effectively used in QFD. Other tools can also be useful according to the project. Which tools and in what sequence can be custom-tailored to the organization and product.

5.2 Voice of customer and voice of stakeholder acquisition outline

Figure 1 describes the VOC and VOC acquisitions outline, where the numbers refer to the relevant clauses in this document.

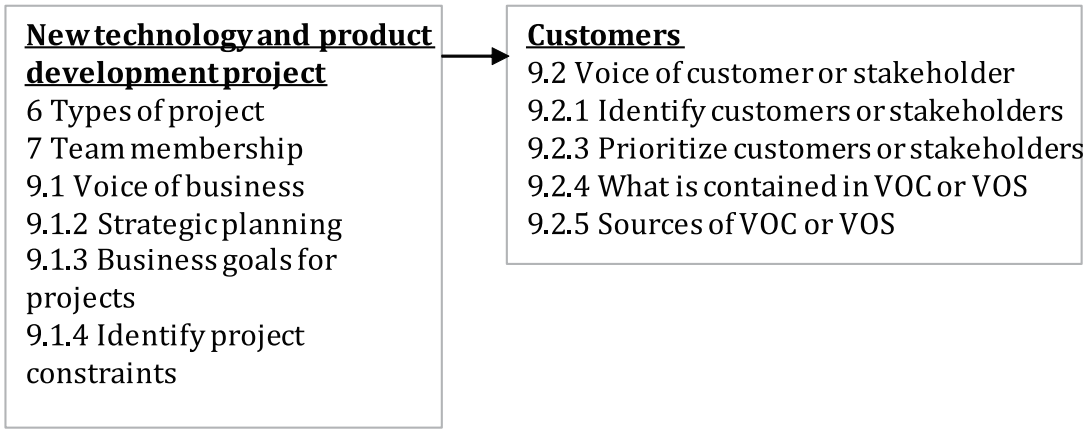


Figure 1 — VOC and VOS acquisition outline

6 Types of new technology and product development project for which VOC and VOS can be acquired

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.

NOTE 1 The VOC and VOS acquisition approaches and their sequence can be scaled to the type of project.

NOTE 2 The VOC and VOS acquisition approaches and sequence can be adapted to the management structure and culture, market research, and problems of each organization to improve participation, integration, and long-term utilization of the method. VOC and VOS acquisition can be integrated with existing research activities.

NOTE 3 QFD is not a method to design a product or process — it is an infrastructure to ensure the product or process satisfies customers.

7 VOC and VOS acquisition 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 are referenced in ISO 16355-1:2015, 7.3.

7.4 VOC and VOS acquisition team leadership

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

8 Tools for VOC and VOS acquisition and analysis

8.1 General

The basic tools for quality control are sufficient for analysis of quantitative data that can be collected from current operations. However, in new product development, quantitative data is not always available until engineering and build operations have begun. Therefore, a new set of quality tools were arranged to acquire, organize, and analyse the qualitative and often verbal information more common in business and product planning as well as voice of customer and voice of stakeholder studies. These are called the seven new quality tools or the seven management and planning tools[3][20][23]. These tools are helpful in acquisition and analysis of the voice of the customer and voice of the stakeholder which is detailed in ISO 16355-4. VOC and VOS analysis are a critical element in QFD to capture and prioritize both language and behaviour of the customers which drive the product development process. See Figure 2.

8.2 Seven management and planning tools

The seven management and planning tools are the following.

a) Affinity diagram. This is used to organize a problem statement where there is uncertainty, often pertaining to future events or unknowns. Verbalized ideas, opinions, and facts are synthesized into a diagram using an anthropological technique known as the KJ™[1)] method named for its creator, Kawakita Jiro.

b) Relations diagram. This is used to unravel complicated issues by displaying the logical connections, cause-and-effect connections, or objectives and strategies. It is useful in planning activities to gain consensus from those with different perspectives.

c) Tree diagrams and hierarchies. These are used to systematically organize issues such as objectives and strategies and also to organize information into levels of abstraction and identify missing elements.

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.

d) Matrix diagram. This is used to organize multi-dimensional problems so that intersecting relationships can be examined rapidly by those with knowledge and experience. Most common are the two-dimensional L-matrix; three-dimensional C-, T, and Y matrices; and the four dimensional X-matrix.

e) Arrow diagram. This is used for project management to show duration and sequence of critical tasks. It is often used with precedence diagrams, critical path method (CPM) and program and evaluation review technique (PERT).

f) Process decision program chart (PDPC). This is used to predict potential failures on plans and develop contingencies.

g) Matrix data analysis. This quantitative method relies on principle component analysis (PCA) to categorize and extract meaning from complex numerical data sets. Analytic hierarchy process (AHP) can also be used when combining objective and subjective information into a decision model.

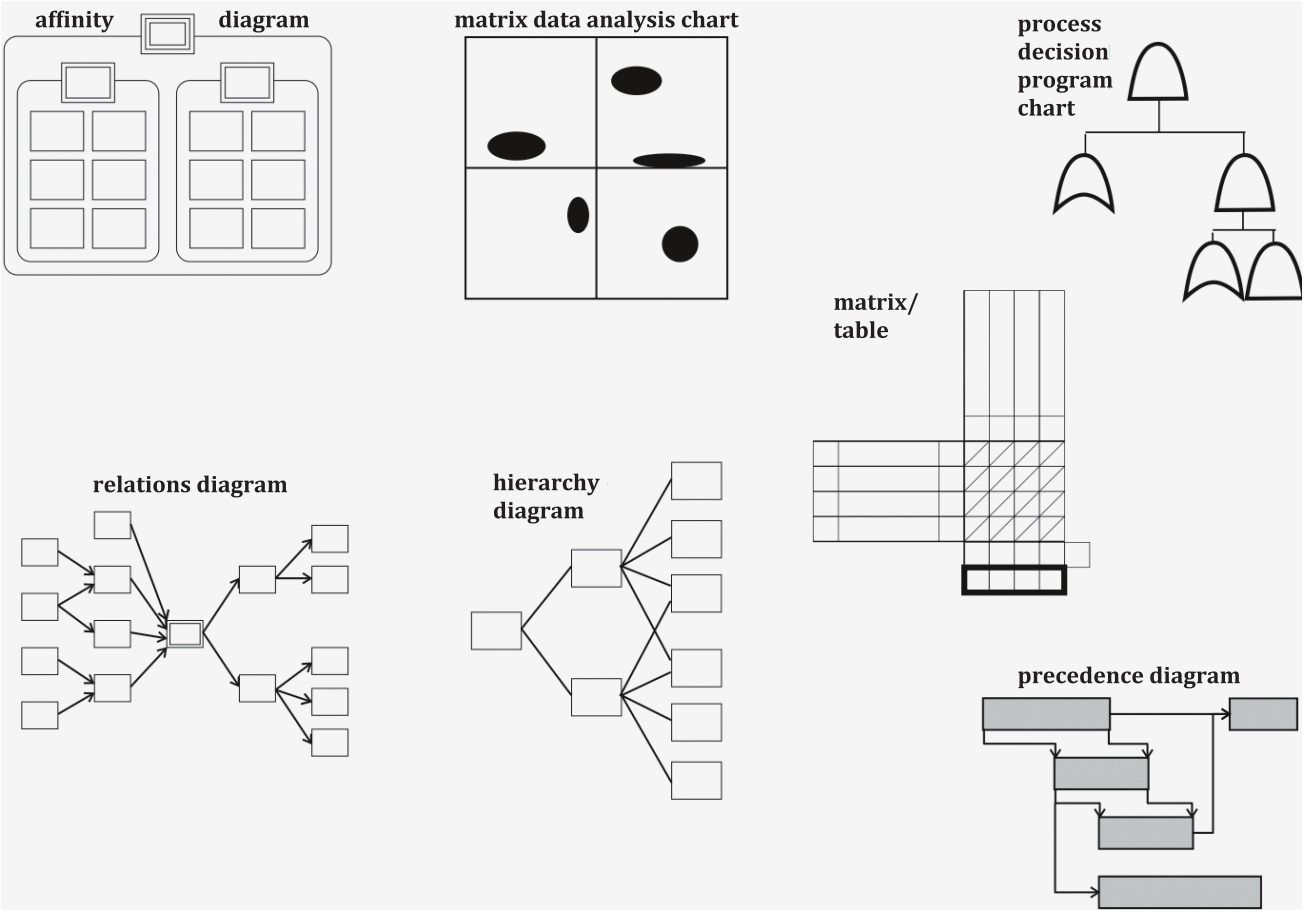


Figure 2 — Seven management and planning tools

9 New technology and product development voices

9.1 Voice of business

9.1.1 General

To keep an organization competitive, it is helpful to seek a deeper understanding of the value that drives customer needs during the early stages of product and process development. QFD enables product and process managers, designers, and developers to comprehend, prioritize, and merge both organizational and project-specific goals with the needs of the customer. QFD helps clarify project direction so that

it remains fluid and responsive to change; if priorities are challenged, the model should be used to recalibrate the design focus. QFD helps improve the process by which these products and processes are developed.

9.1.2 Strategic planning

9.1.2.1 General

When QFD is applied to projects that contribute to strategically important objectives and goals for the organization, projects priorities, design focus, resources, and planning should be fully calibrated with those objectives and goals. The strategic objectives and goals are the main building blocks of the organizational vision, mission, and the core value. Constraints can also exist.

NOTE Not all QFD projects have strategic purpose, so capturing the voice of the business is optional.

9.1.2.2 Hoshin kanri (policy management and deployment)

9.1.2.2.1 Basics of hoshin kanri

Hoshin kanri emerged in Japan in 1964 as a method for management and deployment of strategic organizational policies. It was developed by many of the same people who created QFD who saw it as a way "to link total quality management (TQM) activities for fulfilment of all critical management objectives" and for which QFD was "the powerful tool needed. In quality assurance system flow charts, it is typically the starting point for QFD"[21].

Hoshin not only captures strategic intent, but also applies quality measurement and improvement activities to both targets and the means to achieve them. Hoshin can be used prior to QFD to form organizational strategies and identify projects, for which QFD can be implemented to assure the strategies are achieved. Hoshin can be used following a QFD study that captures market changes and suggests a new policy strategy[1][14][36].

9.1.2.2.2 Inputs to hoshin kanri

The hoshin kanri method considers the following inputs:

a) Strategic analysis and agreement by senior management and other individuals involved with corporate governance of

   1) Vision — what the organization wants to become,

   EXAMPLE 1 Big-U bookstores will become the leading university bookstore in the US by 2020 as measured by relationships with 75 % of two- and four-year college campuses.

   2) Mission — what activities the organization engages to achieve the vision,

   EXAMPLE 2 Buy equity in existing university bookstores and rebrand as Big-U.

   EXAMPLE 3 Develop online ordering under Big-U brand.

   3) Values — what principles guide the activities the organization engage in or not,

   EXAMPLE 4 Create a flexible workplace for student employees.

b) Setting of business goals by senior management and other individuals involved with corporate governance can be done for different time periods;

   1) Long-term (3- to 5-year) goals and how to measure them,

   EXAMPLE 5 Achieve 3 750 relationships by 2020.

   2) Medium-term (2- to 3-year) goals and how to measure them,

EXAMPLE 6 Achieve 2 500 relationships by 2018.

3) Short-term or annual (1-year) goals and how to measure them.

EXAMPLE 7 Achieve 1 800 relationships by 2016.

EXAMPLE 8 Supply 95 % of required textbooks (used and new) by start of semester.

NOTE Business goals can have fixed durations or can be re-examined each year into rolling plans.

9.1.2.2.3 Process of hoshin kanri

The hoshin kanri method employs the following process.

a) Negotiations between all levels of management and their direct reports:

1) division of management goals among direct reports,

2) annual performance targets for each direct report,

EXAMPLE 1 Figure 3 illustrates an example of deploying hoshin targets to direct reports for an internal business process improvement project[17]. The plant manager has set a target of reducing plant-attributed claims to 63/year or less. This target is deployed to two direct reports: the general manager of production is responsible for reducing production related claims to 58/year and the general manager of purchasing is responsible for reducing defective parts-related claims to 5/year; these sum to 63/year. The general manager of production then deploys the target of 58/year to two direct reports: the section manager of manufacturing who is responsible for reducing manufacturing-attributed claims to 53/year and the section manager of inspection who is responsible for reducing audit error–attributed claims to 5/year; these sum to 58/year. The figure illustrates other targets and deployments.

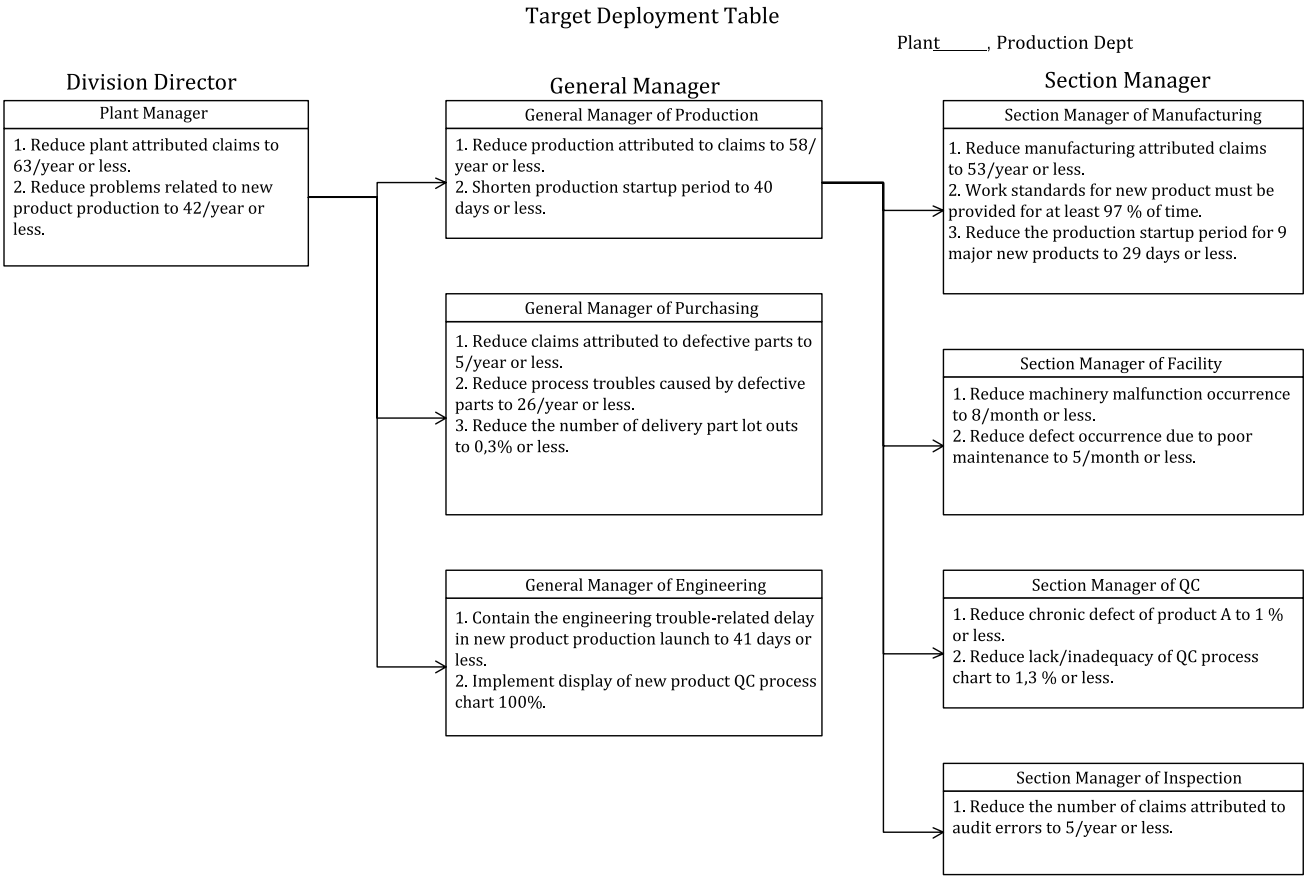


Figure 3 — Example of hoshin target deployment in a plant

It is recommended that managers assign performance targets and not negotiate them with direct reports. Performance targets of the direct reports sum to the management goal.

NOTE 2 Some management goals are not assignable to direct reports because the authority to achieve them is the responsibility of the plant manager, as in this example.

3) means to achieve the targets should be negotiated with managers and coordinated with peer-level direct reports. These multiple relationships are to be clarified. Means can also include performance targets by which the direct report should monitor their own activities.

EXAMPLE 2 Figure 4 illustrates an example of deploying hoshin means among direct reports[17]. The plant manager commits to improving the thoroughness of finding and preventing causes of claims. The direct reports negotiate the means to achieve this: the production manager implements process defect recurrence prevention and a system to prevent process-attributed defects from being passed to the market, the purchasing manager reviews parts suppliers' standards and provide them with quality control assistance, and the engineering manager implements prototype reliability testing.

Means Deployment Table

Plant __, Production Dept. Date:

Division Director	Relationship line	General Manager	Relationship line	Section Manager
Means of Plant Manager 1. Thoroughness of finding causes of claims and preventing recurrence. 2. Completeness of preparation of new product receiving.		Means of Production Manager 1. Process defect recurrence prevention 2. Create a system that does not allow passing of defective products into market 3. Reduce production startup period Means of Purchasing Manager 1. Review of part supplier standards 2. QC assistance to part suppliers Means of Engineering Manager 1. Implement prototype reliability testing 2. Improve production prototype engineering		Means of Production Section Manager 1. Implement fool-proofing. 2. Follow through on Process Work Standards. 3. Improve process capability index for 7 high-priority products. 4. Provide training on use of control graphs. Means of Equipment Section Manager 1. Review the Machine Maintenance Standards. 2. Develop multi-functional production lines. Means of QC Section Manager 1. Early preparation of QC process charts. 2. Build new product accident history database. 3. Solve chronic defects of product A. Means of Inspection Section Manager 1. Improve reliability of final inspection. 2. Early creation of new product inspection system.

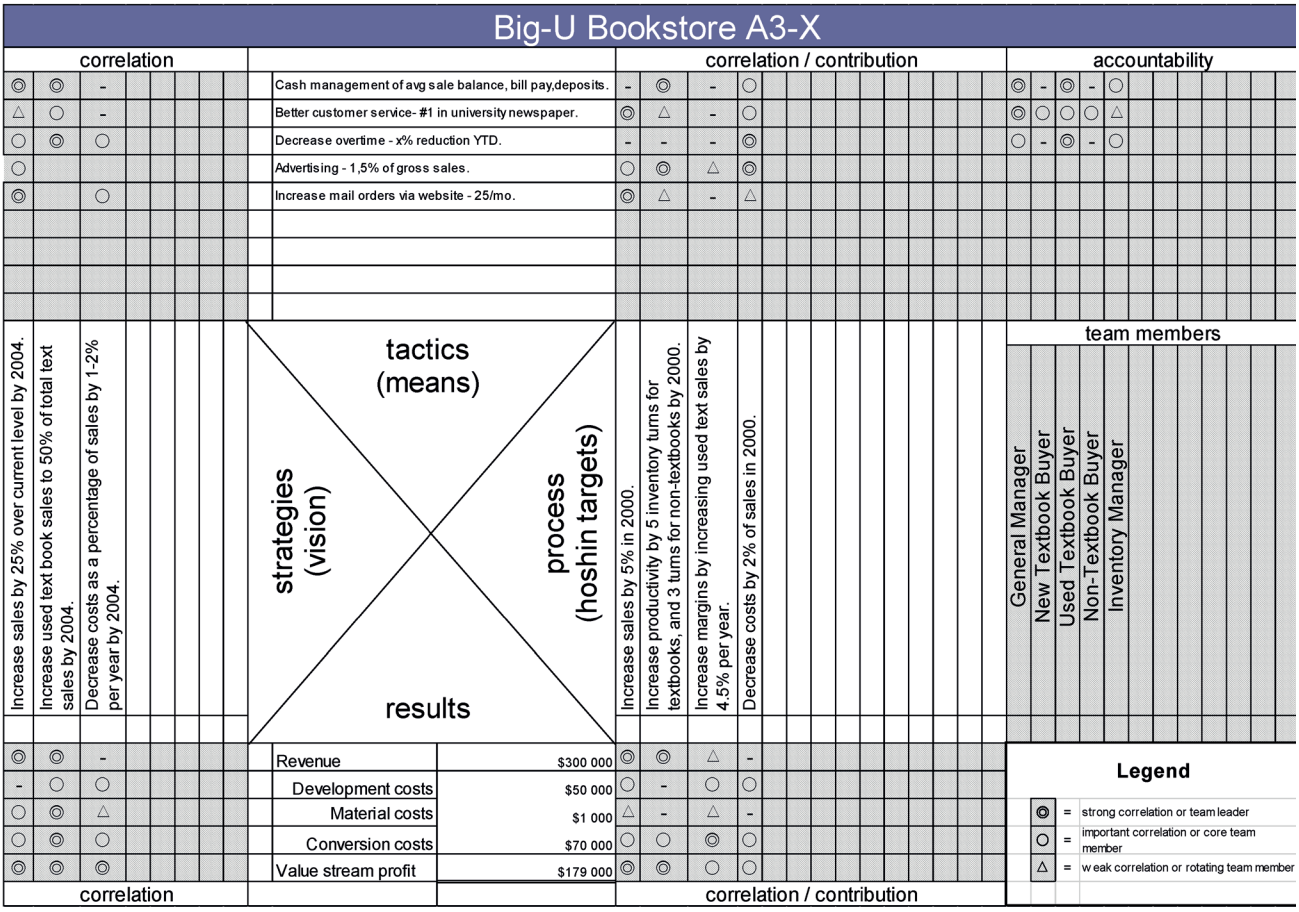
Figure 4 — Example of hoshin means deployment of a plant manager

b) The various targets and means for the organization can be illustrated in matrices at each organizational level to check for completeness and contradictions, such as the A3-X matrix shown in Table 1[10].

NOTE Many of the charts are formatted to fit the A-3 size of paper and have thus earned this nickname.

EXAMPLE Big-U bookstore has identified a number of tactical projects. Table 1 (reading clockwise from the left) shows how their strategy of increasing sales by 25 % by 2004 correlated strongly to a tactical QFD project to develop a mail order website. They expected to achieve a sales increase of 5 % by 2000 (year 1 of 5, so 5 %/year to achieve 25 % by 2004), which contributes to its annual revenue increase of $300 000 and profit of $173 000 per store.

Table 1 — Hoshin kanri target-means x-matrix



9.1.2.2.4 Outputs of hoshin kanri

The hoshin kanri method creates the following outputs.

a) Roll out of targets and means begins and results are monitored periodically to confirm means are being performed sufficiently and targets are being achieved.

b) Targets and means that are not within the forecast levels can become quality improvement projects to uncover the cause of their under- or over-performance so that corrective actions are taken in a timely manner.

c) End-of-year reviews can be conducted by managers and direct reports to review unmet targets for continuing activity as well as to improve the hoshin kanri process itself.

d) Hoshin that requires new products, services, information systems, or business processes can trigger a QFD project to execute the hoshin targets and means.

9.1.2.3 Porter five force competitive analysis

Strategic business environment intelligence is commonly used in determining which market forces support or threaten strategic plans. Porter five force analysis[27] has been used with QFD to give a high-level view of future markets, growth segments, value proposition competencies, and a road map with metrics. It helps create a single view of the environment, competitors, and the company position. This analysis can be led by the business environment or market research department to clarify the business environment in which the new QFD project must succeed. Figure 5 is an example of the five forces at a health insurance company[7].

a) Threat of new entrants.

EXAMPLE 1 Environmental Situation Analysis (ESA) to look at what could erode the existing market, such as a competitor entering all 50 US states, consumer-driven health plans (CDHP), affordable health plans (AHP) including buying coalitions, medical tourism, and other alternatives.

b) Bargaining power of suppliers.

EXAMPLE 2 Cost transparency increases the ability of health care providers such as doctors and clinics to market services directly to patients and helps providers negotiate higher reimbursements with payers. Also, new health care providers change the existing structure of relationships.

c) Threat of substitutes.

EXAMPLE 3 Other financial services organizations could enter the market to provide transaction services, which is a significant function that is performed. CDHPs and third-party administrators (TPA) could provide disease management services, a significant function that is performed. Large insurance aggregators could provide risk management, which is a significant function that is performed.

d) Bargaining power of buyers.

EXAMPLE 4 AHPs and buying coalitions, as well as cost transparency, can increase bargaining power of health care providers, large employers can negotiate rated directly with health care providers, and increased defined health insurance payments by employees can lead to more consumer power.

e) Competitive rivalry.

EXAMPLE 5 These factors helped a company to focus a strategy to grow market share and dollar share, as well as compete by bringing new insurance products to market faster. This analysis was conducted in the year before a US presidential election that had a health care platform and allowed the company to fine tune new insurance products as the most likely candidates emerged in the presidential primary elections.

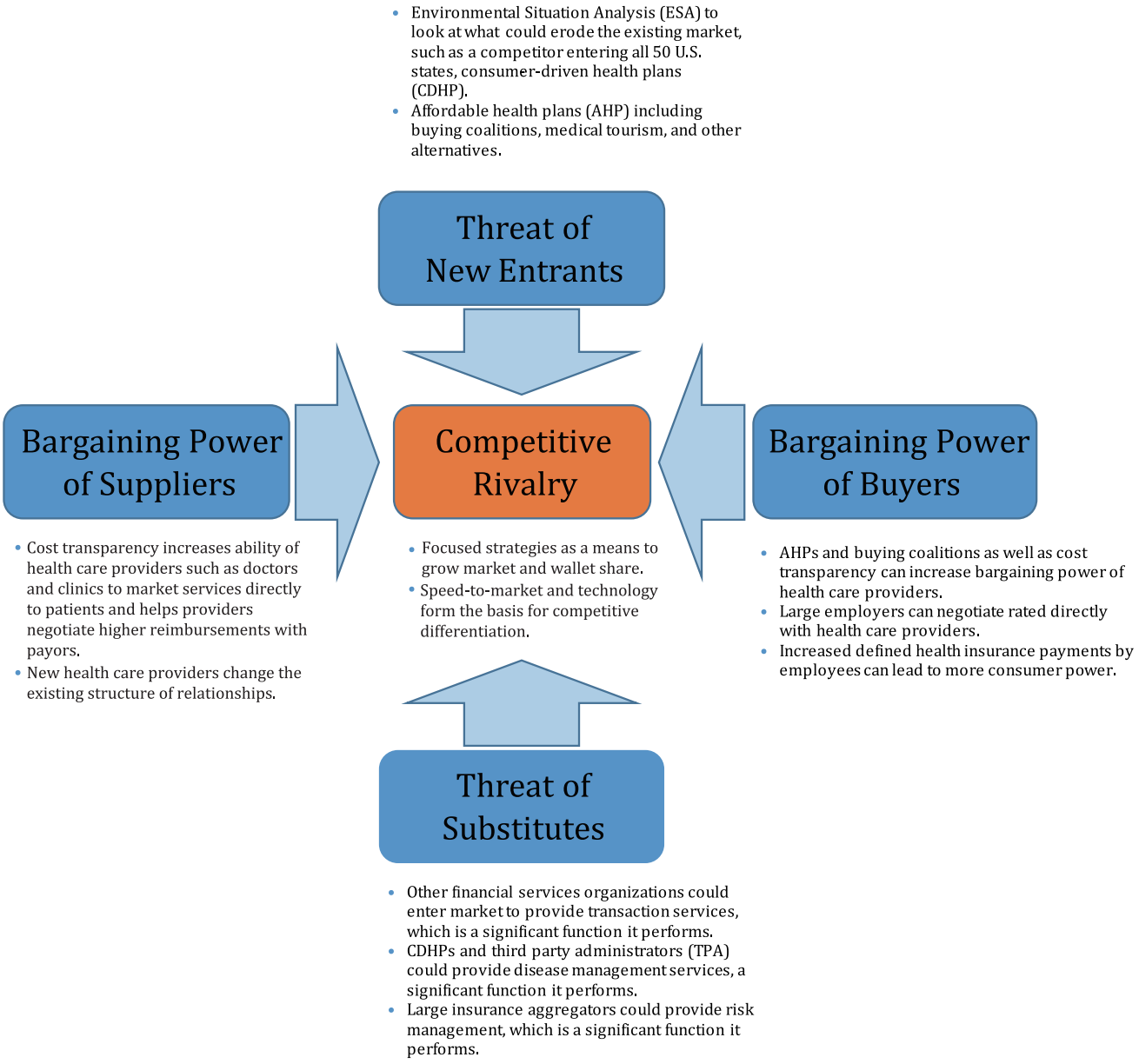


Figure 5 — Porter 5 force analysis at a health insurance company

9.1.2.4 Kotler's market portfolio planning

Philip Kotler pioneered the concept of the four Ps of marketing: product (what product or service is offered), price (what the customer pays, relative to its value and what alternatives are available), place (where the product or service is sold, how it is sold), and promotion (what message is to be explained or demonstrated) to attract and retain customers[15]. While the technology for these four Ps continues to evolve, the fundamental principles can help define and focus portfolios of QFD projects.

EXAMPLE Company C is a maker of machine tools, which must cover a variety of sizes. While some competitors choose only to manufacture and sell the best-selling sizes, Company C promotes itself as a full-line supplier. To strengthen their competitiveness, it conducts QFD projects on some slow-selling sizes in order to implement the latest technologies in all its products.

9.1.2.5 Blue Ocean Strategy

Companies can enter a price competition for short-term advantage, but over time, this can result in a "red ocean" of profit bleeding. The "blue ocean" seeks an uncontested market opportunity based on

future product concepts to meet unmet customer needs. One company in the agricultural business conducts "farm products of the future" studies to identify future QFD projects[13][22].

9.1.2.6 New Lanchester strategy for sales and marketing

9.1.2.6.1 General

Adapted from the aircraft in warfare theories of Frederick Lanchester in 1916, Nobuo Taoka[34] created a competitive strategic analysis that can help QFD projects determine what markets to launch in first, which competitors to avoid, which customers to focus on, and what product features are most likely to win market share. The New Lanchester strategy for sales and marketing[37] expanded and refined the method to include both sales and marketing activities as well as niche-based product development.

9.1.2.6.2 Shooting ranges theory

Based on the numbers of competitors and relative market shares, some competitors can be difficult to challenge. This is based on the military concept that bullets that do not hit the enemy do not hurt. New Lanchester strategy calculates shooting range as market share × 1,7. So, a company with a 10 % market share has a shooting range of 17 %, and competitors with larger market shares become difficult to challenge.

9.1.2.6.3 Market structure

New Lanchester strategy describes five market structures that can be considered. Depending on the market structure and the company's relative share, the QFD team can elect what is called the "strategy of the weak" to attack a stronger competitor outside one's shooting range, or the strategy of the strong to prevent a weaker competitor from successfully attacking.

a) Monopoly: leader has more than 73,9 %.

b) Premium: leader has >41,7 % and is >1,7x 2nd.

c) Duopoly: 1st + 2nd >73,9 %, leader <1,7x 2nd.

d) Oligopoly: first 3 companies >73,9 %, 2nd + 3rd > leader.

e) Unstable: no company has more than 26,1 %.

9.1.2.6.4 Strategy of the weak and strategy of the strong

Table 2 shows the 12 strategies for a weak company to attack a stronger competitor, or for a strong company to prevent a weak competitor from using the strategy of the weak against them.

Table 2 — New Lanchester strategies of the weak and strong

Military strategy	Marketing strategy for the weak	Military strategy	Marketing strategy for the strong
Differentiation	Offer superior products and service.	Matching Operations	Match weaker competitors to prevent their differentiation strategy from working.
Local Battles	Compete only in specific territories or segments.	Wide-Area Battles	Compete with wide ranging product lines, territories, and customer bases.
Single Combat	Fight where there are few competitors.	Stochastic Battles	Force competitors and even allies to battle each other.

Table 2 *(continued)*

Military strategy	Marketing strategy for the weak	Military strategy	Marketing strategy for the strong
Close Combat	Go directly after the dominant players' customers who are in target segments. Go after weaker players' customers.	Remote Battles	Use distributors and suppliers to one's advantage. Use strong advertising and publicity campaigns.
One-Point Concentration	Sales strategy should be to reinforce and protect one's core competencies and key customers. Become number 1 in at least one area.	Comprehensive Battles	Fight on all fronts with comprehensive product lines, territories, and customer bases.
Diversionary Operations	Demoralize and confuse competitors with decoys.	Inducement Operations	Find out competitors' plans and beat them to the market.

9.1.2.6.5 Using the New Lanchester strategies

Based on a weak or strong market position, a QFD team can elect, for example, a differentiation strategy to develop a product for a specific customer niche (if they are the weak) or offer a full product line (if they are the strong). Sales, logistics, channels, and other marketing considerations can be included as support service QFD projects.

EXAMPLE A manufacturer of air conditioning components held 10 % market share versus its competitor's 90 %. The shooting range theory predicted this is nearly impossible to challenge. However, using one-point concentration, it formulated a plan to help its key customer, who was the number 2 air conditioner maker in the market, beat its number 1 competitor by using its new QFD-designed component.

9.1.2.7 Monitoring the strategy

9.1.2.7.1 General

It is recommended to periodically review the effectiveness of the strategy and how well the QFD projects contribute to the strategic objectives and goals.

9.1.2.7.2 Balanced scorecard

Balanced scorecard[12] is one method to monitor specific metrics that can be grouped as follows. Within each group, there can be several key performance indicators[9], as follows:

a) Customer perspective — how do our customers see us;

   EXAMPLE 1 Customer satisfaction surveys, on-time delivery, share of customer purchases, and strategic alliances are examples of indicators. These are key project goals that can be targeted at the start of a QFD project.

b) Internal business perspective — what must be exceled at;

   EXAMPLE 2 Regulatory compliance, costs, and number of full-time employees are examples of indicators.

c) Learning and growth perspective — how to continue to improve and create value;

   EXAMPLE 3 Time to market, ROI on new technology, and percent sales from new products are examples of indicators.

d) Financial perspective — how does the organization look to shareholders.

EXAMPLE 4 Market share, sales, and profit are examples of indicators. These are key project goals that can be targeted at the start of a QFD project.

9.1.2.8 Project prioritization and selection using the analytic hierarchy process (AHP)

9.1.2.8.1 General

Organizations can have more projects than they have the resources, funding, or time to complete. Until a product or process is put into use by customers, it brings little value to the business or to the customer. Thus, it can be helpful to assure resources, funding, and time are not spread too thinly across too many projects. It can be helpful to prioritize projects in order to select first those that bring the most value to the business and customers.

9.1.2.8.2 Create project concepts

Project concepts can result from both internal and external perspectives, such as taking existing products into new markets, competitor offerings, demographic trends, technology advancements, customer visits, regulatory changes, and other creativity activities.

9.1.2.8.3 Create criteria to evaluate projects

Prioritizing projects should be done by rating them against relevant criteria developed in the above analyses. Criteria can be objective or subjective. For example, from the hoshin kanri, criteria such as lower costs through reduced defects and increase sales; from the Kotler portfolio analysis, criteria such as retain current customers; from the Blue Ocean strategy, criteria such as create a disruptive technology; from the New Lanchester strategy, criteria such as create a niche product; and from the balanced scorecard, criteria such as increase market share.

9.1.2.8.4 Using the analytic hierarchy process (AHP) to evaluate projects against multiple criteria

Multi-criteria decision making was made more precise with the mathematical modeling of AHP[28][29][30]. This modelling enhances the precision of the statistical methods of QFD by employing absolute ratio scale values that can be added, subtracted, multiplied, and divided; ordinal scale values do not contain sufficient information to perform these mathematical functions properly.

EXAMPLE 1 An example of an ordinal scale are the Olympic medals: gold, silver, and bronze for first, second, and 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, or other factors. Thus, ordinal scale values cannot be divided, or other mathematical functions.

EXAMPLE 2 An example of an absolute ratio scale is distance. Two kilometers is twice the distance of one kilometer. Thus, ratio scales values can be multiplied and other mathematical functions.

9.1.2.8.5 Types of criteria

The most common project evaluation criteria are of two types: objective or subjective. With AHP, both can be combined in one evaluation model.

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) staff required where 5 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 3 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 4 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 use several criteria of each type.

9.1.2.8.6 Evaluate each project against each criteria

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

EXAMPLE 1 Table 3 is an example of an objective criteria, where a larger value is better — in this case, projected first-year revenue in million euros. Each project is evaluated: project alpha is estimated to produce €100 million, project bravo is estimated to produce €60 million, and so forth. Since each criteria is measured differently, it is helpful to normalize them into percentages by summing the estimated values and dividing each value by the sum. 100 + 60 + 120 + 80 = 360. 100/360 = 0,278 and so forth. These mathematical calculations are permitted because revenues in euros are already in the ratio scale. Numbers are rounded to three decimal places.

Table 3 — Project selection criteria — Objective, bigger is better

		projects			
		Alpha	**Bravo**	**Charlie**	**Delta**
	(projected first-year revenue, in millions) ***bigger is better***				
revenue					totals
	estimated value	100	60	120	80	360
	normalized	**0,278**	**0,167**	**0,333**	**0,222**	1,000

EXAMPLE 2 Table 4 is an example of an objective criteria, where a smaller value is better — in this case, the number of research fellows needed on the project. Each project is evaluated: project alpha is estimated to require 10 research fellows, project bravo is estimated to require 12 research fellows, and so forth. Since each criteria is 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. 1/10 = 0,100, 1/12 = 0,083, and so forth. 0,100 + 0,083 + 0,091 + 0,071 = 0,346. 0,100/0,346 = 0,289 and so forth. These calculations are permitted because the number of people is already in the ratio scale. Numbers are rounded to three decimal places.

Table 4 — Project selection criteria — Objective, smaller is better

	projects				
	Alpha	**Bravo**	**Charlie**	**Delta**	
(number of research fellows needed)					
smaller is better					
minds					totals
estimated value	10	12	11	14	47
the inverse	0,100	0,083	0,091	0,071	0,346
normalized	**0,289**	**0,241**	**0,263**	**0,207**	1,000

EXAMPLE 3 Table 5 is an example of subjective criteria, where these are an absolute or expert scale — in this case, the degree of technical risk of each project. Before evaluating each project, 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 (lightning bolts representing danger), numerical (1 to 5 with 1 being the safest), and verbal (from safe to foolhardy). 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 diagonals are 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, safe is moderately preferred to some risk, safe is strongly preferred to risky, 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 (safe 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, people 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 to be checked for math or judgment errors.

Once the ordinal scale has been converted into ratio scale, each project should be evaluated. In this example, both projects alpha and bravo are considered foolhardy and have earned five lightning strikes or arrow, Project Charlie is considered risky and has earned three arrows, and Project Delta is considered bold and has earned four arrows. Substituting the ratio scale row averages from the conversion grid, five arrows has a weight of 0,035, four arrows has a weight of 0,068, and three arrows has a weight of 0,134. These are summed (0,035 + 0,035 + 0,134 + 0,068 = 0,271 8) and normalized (0,035/0,2718 = 0,128 and so forth). Numbers are rounded to three decimal places.

Table 5 — Project selection criteria — Subjective, absolute or expert judgment

	projects			
	Alpha	**Bravo**	**Charlie**	**Delta**

absolute judgment scale:		*risk* (the degree of technical risk)	**safe**	**some**	**risk**	**bold**	**fool**	normalized columns					row total	row avg.
↓	1	**safe**	1	3	5	7	9	0,560	0,642	0,524	0,429	0,360	2,514	**0,503**
↓↓	2	**some risk**	1/3	1	3	5	7	0,187	0,214	0,315	0,306	0,280	1,301	**0,260**
↓↓↓	3	**risky**	1/5	1/3	1	3	5	0,112	0,071	0,105	0,184	0,200	0,672	**0,134**
↓↓↓↓	4	**bold**	1/7	1/5	1/3	1	3	0,080	0,043	0,035	0,061	0,120	0,339	**0,068**
↓↓↓↓↓	5	**foolhardy**	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		0,06

risk (the degree of technical risk)					
select absolute judgment level	↓↓↓↓↓	↓↓↓↓↓	↓↓↓	↓↓↓↓	no. of arrows
weight	**0,035**	**0,035**	**0,134**	**0,068**	0,272
normalized	**0,128**	**0,128**	**0,494**	**0,249**	1,000

EXAMPLE 4 Table 6 is an example of a subjective criteria, where there is no absolute or expert scale and so a relative scale is used — in this case, the potential enjoyment of crushing the competition for each project. Similar to the ratio scale conversion grid in Example 3, each project is pairwise compared to each other project relative to its enjoyment or fun. Projects compared to themselves earn a score of 1 as shown in the diagonal of the grid. When the row project 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, bravo is moderately preferred to Alpha, Charlie is strongly preferred to Alpha, 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, Project Alpha has a relative "fun" score of 0,133, bravo of 0,268, and so forth. Numbers are rounded to three decimal places.

Table 6 — Project selection criteria — Subjective, relative judgment

(competitor crushing enjoyment potential) ***relative judgement***

fun	Alpha	Bravo	Charlie	Delta	normalized columns				row total	row avg.
Alpha	1	1/3	1/5	5	0,109	0,074	0,122	0,227	0,532	**0,133**
Bravo	3/1	1	1/3	7	0,326	0,223	0,203	0,318	1,070	**0,268**
Charlie	5/1	3/1	1	9	0,543	0,670	0,608	0,409	2,231	**0,558**
Delta	1/5	1/7	1/9	1	0,022	0,032	0,068	0,045	0,167	**0,042**
	9,20	4,48	1,64	22,00	1,000	1,000	1,000	1,000	4,000	1,000
								Inconsistency Ratio		0,06

9.1.2.8.7 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 market share. This evaluation allows the project selection process to more precisely reflect the strategy of the organization.

EXAMPLE Table 7 uses the AHP pairwise grid to weight the project 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 strategy. Criteria compared to themselves earn a score of 1 as shown in the diagonal of the grid. When the row criteria are 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). In this example, revenue is moderately more important than the number of minds, and so forth. When the column is preferred, the inverse fraction is entered. Thus, the lower left values are inverse of the upper right. The relative importance of the criteria are revenue (0,558), # minds (0,263), technical risk (0,122), and fun (0,057). Numbers are rounded to three decimal places.

Table 7 — Weight the project selection criteria

(importance of criteria to project selection)									row	row
criteria	revenue	minds	risk	fun	normalized columns				total	avg.
revenue	1	3	5	7	0,597	0,662	0,536	0,438	2,232	**0,558**
minds	1/3	1	3	5	0,199	0,221	0,321	0,313	1,053	**0,263**
risk	1/5	1/3	1	3	0,119	0,074	0,107	0,188	0,487	**0,122**
fun	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**

9.1.2.8.8 Synthesize the project priorities

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

EXAMPLE In the centre of the synthesis grid in Table 8, the previous work is displayed. For example, the revenue estimate for project alpha was €100 million, which was normalized to a ratio scale score of 0,278 in Table 3. Here, it is represented as 27,8 %. This score is then multiplied by the criteria weight for revenue (0,558 or 55,8 %) giving what is called a "global" weight of 15,5 %. This is repeated for each cell in the grid, and the global weights are then summed for each column to give a project selection weight in ratio scale. Here, Project Charlie (34,7 %) has almost twice the priority as Project Bravo (18,7 %). Numbers are rounded to three decimal places.

Table 8 — Synthesized project priorities

		project selection			
		Alpha	Bravo	Charlie	Delta
criteria	% wt.				
revenue	55,8%	*100* 27,8 **15,5**	*60* 16,7 **9,3**	*120* 33,3 **18,6**	*80* 22,2 **12,4**
minds	26,3%	*10* 28,9 **7,6**	*12* 24,1 **6,3**	*11* 26,3 **6,9**	*14* 20,7 **5,4**
risk	12,2%	↓↓↓↓↓ 12,8 **1,6**	↓↓↓↓↓ 12,8 **1,6**	↓↓↓ 49,4 **6,0**	↓↓↓↓ 24,9 **3,0**
fun	5,7%	13,3 **0,8**	26,8 **1,5**	55,8 **3,2**	4,2 **0,2**
	%	**25,4**	**18,7**	**37,7**	**21,1**

When there are many projects 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 AHP software packages and Excel sheets that do the above math in the background.

9.1.3 Business goals for projects

9.1.3.1 General

Once projects are selected, more specific goals can be clarified from the project selection criteria. Goals include financial targets such as revenue, profit, and facility and resource optimization; marketing targets such as market opportunity, market share, market growth, market leadership, and competitiveness; and others. The voice of the business can also define what is required for legal, asset and information security and vulnerability, or other business reasons that then trigger value-enabling activities.

NOTE 1 QFD focuses the project team on its goals and objectives by minimizing deviations and distractions that lead to cost over-runs, too many design iterations, and missed project milestones and deliverables. When schedules are delayed, project teams are at risk of assuming they know what customers and stakeholders want based on the loudest voice or past experience. Overlooking critical requirements and losing sight of the original priorities can occur when project-wide understanding of goals and objectives are rushed and not shared among team members.

NOTE 2 Enabling activities can include new product development, next-generation product development, product improvement, and business process improvement of how work is done within an organization necessary to produce value to the customer.

NOTE 3 A business process is a linked set of steps, activities, or tasks designed to produce a specific output — each step, activity, or task in a business process has both a supplier and a customer.

9.1.3.2 Business goals table

Business goals assure alignment of the business with the most critical customer messages. There are many stakeholders who can be internal or external customers or can be QFD team members from

different functions in the organization. These stakeholders can represent different organization functions that can have competing and sometimes conflicting goals. The business goals table enumerates what the project must deliver to the organization and allows for different stakeholders to contribute and to reflect on the goals of others. The business goals table can contain very specific targets and deadlines on some projects, or be more generalized on other projects.

NOTE 1 QFD uses quality methods, so the goals and constraints can include a metric and measurement method, current performance level of the metric, desired performance level of the metric, timeframe in which to achieve the desired performance level of the metric, and who judges if the desired performance level of the metric has been met within the timeframe.

EXAMPLE Table 9 is from an automotive supplier, designing a new brake sensor[11]. Stakeholders included the company, various subsystem engineering groups, assembly teams, and customer engineering and assembly. The quality engineering group is responsible for the design validation plan and report (DVPR) and production validation plan and report (PVPR) and sets a goal for making and delivering the right product on time. Other business goals are defined for price, market reach, and technology.

Table 9 — Business goals table for a manufacturer

Goal statement	Description
Best quality	Engineering development, DVPR and PVPR test results (total cost). **Ensure we make the product right the first time and deliver only quality products on time.**
Lowest price	Component BOM and engineering development cost not passed on to other areas of the system. **Relentlessly drive down costs to offer customers the best price while meeting profit goals.**
Global reach	Adaptable to different brake system applications that require a similar sensor. **Position globally to service key customers and grow with new markets.**
Innovative technology	Adaptable for both system and modular level integration. **Offer leading-edge systems and products that add value for our customers. TRW is uniquely positioned to be a leader in active and passive safety technologies.**

NOTE 2 Measures of an internal business process are called “process indicators” and measure how well a process is meeting the voice of the business. Output indicators are a measure of how well a process is meeting the voice of the customer of the business process, often a later step in the business process. Objectives or goals can be defined relative to the current state of the process.

9.1.3.3 Prioritizing business goals

Business goals can have different priorities depending on the project. It can help the team to align itself by discussing which are most important to achieve in case trade-offs must be made later. The analytic hierarchy process (AHP) can be used. The prioritization process described in 9.1.2.8.7 is applied in Table 10 with the priorities displayed in the rightmost row average column. Numbers are rounded to three decimal places.

Table 10 — Business goals prioritized with AHP

	Best quality	Lowest price	Global reach	Innovative technology					sum	row avg
Best quality	1	**2**	**5**	**7**	0,543	0,609	0,357	0,438	1,946	0,486
Lowest price	1/2	1	**7**	**7**	0,271	0,304	0,500	0,438	1,513	0,378
Global reach	1/5	1/7	1	**1**	0,109	0,043	0,071	0,063	0,286	0,071
Innovative technology	1/7	1/7	1	1	0,078	0,043	0,071	0,063	0,255	0,064
	1,843	3,286	14,000	16,000	1,000	1,000	1,000	1,000	4,000	1,000
								Inconsistency		0,04

9.1.4 Identify project constraints

Constraints include schedule, human resources and technical expertise, and cost or investment. Other constraints include external ones such as patents, governmental legislation, and regulations such as export or import controls and trade agreements, environmental and sustainability matters, industry standards; and internal ones such as technology readiness and feasibility, manufacturing site and equipment considerations, resource availability, information vulnerability, privacy, etc.

EXAMPLE Table 11 details other project objectives that rein in downstream design choices[11]. In this example, the design must be flexible to work for a variety of automobile vehicle platforms, not just a single platform. This means they must consider a broad number of applications, which could require more engineering than designing for a single application. QFD team understanding this at the start of the project helps ensure that resources, money, and time are allocated appropriately.

Table 11 — Project constraints table for a manufacturer

Goal statement	Description	How measured?
Flexible design	Capable of being used on a variety of vehicle platforms./Low design risk.	# platforms applied
Low BOM price	Cost reduced from current sensor. Cost not to be passed on to other areas of the system.	Cost ratio: (Sensor/System)
Technology leadership	Low error performance.	Sensor performance (error)
Low customer risk	No loss in performance due to component variation or all-out failure, “adequate redundancy”. No “surprises” at SOP/launch.	# launch or field issues

9.1.5 Project scope

9.1.5.1 General

Once a project has been chartered with a budget, resources, deliverables, and time schedule, any change in scope can have significant impact. The project should have a clearly defined scope in order to prevent scope drift and creep. Information related to scope can include information from the business goals table, the project constraints table, and the project charter document. The project scope information can be used to clarify the project charter.

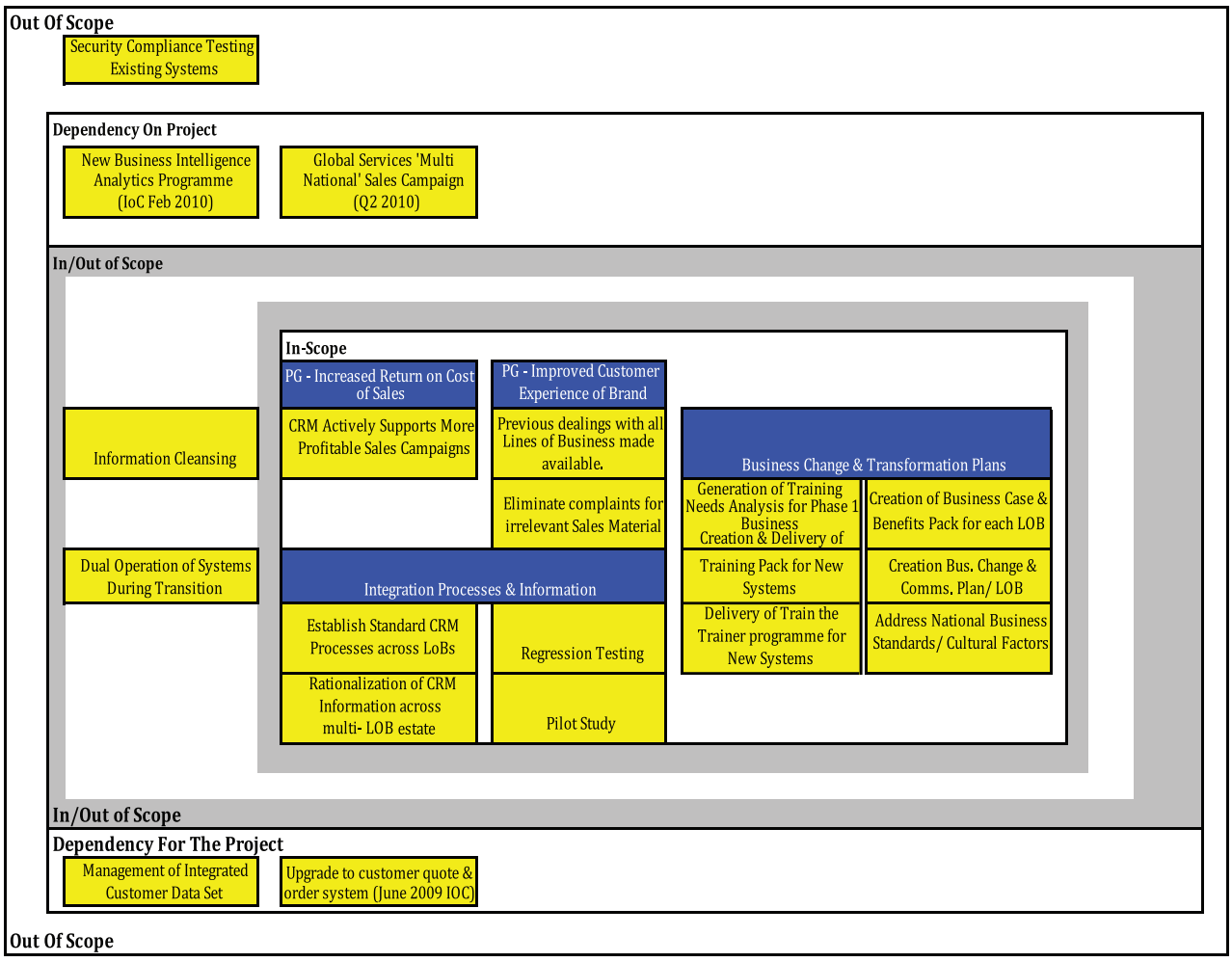
NOTE After market information is acquired, the scope can be adjusted to reflect new information regarding demand and competition.

9.1.5.2 Scope boundary analysis

The QFD team and product manager should clearly define the scope of the project in order to prevent scope creep (expansion of the scope) or scope drift (changing business goals or project constraints). The scope boundaries can be displayed as what is in-scope, out-of-scope, shared in/out-of-scope, or unsure. Also, dependencies can indicate related concerns or tasks.

EXAMPLE Table 12 is an example from a customer relationship management software (CRM) system[33]. The QFD team considers goals such as improved customer experience with brand is in-scope, while security compliance testing of the existing systems which are to be replaced, is out-of-scope. Dependencies on the project are those projects or goals which rely on the development of this project are mapped. In this example, a new business intelligence analytics programme would depend on the goals of the CRM software programme being satisfied. Similarly, there is a field near the bottom of the chart where dependencies for the project or goals which need to be satisfied for the CRM project to be successful are mapped. In this example, management of integrated customer data set capability must be in place. These two areas help identify potential stakeholders not immediately involved in the project, but whose goals and needs should be considered during the QFD analysis. Immediately around the in-scope area is an area called “in/out-of-scope” for goals that are neither agreed to be in- or out-of-scope. In this example, dual operation of systems during transition is identified for further consideration; in/out-of-scope goals must be allocated to in-scope or out-of-scope before this stage of analysis is completed as this impacts stakeholders, needs, and allocation of associated development resources.

Table 12 — Scope boundary analysis in information technology (IT)



9.1.5.3 Process beginning and end table

The process beginning and end table maps business processes that are linked in a business process. It identifies the start point and the end point of the process that are within the scope of the project. Process goals, customers and stakeholders, and any special requirements are also identified by the QFD team.

EXAMPLE Table 13 is an example from a QFD project to improve the patient experience in a cancer clinic[4]. The scope was set to focus on the experience that patients have from the time they enter the department where they are to receive service, beginning with the first encounter between the patient and hospital staff and end when the patient departs from the area. It was also noted that it might be possible that later in the QFD analysis of the service process from the customer's perspective, the process beginning and end points might need to be revised, should additional needs be exposed. This could, of course, require that the project scope be reviewed again by the leadership team. By spending time defining the boundaries (beginning and end) of the process from the customer's perspective, the team was able to agree that the greatest leverage for improving the patient's experience begins at the moment they arrive at the department and ends not when the service is over, but when they leave the department. While it was recognized that other opportunities exist to improve the patient experience well before they ever enter the hospital and days or weeks after their service, these were considered out of scope for this project. This focus helped the team to stay on track and not drift into other areas.

Table 13 — Process beginning and end table for health care service

Begin	Process	End	Customers and stakeholders	Special requirements
Enter Individual Department reception	Consistently make patients feel like individuals	Discharged from department at door	Patients and family of lab, oncology, and DI	None

9.2 Voice of customer (VOC) or stakeholder (VOS) (non-quantitative)

9.2.1 Identify customers or stakeholders

9.2.1.1 General

A product provides benefit to one or more customers. There can also be a chain of involved customers or stakeholders including constituents (of a social service); end users and consumers; intermediate users such as dealers, installers, operators, maintenance, and other users; and internal customers such as human resources, manufacturing, and other departments who reflect the underlying activity network of delivery of the product to the user. The relationships among these various customers should be clarified. When many customers exist, they can be prioritized in order to focus resources first on high-priority customers.

9.2.1.2 Customer value chain

Some new technology and product development projects have easily defined users or consumers such as in business-to-consumer products (B2C), but it can be the case that there is a chain of customers who can influence the success or failure of the product in the market, especially in business-to-business products (B2B). Identifying this chain of customers can later help the VOC and VOS acquisition team fulfil its critical needs or prevent any critical failures that could cause the product to fail to satisfy. A VOC and VOS acquisition team choosing to investigate part of the value chain to acquire quantitative or non-quantitative information can prioritize either links in the value chain or within a link specific customers. Marketing and sales members of the VOC and VOS acquisition team typically lead this analysis.

NOTE New technology and product development projects that focus on internal business processes can also have a customer value chain. In this case, a customer is the receiver of the output from the prior step, activity, or task within a process. The customer most impacted or who has the most to lose or gain as a result of the quality of the output is considered a key customer.

EXAMPLE Figure 6 is a simple flow chart of the many customers of a bottle of wine, beginning with the winery and flowing to the wine drinker. Each of these customers can have needs for the product to satisfy or at least not fail. For example, the wholesale distributor can be most concerned about delivery schedules, packaging and handling, and storage dimensions. The restaurant and retailer can be concerned about storage dimensions, bottle height on shelf in order to maximize retail space, label graphics, shelf life, and return policies. The sommelier can be concerned about information related to vintage cork properties that ensure product quality, and wine characteristics for recommending food pairing. The dinner host can be concerned that their guest has a memorable experience, thinks highly of them, and trusts them. The wine-drinking guest can be looking forward to that memorable experience and a future relationship with the dinner host.

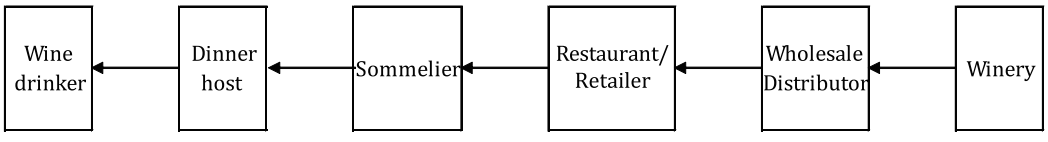


Figure 6 — Customer value chain for winery

9.2.1.3 User personas

It can be useful to synthesize from different customers with similar attributes a fictional persona that represents similar modes of use, applications, brands, attitudes, and other factors. Photos can also be added to make the customer seem more real. A persona helps communicate target attributes throughout downstream QFD activities. Personas are commonly used in agile software development to bring users and their motivations to real life for developers[6].

EXAMPLE For example, meet Donna. Donna is a 73-year-old recent widow whose children have bought her first mobile phone to use in case of emergencies. She has always kept a handwritten telephone book in her purse for use with pay phone booths if she needed to make a call away from home. Donna keeps up with many activities she used to participate with her late husband, including once-a-month golf outings, three-times-a-week swimming, weekly card games with long-time friends, and driving to doctor's appointments. She has a home computer that she uses to email relatives, but she has never owned a camera, uploaded pictures or documents to her computer, or even done online shopping. She pays for most purchases by credit card and pays her monthly statement on-time by mailing in a check.

9.2.1.4 Stakeholder analysis

Stakeholder analysis is used to evaluate the role and position of individuals involved, affected by, or have some control over the outcome of a project or process. In complex technical systems and infrastructures, there can be several layers of management from different organizational functions, a multi-stage chain of providers and sub-contractors of hardware, software, and services representing different aspects of the product offering including purchase, implementation, training, support, and others. This should also include groups of external customers in the value chain. Suppliers can even be customers and vice versa. The design is made more complex because it has to address the needs of this diverse set of stakeholders who often have conflicting views on what functions and performance requirements are needed. Analysing the relationships among stakeholders helps negotiate and maintain coherence of requirements, priorities, and other factors in the system design.

NOTE Stakeholders can include legislators, regulators, and standards bodies who put demands and constraints that must be met or exceeded, such as data protection, security, safety, and recyclability. It is possible that in the timeframe that products and services are developed, the legislative, regulatory, and standards requirements can change significantly. So, understanding trends or direction of travel in these stakeholders is particularly important.

EXAMPLE In information technology (IT), who is the customer and who is the supplier? From an external point of view, the end users are the customers; they demand a service that has been defined by contract, i.e. the end user of a mobile phone demanding the availability of their data service. The suppliers are the originators or designers of the services, i.e. the IT department or an external provider of IT services. From an (enterprise) internal view, the authorities that are responsible for the business processes that require a specific IT service, i.e. departmental management, can be considered to be customers as well. Thus, representatives of a subcontractor, i.e. a key account manager of an IT service provider, can be suppliers as well. There is a multi-stage supply chain of services: a supplier can be a customer as well and vice versa. The quality of the service provided to the end user is more than the sum of the services of all links of the chain — the service supply chain must be considered as a whole, integrating all stakeholders. This can be mapped as shown in Figure 7[24].

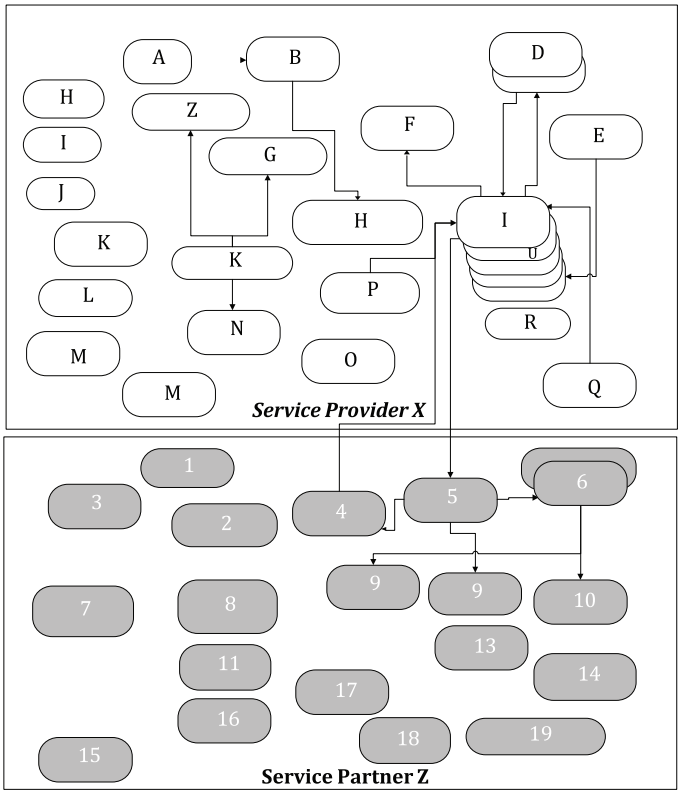


Figure 7 — IT stakeholder analysis chart showing interrelationships

9.2.2 Marketing perspective and engineering perspective of customers and their activities

9.2.2.1 General

For product development, customers or stakeholders should be defined from both a marketing perspective (channel, region, size, and other related demographics) and an engineering perspective (who, what, when, where, why, and how the product is or could be used).

NOTE Product use modes can be important in studies for parameter design for robust products, security products, system security design, for reliability, and for minimization of system vulnerability.

9.2.2.2 Customer segments table

The marketing perspective of customer segments can be tied to three of Kotler's four Ps of marketing introduced in 9.1.2.4, namely price, place, and promotion to attract and retain customers. Mostly, these address issues related to such customer attributes as income, education, lifestyle, attitudes and beliefs, and other demographic and psychographic attributes. The fourth P, product, is of great concern to the engineering, technical, operational, and support functions of the organization because this is the focus of design, development, build, and commercialization quality. To achieve quality in these areas, engineers need to know the 5W1H of the customer's application listed below. There can be additional categories depending on the product.

NOTE 1 There are two types of customer segments tables described in the examples. Type I is used when customers are well defined and known, such as when the QFD project is a refresh of an existing project. Type II is used when customers are ill defined and the team wishes to brainstorm unfamiliar market spaces.

a) Who uses the product?

NOTE 2 Describes the purchaser, user, beneficiary, and others.

NOTE 3 Can also include who else could use it and who should not use it.

b) What is the product used for?

NOTE 4 Describes the application or use case.

NOTE 5 Can also include what else it could be used for and what it should not be used for.

c) When is the product used?

NOTE 6 Describes a temporal factor, such as season, time of day, and prior or during or following an event (such as before the monsoons begin and at end-of-year accounting).

NOTE 7 Can also include when else it could be used and when it should not be used.

d) Where is the product used?

NOTE 8 Describes a location or geographical position, such as country, altitude, room in a building, and climate.

NOTE 9 Can also include where else it could be used and where it should not be used.

e) Why is the product used?

NOTE 10 Describes the customer's expectation of benefit, problem to be solved, and reasoning.

f) How is the product used?

NOTE 11 Describes a mode of use such as continuous or intermittent, automatic or manual, and alone or part of a system.

NOTE 12 Can also include how else it could be used and how it should not be used.

EXAMPLE 1 Table 14 is an example for an existing paediatric clinic developing a new electronic health record system (EHR) to help medical specialists seeing the same patient communicate better among themselves as well as with the patient and their caregiver, usually a parent[6]. Since the patients and specialists are known, a type I customer segments table that is constructed row-by-row can be used. In this example, one customer is the paediatric patient (pt) and family suffering from spinabifida, in order to improve communications between the parent and the visiting physicians, primarily at the Children's Mercy Hospital (CMH) daytime ambulatory clinic, because the visiting physicians do not have enough time to interact with the parents, and so they want a tool to help better evaluate treatment options.

Table 14 — Customer segments table for hospital paediatric clinic

Customer segment	Who uses process	What morbidity or condition	What is process used for	Where	When	Why	How
Pediatric patient	Pt and family	Spinabifida	Improve interaction between visiting physicians	CMH main campus	Daytime ambulatory clinic	Visiting physicians do not have sufficient time to interact	Develop new tools to better evaluate treatment options
Visiting physicians		Mild traumatic brain injury				Share medical records from urban to rural facility members	Improve communication between physician and patient
Nursing staff and access representatives		Muscle and nerve					Improve communication among providers

EXAMPLE 2 Table 15 is an example of a motorcycle brake supplier identifying several links in the customer value chain [original equipment manufacturer (OEM) purchasing department, marketing department], as well as the after-sale service and the end user[5]. Its purpose was to explore new user experiences and so a type II customer segments table that is constructed column-by-column can be used. The QFD team, often led by sales and marketing, brainstorms all the whos, all the whats, all the whens, and so forth. Then, potential segments are identified by linking different cells with lines and bubbles. This table shows two potential segments of end users that the QFD wishes to learn more about. First (solid lines and bubbles) is the 38- to 49-year-old male who uses the motorcycle to commute to work in the summer, in a dry climate with concrete roads in the US and Canada, as an alternative mode of transportation, and often carries a passenger. Second (broken lines and bubbles) is the 38- to 49-year-old male who uses the motorcycle for leisure in the summer, in a humid climate to go to the beach (drives on sand) in Australia or New Zealand, who sees this as part of his self-image, and often attaches a trailer for camping.

Table 15 — Customer segments table for motorcycle brake

Who uses product?	What is product used for?	When is product used?	Weather	Surface	Where is product used?	Why is product used?	How is product used?
OEM-Purchasing	Commute	Summer	Dry	Concrete	Asia	Image	Xtreme
OEM-Marketing	Leisure	Fall	Dusty	Gravel	US/Canada	Transport	Trailers
OEM- Service	Status	Winter	Hot	Sand	Latin America	OTJ	Side Cars
End User-Males, 38-49	Patrol	Day	Humid	Mud	Aust/NZ	In lieu of car	w/Passenger

9.2.3 Prioritize customers or stakeholders

Customers or stakeholders can be prioritized so that information acquisition begins with high-priority customers whose satisfaction is most critical to achieving the business goals of the project. Once potential customer segments are identified, some criteria can be used to prioritize them. One criteria set is the business goals from 9.1.3.3. These can be combined in an L-matrix as shown in Table 17 which is used to transfer the priorities of the business goals into priorities of the customer segments. Here are the steps.

a) Enter the business goals and their weights into the rows. Enter the potential customer segments into the columns.

b) The L-matrix indicates the cause-and-effect relationship of the column to the row. Working row-by-row, the QFD team, led by the product owner and marketing department members, judges how important each customer segment is to achieving each business goal. Relationships strengths are indicated using the icons or ratio scale weights in Table 16. These ratio scale weights are appropriate for the next mathematical calculations.

   Judging the strength of the relationship between the customer segment and the business goal is somewhat subjective. When making subjective judgments, it is recommended to use at least five or nine levels of judgment, as this optimizes human decision making capabilities. Sometimes called the “magic number 7”, plus or minus 2 for memory processing or more simply Miller’s Law written by George A. Miller in 1954, it suggests that limits in absolute judgment and short-term memory are optimized at seven “chunks” of information. Depending on other factors including whether the information is digits, letters, or words, familiar or not, allows for some variation between five and nine levels. Saaty used this to develop his fundamental scale of absolute numbers further explaining that humans break the levels into groups of 3 (high, medium, and low) and then each of these into groups of 3, thus yielding nine levels. Saaty also explains that words are more familiar than numbers to most people when describing intangibles so he recommends the five words of equal or weak (W), moderate (M), strong (S), very strong (V), and extreme (X) and their four intervals for compromises[28].

   NOTE The next steps use the mathematical functions of addition, multiplication, and division. The ratio scales given in Table 16 support these functions because the ratios between the weights are equal. Ordinal scales such as 1 to 5 do not have equal ratios between the weights and thus should not be added, multiplied, or divided. This misuse of ordinal scales is commonly found in older QFD case studies conducted before electronic calculators and personal computers were introduced in the late 1970s. It is still common to see this ordinal math in newer case studies, but it can be replaced with ratio scale weights.

c) Multiply the business goal weight by the relationship weight for each cell. Sum these products for each column. Normalize to a customer segments weight percentage. These priorities help the QFD

focus available resources, time, and money on investigating the customer segments according to their contribution to the business goals of the project.

Table 16 — L-matrix relationships strength, icons and weights

	Symbols	Weights
Extremely strong relationship	●	0,503
Very strong relationship	◕	0,260
Strong relationship	◑	0,134
Moderate relationship	◔	0,068
Weak relationship	○	0,035
No relationship	·	0,000

EXAMPLE Table 17 takes the prioritized business goals from Table 10 and enters them into a row of a relationships L-matrix. In the columns are entered the potential customer segments, in this example, the plant operations, the OEM plant operations, the domestic Detroit 3 manufacturer's engineering department, and foreign manufacturer's engineering departments. For this example, the relationship strengths show both the icon and the priority value in the split cell, but it is acceptable to use only the priority values. To calculate the absolute weight of the segment of the manufacturing plant, multiply the weight of business goal best quality (0,486) × the weak relationship weight (0,035) = 0,017. Multiply the weight of business goal lowest price (0,378) × the weak relationship weight (0,035) = 0,013. Multiply the weight of business goal global reach (0,071) × the very strong relationship weight (0,260) = 0,019. Multiply the weight of business goal innovative technology (0,064) × the moderate relationship weight (0,068) = 0,004. Sum these products 0,017 + 0,013 + 0,019 + 0,004 = 0,053, rounded to three decimals. This is repeated for each column and the absolute weights are summed to 0,669. Then the absolute weights are normalized by dividing each by the sum to get the customer segment weights of 0,079, 0,292, 0,160, and 0,469. The team decides to utilize its project resources, time, and budget by allocating 7,9 % to investigate the manufacturing plant, 29,2 % to investigate the OEM manufacturing plants, 16,0 % to investigate the Detroit 3 manufacturing engineering, and 46,9 % to investigate the foreign manufacturing engineering.

Table 17 — Business goals/customer segments prioritization matrix

Business Goals	Business Goal Weights (Management	Customer Segments: Our manufacturing plant	OEM manufacturing plant	Detroit auto manufacturers	Foreign manufacturers (Europe and Japan)	
Best Quality	**0,486**	0,017	0,000	0,065	0,245	
Lowest Price	**0,378**	0,013	0,190	0,000	0,051	
Global Reach	**0,071**	0,019	0,005	0,010	0,019	
Innovative Technology	**0,064**	0,004	0,000	0,032	0,000	
Absolute Weight		0,053	0,195	0,107	0,314	**0,669**
Customer Segments weight		**0,079**	**0,292**	**0,160**	**0,469**	1,000

9.2.4 What is contained in the voice of customer (VOC) or voice of stakeholder (VOS)

VOC and VOS are raw, unprocessed information from the customer and stakeholder, respectively. It often includes complaints, needs, functional requirements, performance specifications and targets, solutions, components, materials, activities, information, and other customer or stakeholder statements. To be most useful, these can be sorted, analysed, structured, quantified, and prioritized by key customers. This analysis is detailed in ISO 16355-4.

9.2.5 Sources of VOC or VOS

9.2.5.1 General

Sources of VOC and VOS can be acquired through several methods and tools. The voice of customer or stakeholder can be obtained through non-quantitative and quantitative methods below. Surveys should be properly designed, tested, and evaluated.

9.2.5.2 Customer gemba visits

9.2.5.2.1 General

One of the strengths of the QFD process is to gain first-hand information directly from the customer as they are using the product. The Japanese word *gemba* captures this as going to the place where the truth is to be found. It is no wonder this term is used to by Japanese police to describe a crime scene where evidence is collected, and by Six Sigma and quality professionals to encourage problem-solving teams to go to the work site to truly grasp not only the cause of a problem, but also the people, conditions, process, materials, and other often overlooked contributors to the problem. In QFD for new product development, the organization's gemba of operations is not yet designed or in place yet, so the gemba shifts to the customer's work site or place of use to understand the customers, conditions, process, materials, and other contributing factors to the customer's negative problem or positive opportunity. The gemba visit focuses on the customer, not the product.

9.2.5.2.2 Gemba visit checklist

Plan in advance the details of the proposed gemba visit as shown in Table 18.

a) Who is to be visited and who are to be the QFD team members? The QFD team should have at least two persons, balancing one with a customer-facing role and one with a technology- or operations-facing role.

b) What is the team looking to investigate during the gemba visit? This could be a customer action, process, environment, or some other factors related to the project.

c) When is the team going to the gemba? The season, time of day, or other temporal plan should be connected to the customer segments table. If the team arrives too early or late, they can miss the very event they planned to investigate. How long to stay?

d) Where is the team going? The place, environment, or other geographical plan can be connected to the customer segments table. If the team goes to the wrong place, they can miss the very event they planned to investigate.

NOTE 1 Unless the product is tables and chairs, the gemba is rarely a meeting room. Rather, one navigates to the very place where the action takes place.

NOTE 2 There are some gembas that are difficult or impossible to reach. In such a case, a proxy gemba can suffice, provided one's competitor has no better access.

EXAMPLE When designing an animatronic triceratops for a theme park attraction, the QFD team was unable to find a location where living dinosaurs and humans interact. A suitable proxy gemba was visited, leading to valuable performance-enhancing and cost-saving results[2].

e) Why is the team going to the gemba? This can have been determined earlier in the QFD process as business goals or other elements in the project charter. If not, clarify the purpose prior to gemba visits so that the team is clear about their purpose.

f) How does the team visit the gemba? What recording devices to bring? What gifts are required or limited according to the company policy (see values and guiding principles from 9.1.2.2.2 or local traditions. Who talks and who records?

g) How many gembas do the team visit? Since the information is non-quantitative, sample sizes can be smaller than with quantitative information. Many QFD studies find that gembas quickly become repetitive and yield little new insight.

Table 18 — Gemba visit checklist for sleep clinic

#	Customer segment	Who goes	What to prepare	Where to go	When to go	Why go (what to investigate)	How (methods)
1	Middle age male patient	CK, RS	Note pads, voice recorder	Main hospital sleep clinic	Arrive 5:00pm	Understand PT setup and full night experience	Observation
2							

9.2.5.2.3 Customer process model

Either before the first customer gemba visit, or during the first customer gemba visit, draft a model of the customer's business or life process for which the new product is going to improve. The model can be as simple as a flow chart or can be detailed if the customer is sufficiently technical and detailed. The customer process model can be reviewed with the customer, step by step, and annotated with feedback.

a) What goes right with the customer's process and should be preserved in the new product?

b) What goes wrong with the customer's process and could be improved?

c) How does the customer measure their success or failure and at what thresholds?

d) What is the biggest pain point in their process that the QFD team should investigate more thoroughly? This focuses the team on where in the process the customer is most motivated to purchase a solution, and the magnitude of their problem which could help set a price point and cost targets.

EXAMPLE Table 19 is an annotated customer process model for a radiotherapy quality assurance medical device used in cancer treatment centres[16]. The process modelled here is to check the daily setup of the therapy devices and software before patient treatment. For example, step 2 is to set up the xxx quality assurance (QA) device and to start the software (SW). Things gone right include simple usage of the SW for the setup, which alerts the QFD team that the new product should continue to have simple software startup. Things gone wrong include that while simple, non-software components are still cumbersome and time consuming to set up, and due to weight, is not easy for everybody in the department to manipulate. The operator's way to measure these includes checks that need to be completed by 7:00am so patient treatment can begin, and that more QA checks can be done in the same time span as now. This is a major pain point for the device operator and requires additional investigation and observation.

Table 19 — Customer process model for medical device, with annotations

	Regular daily working routine (Patient treatment, document review)	Setup xxx QA device + start SW	Select energy and parameters	Beam on measurements	Analysis of measurements	Repeat the last 4 steps for different settings	End of day
Things gone right		Simple usage of SW for setup.					
Things gone wrong		Cumbersome time consuming setup, device + MC setup not easy for everybody in department (weight constraints).	Tests defined by user can be not sufficient. Setup at the beginning very time consuming. Knowing how transfer to colleagues is problematic.	Spending lot of time on the machine –> long working day (after patient treatment).	Lack of efficiency as more information is available then can be analyzed manually. Displayed information too much –> confusion of user.	Efforts to spend here. More automation favorable.	Open end.
How is (dis)satisfaction measured? Targets?		Checks need to be finished by 7 am or switch to the end of the day (SW alignment tool). Work-life-balance More QA in the same time span.	Pre-defined tests for quick setup. Sharing possibilities of results and test setups.	User has to stay long at work. Measurement in hours after end of regular patient treatment (without new product and with new product). Goal: reduce time user has to stay to <50% (<15h) of time used now (30h).	Automatic routines when data available. Target accuracy of 0.1 mm.	5 min + beam time, reduction of monthly time (30h) by 15h target.	Interruption possibility required. Reproducibility of setup is essential (SW correction functionality).
Which tasks are key pain points for the customer?	□	■	□	■	□	□	□

9.2.5.2.4 Gemba visit table

When the customer or stakeholder can identify problems in their work or life process, a visit to the actual activity can help identify unspoken needs. Unspoken needs can come from areas in which the customer forgot to say something in the customer process model review, something the customer is hiding because of embarrassment or misunderstanding of proper use of the product, something the customer did not think was possible, and other reasons. Discovering unspoken needs is an opportunity for product developers to create a differential advantage in the new product because competitors can also be unaware of unspoken needs. The gemba visit table consists of two parts.

a) The top part records such details as who was visited and any memorable characteristics, who were the team members, when and where of the visit, what were the conditions of the visit. This information provides context to help extract the unspoken needs.

b) The lower part of the table includes hard data inputs: a description of the pain point step, what was observed as the activity was engaged, what was heard (verbatim words, sound), and other relevant sensory inputs such as touch, smell, taste, and any documents or data. Also included is soft data input: the VOC and VOS acquisition team's thoughts or notes about the customer and activity. From these complex inputs, reword and clarify discrete output statements. If possible, ask the customer to explain how they would measure if these statements were fulfilled and what target thresholds might be. This information is useful later when setting product performance targets.

NOTE While it is ideal to investigate the entire customer process model, time and access limitations can make this difficult. When possible, ask to visit the actual activities of the key pain points identified in the customer process model first.

EXAMPLE Table 20 indicates that in a customer process, task 2, to deliver and measure representative xxx fields, is a major pain point for the dosimetrist who is the operator of the device[16]. The VOC team observed that all needed measurements should be acquired in one "shoot" of the radiotherapy equipment. The dosimetrist verbally highlighted that the process should have good usability and be simple. The dosimetrist also produced computer screen shots from the software application to further illustrate how information is currently displayed and what is good and bad. The VOC team notes also that similar concerns were raised in task 1 with a wrong gantry position that is frequently detected too late and results in bothersome phone calls. An analysis of these hard and soft inputs produced the following clarified outputs: required tasks can be performed by a dosimetrist level person, measurements can be acquired in one shoot, additional parameters such as gantry angle should be logged in to be more efficient, and so forth. Since the issue of gantry angle input was raised, the team also believes that other parameter inputs also increase efficiency so they have added collimator rotation. So, even though the customer only mentioned gantry angle, it is reasonable to assume that collimator rotation should be considered. Until customers prioritize their needs, no design decisions are reached. Adding to clarified items allows the customer to later prioritize this; if it is omitted, the customer is not able to indicate its priority. This is how unspoken customer needs can be extracted from the gemba.

Table 20 — Gemba visit table for medical device user

Step, task #	Process step, tasks	Observations	Verbatims	Documents, data	Team notes	Clarified items *with measures*
T2	Deliver and measure representative xxx fields	Task was executed by the dosimetrist. All needed measurements are acquired in one shoot.	The dosimetrist highlighted the good usability and its simplicity.	See screenshots from SW.	As mentioned in T1, the main failures are connected with the wrong gantry position and only detected relatively late (ending up in "Morning Calls" to him which he does not like). He also was mentioning that a better resolution would be of help.	Task can be performed with dosimetrist skills.
						Measurements acquired in one shoot.
						Additional parameters like gantry angle should be logged to help increase the workflow efficiency.
						Additional parameters like collimator rotation should be logged in addition and would help to increase the workflow efficiency.
						See screenshots from SW.
						Can tell if gantry position is correct at the beginning.
						Tests do not need repeating.
						Need better resolution.

9.2.5.3 Customer-supplied specifications

Especially in business-to-business transactions, a customer can provide drawings, blueprints, or specification documents with their requirements. Often, these are requirements for the product, but do not explain why the specification is required.

EXAMPLE From a motorcycle manufacturer to its brake system supplier. S5.1 Required equipment — split service brake system. Each motorcycle shall have either a split service brake system or two independently actuated service brake systems.

9.2.5.4 Customer support and help systems

Many companies offer customer support by telephone, online chat, and other remote methods. The records of these communications include both the frequency of which topics are inquired as well as

verbatim comments by the customer. These can be useful in designing new products and business processes to address both the customer and the support staff needs.

EXAMPLE A software company has 24-h help desks located around the world so that they are always online. The staff answer frequently asked questions by searching company technical reports on similar issues. The technical reports do not follow any formatting standards, so the support staff must read through many unnecessary sections before finding the required information. QFD was used to understand the needs of the staff to locate useful information quickly and to create a format standard for engineers to follow.

9.2.5.5 Analysis of beliefs (AoB)

Analysis of beliefs enquires into implicit and individual knowledge, which can be buried deeply within the soul and beyond actual awareness. In order to uncover such kind of implicit knowledge, this analysis is not limited to a specific product or service at first. However, there must be a certain reason for action, an initial problem, or a challenge. This problem or challenge becomes an explicit starting point, such as "what do you feel when using product x?" The statement should address a specific aspect of acquisition or application but should not comprise a solution, thus leaving room for interpretation of the reasons. This statement is the starting point of AoB. It is then followed by further inquiries into roles, situations, and empathy as shown in Figure 8[25].

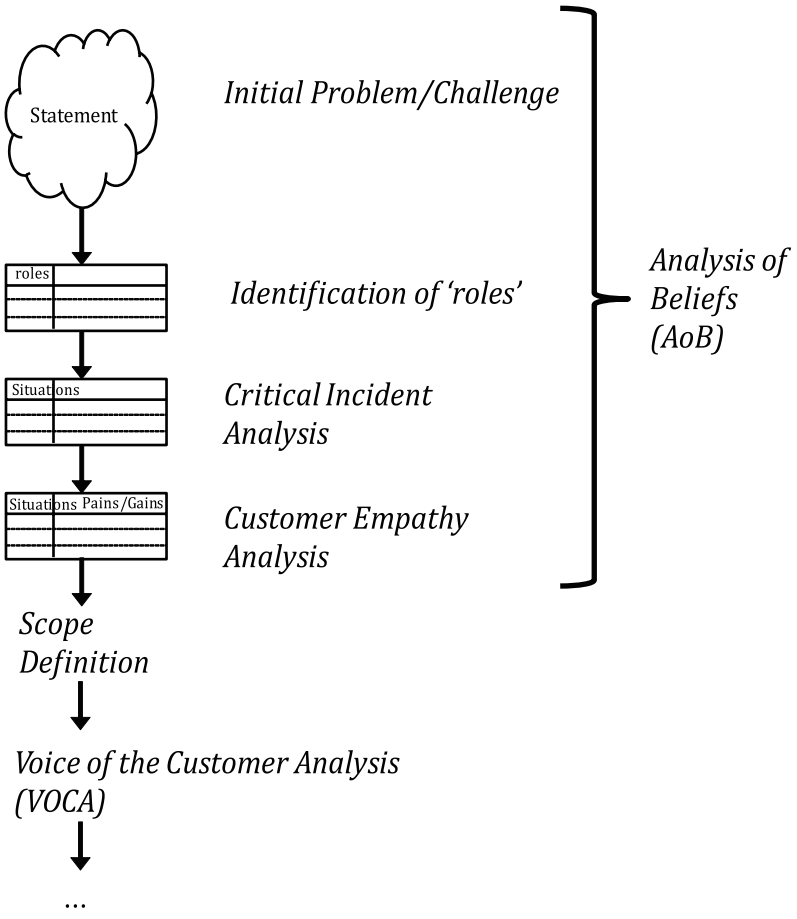


Figure 8 — Analysis of beliefs flow

9.2.5.5.1 AoB workshop

Teams of three people take on the roles of customers and providers and question each other as follows. These are then recorded in the situation table (see Table 21)[25].

a) Regarding times and places (role) they would like to experience again or avoid when using the subject product (critical incidents).

b) Think of other products and situations they would like to experience again or avoid.

c) Think of another time or place where the subject product might be used or avoided.

d) What was sensed or felt before, during, or after the situation, and what pains or gains were experienced?

Table 21 — AoB situation table

	Situation	See and smell	Hear and sense	Say and do	Think and feel	Pains	Gains
Customer → Provider	visit of sales rep.	elegant car	smells new	offer compliment	high price?	distrust	respect
Provider → Customer	visit of sales rep.	sleazy outlook, bad odor	street language	where do you come from?	laid-back☺ not trust-worthy☹	payment shortfall 💣	easy-going

9.2.5.5.2 Using AoB information

Based on the statements in the situation table, empathetic insights can be drawn about the deeper beliefs of the customers. These statements and insights can be included in the voice of customer analysis in ISO 16355-4.

9.2.5.6 Focus groups

Customers meeting certain criteria are brought together to discuss topics of interest to the organization. Topics include problems, solution concepts, prices, and other matters. They can also be used to expose consumers to a new product concept and analyse reactions, to evaluate market positioning; advertising, and promotions; habits, attitudes, and usage studies; and packaging studies. Focus group participants should be carefully screened and selected to represent the key customer and stakeholder segments. A trained moderator should conduct the focus group, and, if possible, video or audio taping should be made for later review.

EXAMPLE A diabetes clinic conducted a focus group of children and their parents to discuss their difficulties in determining the nutritional values of school lunches. Children were asked to describe their lunches, what their friends were eating, and peer pressures that affected their eating habits. This was helpful in producing guidelines the children could follow.

9.2.5.7 Social media

Searching the Internet by use case, brand name, and complaints uncover how the product is used, could be used, or should never be used. YouTube self-made video clips range from the initial unboxings of a product (hints to package designers) to common and unexpected use and to disposal. Unexpected use modes can be useful to developers because it can predict unmet needs that the consumer is adjusting the product to achieve or it can identify safety issues if the consumer is abusing the product.

EXAMPLE Figure 9 shows user-added welds in order to handle more extreme applications[19].

Figure 9 — User-added welds shown in photo

9.2.5.8 Free response questionnaires

These are useful for collected complaints and later translate into positive customer needs[19].

EXAMPLE A QFD study on cigarette lighters asked consumers how the appearance of the lighter impacted their self-image.

9.2.5.9 Interviews (direct and secret shopper)

These are useful for getting direct information from users during purchase, use, and other stages in ownership.

EXAMPLE 1 A tractor manufacturer's market research group investigates market-demanded quality including known and hidden needs. Known needs can be obtained easily, but identification of hidden needs is difficult. The Kubota division has been in contact with product users at product test locations and has talked with them in order to obtain first-hand information on the hidden needs of farmers[21].

EXAMPLE 2 An automobile manufacturer has employees work in dealer showrooms to better understand what buyers and families are looking for in terms of quality, and communicate that back to their peers.

EXAMPLE 3 A beer company looking to better understand consumer motivations asks for recommendations from other shoppers in a supermarket[35].

9.2.5.10 Customer satisfaction surveys

A common marketing instrument, customer satisfaction surveys often focus on the product itself, rather than customer needs. Note that if responses are on a numerical scale, a ratio scale should be used if averages are to be reported. Converting ordinal scales such as 1 to 5 into ratio scales can be easily done using the AHP technique in Table 5.

EXAMPLE A major airline electronically surveys frequent fliers after flights on their experience with the airplane boarding process, the cabin comfort, the flight attendant service and appearance, the seat comfort, and other services. The survey allows free response explanations whenever service is not scored as excellent.

9.2.5.11 Lead user analysis

Lead user analysis was developed to help leading-edge companies develop long-range growth strategies, identify new markets to enter, improve existing products, and develop breakthrough produce concepts. Researchers learn from leading practitioners or users in targeted fields about emerging needs and collaborate on developing innovative solutions. Interactive sessions can take several days.

EXAMPLE A pharmaceutical company wished to investigate the safety of using its product on skin. A lead user study included a dermatologist as well as a theatre makeup artist. Over the course of a year, it brought several teams together to generate new product concepts, refine market needs, and identify markets where they could introduce leading-edge products [32].

9.2.5.12 Warranty returns, scrap, maintenance records, unplanned field failures, and complaints

Products that have failed in use or exhausted their useful life present an opportunity to investigate reliability and durability issues, as well as to evaluate how the product held up against the initial design. For companies that scrap in the field, it can be useful to have representatives send photographs, reports, and even samples back to engineering.

EXAMPLE 1 An automobile component manufacturer regularly visits scrap yards to see the condition of its parts and its competitor's parts after the vehicle is retired from service. This helps its engineering and quality departments better understand the true operating conditions of the vehicle and how that impacts the components.

EXAMPLE 2 An automobile company had to replace leather seat coverings due to fraying and tearing. Analysis showed the door opening position during entrance forced the driver to slide down the side bolster, stressing the material beyond its intended design.

9.2.5.13 Sales, maintenance, and technical visit reports

Company representatives who are regularly in the field or at parts depots have an opportunity to observe products in use and listened to customer stories. A clear procedure for capturing this information and feeding to engineering and operations people should be established.

EXAMPLE An automobile manufacturer of fuel systems sent an engineer to a car dealer regarding a component problem. While there, he noticed another mechanic struggling to replace a fuel line hose because the hose clamp was oriented in the wrong direction. Curious, he inquired and learned that the hose clamp which was oriented "up" for ease of assembly at the auto plant was impossible to remove from "down" underneath during dealer repair.

9.2.5.14 Ethnographies

Ethnographical studies can help understand consumer attitudes, motivators, inclinations, and other influencing factors. These studies can include anthropologists trying to understand deep cultural values. They can be useful for both product design as well as for marketing and promotion.

EXAMPLE A clothing manufacturer used an ethnographic study to better understand the role fashion played in selecting garments. Some of the questions are as follows[18].

a) What is your biggest opportunity, concern, challenge, or difficulty?

b) Who do you relate to? Who is your favourite movie star?

c) What event in the last six months has affected you the most?

d) What does your clothing say about you?

9.2.5.15 Continuous QFD and collaborative QFD

A QFD project is always 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) as well as product characteristics (PC) 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) as shown by the strong relationships in Table 22[8].

Table 22 — Continuous QFD matrix showing importance of ongoing collaborative meetings between developers and customers

		Specifics of Continuous QFD							
		Incremental planning and implementation cycles							
	Problems/Requirements	Simultaneous 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

9.2.5.16 Design thinking

Design thinking incorporates subjective studies of customers and uses iterative design cycles to focus on best solutions. Rather than investigating customer wishes and problems, design thinking seeks an empathetic approach at the start of design. Some models use a six-step approach of interactions to understand, research a 360-degree perspective, synthesize, ideate, prototype, and validate. It integrates well with QFD[26][31].

9.2.5.17 Conference papers, reports and journals

Every industry offers academic and professional conferences and journals. These can provide invaluable insights into problems facing markets, customers, and users as well as other stakeholders.

9.2.5.18 Gender mainstreaming

Identifying different user and customer expectations associated to their gender increases the chance to address important concerns. It fosters provision of services and products answering customers' needs, while raising the accuracy of planning, quality and success of services.

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