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

**Part 7:
Guidelines for developing digitalized
products and services — General
principles and perspectives of the QFD
method**

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

*Partie 7: Ligne directrice pour le développement de produits et
services numérisés — Principes généraux et perspectives de la
méthode de déploiement de la fonction qualité (QFD)*



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Foreword

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

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

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

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

For an explanation of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

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

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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 are well understood through the use of quantitative and non-quantitative tools and methods to improve confidence of the design and development phases that they are working on the right things. In addition to satisfaction with the product, QFD improves the process by which new products are developed.

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

The current ISO 16355 series describes methods and tools of QFD independent of industry because the principles of applying statistical methods for product and technology development are similar for all types of products. However, when applying the standard for the development of fully or partially digitized products, specific characteristics of digital goods in product development (such as measurability, immateriality, etc.) should be taken into account. Digital goods such as software are specific in economies of scale and network effects and thus require specific strategies and concepts for design, development and marketing. Due to the progress of digitalization in almost any market, the observed phenomena and measures gain relevance and importance in business and academia. Hence the emerging convergences in industries, suppliers, businesses and products cause a game change in markets for digital or digitized goods.

Therefore, this document describes guidelines for developing digitalized products and services. It aims at adapting the (QFD) process, its purpose, users, and tools as they are described in the ISO 16355 series with respect to the specific characteristics of digitalized products and services. All companies affected by the digitization of their products and services are intended users of this document.

The methods and tools shown and described represent decades of improvements to QFD; the list is neither exhaustive nor exclusive. Users should consider the applicable methods and tools as suggestions, not requirements. As the other parts of the ISO 16355 series, this document is descriptive and discusses current best practice; it is not prescriptive by requiring specific tools and methods.

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

Part 7:

Guidelines for developing digitalized products and services — General principles and perspectives of the QFD method

1 Scope

The current ISO 16355 series is written intentionally independent of industry because the principles of applying statistical methods for product and technology development are similar for all types of products. However, when applying the standard for the development of fully or partially digitized products in practice, specific characteristics of digital goods in product development (such as measurability, immateriality, economies of scale effects, etc.) are taken into account.

This document gives guidelines for adapting the quality function deployment (QFD) process, its purpose, users, and tools as they are described in the ISO 16355 series that consider these specific characteristics for developing digitalized products and services. [Table 1](#) illustrates the scope of this document by stating examples of the types of products the standard focuses on.

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 terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 digitalized products and services

works that incorporate components consisting of operable objects from digital information and communication technology

Note 1 to entry: In this document, the terms digital, digitized and digitalized are used synonymously. A digitalized good is an intangible software enabled product or service that can be sold and distributed repeatedly online without the need to replenish inventory. Digitalization may cause services to have a stronger product character.

Note 2 to entry: In this document, software product development means the development of digitalized products and software parts of software-intensive products, i.e. systems or services.

Note 3 to entry: Software parts of software-intensive systems that are not marketed and priced as separate entities are called embedded software.

Note 4 to entry: Software-intensive systems can be products from all industries such as automobiles, airplanes, smartphones etc.

Note 5 to entry: Software-intensive services, often delivered as cloud services, can also be products from all industries like financial, insurance, gaming, social software, or human services based on software support.

Note 6 to entry: This document will generally use the term “software products” instead of explicitly referring to software-intensive products.

Note 7 to entry: When other parts of ISO 16355 series or ISO 9000 series standards are referenced in this document, note they may not differentiate explicitly between products and services.

3.2 quality function deployment

QFD
managing of all organizational functions and activities to assure product quality

Note 1 to entry: The organization is responsible for product quality and strives for it via defining, testing, building, commercializing, and supporting the product.

Note 2 to entry: Literal definition is that the “quality function” is “deployed” to all other business functions and departments who play a role in assuring quality and customer satisfaction.

Note 3 to entry: In most cases, the interests of an organization are commercial, but there are exceptions, as is sometimes seen in open source-based products or in the public sector.

3.3 voice of customer

VOC
communications from the customer, user, and others

Note 1 to entry: The communications from the customer may be verbal, written, video, audio, animation, or other form and may be descriptive, behavioural, or ethnographic.

Note 2 to entry: Customer is defined in ISO 9000:2015, 3.2.4.

Note 3 to entry: For digitalized products and services, the voice may not come from the customer itself but from data or other artefacts relevant for quality.

Note 4 to entry: Customers may be not only human but also digitalized actors (digital agents).

3.4 customer need

potential benefit to a customer

Note 1 to entry: The benefit to a customer from having their problem solved, their opportunity enabled, their image (self or to others) enhanced, or being advanced to a more desirable state.

Note 2 to entry: The benefit is positively stated.

Note 3 to entry: The benefit describes a single issue.

Note 4 to entry: The benefit is independent of the product or service performance, functional requirements, non-functional requirements, functions, features, or enabling technologies.

Note 5 to entry: A need may be explicit or latent.

Note 6 to entry: Customer is defined in ISO 9000:2015, 3.2.4.

Note 7 to entry: Requirements engineering for digitalized products and services defines customer needs differently than ISO 16355-1. Requirements engineering in focusing on product requirements may not deal with customer needs explicitly. Customer needs may be latent according to ISO 16355-1 which does not match the definition of requirements in ISO 9000 where needs must be stated explicitly. If the input to voice of customer is considered as customer needs in requirements engineering, the voice analysis yields stated requirements which may be interpreted as customer requirements as the complement to product requirements. Hence in requirements engineering the term customer requirements may be used synonymously to customer needs^[2].

Note 8 to entry: The term demanded quality is also used in software QFD projects.

3.5 functional requirement

characteristic that a product or service is specified to possess

Note 1 to entry: The characteristic may be an inherent performance of the product or service or an action that the product or service may be able to accomplish. The manner in which the product accomplishes the action does not include specific mechanisms or internal procedures as part of the functional requirement.

Note 2 to entry: Product is defined in ISO 9000:2015, 3.7.6.

Note 3 to entry: Service is defined in ISO 9000:2015, 3.7.7.

Note 4 to entry: Common methods for the specification of requirements for digital products and services differentiate between functional and non-functional requirements, whereas functional requirements address actions a product may accomplish and non-functional requirements the inherent performance of a product. The terms quality requirement, and quality characteristics are also used in software QFD projects.

3.6 voice of stakeholder VOS

communications from stakeholders

Note 1 to entry: Communications from stakeholders may be verbal, written, video, audio, animation, or other form and may be descriptive, behavioural, or ethnographic.

Note 2 to entry: Stakeholder is defined in ISO 9000:2015, 3.2.3.

Note 3 to entry: Stakeholders may be not only human but also digitalized decision-makers (digital agents).

Note 4 to entry: For digital goods, the stakeholder "solution developer" is particularly important because the product is often created incrementally in close cooperation with the customer.

3.7 customer gemba

location where true customer information is found

Note 1 to entry: Gemba is a Japanese word meaning the place where the truth is discovered. In Six Sigma, this usually refers to the shop floor where internal activities take place. In QFD for new product development, the new product does not exist yet, so the gemba changes to where the customer's activities or encounters take place.

Note 2 to entry: The gemba may be not limited to physical location. For digitalized products, digitalized spaces may exist where human actors directly may not explore (for example, cyberspace).

Note 3 to entry: Gemba visits help discover unknown or latent customer needs and requirements.

3.8 hoshin kanri

method for management and deployment of strategic organizational policy

Note 1 to entry: English translations of the Japanese include policy management, policy deployment, management by policy, and strategy deployment.

4 Basic concepts of developing digitalized products and services

4.1 General

This standard describes guidelines for adapting the methods described in ISO 16355 series standards that consider the specific characteristics for developing digitalized products and services. See [Table 1](#).

Table 1 — Digitalized products and services in scope of this document

Degree of servizitation	Degree of digitization		
	Physical	Digitalized(hybrid)	Digital
Product	Watch with mechanical movement	Smart watch	Watch App on smartphone or notebook
Hybrid product/ Hybrid service	Phone with contract	Intermodal mobility services	Online booking (with chipTAN)
Service	Car repair	Car navigation system (update performed by car garage)	Automatic download via web services

not focus of ISO 16355-7	focus of ISO 16355-7
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4.2 Characteristics of digitalized products and services and their development

4.2.1 Specific characteristics of digitalized products and services

Digital products and services have specific characteristics that influence the applications of statistical and related methods to new technology and the product development process.

- a) digital "voices" from customers and stakeholders;
- b) availability of digital data from product usage;
- c) easier product changes during development;
- d) easier product changes after delivery;
- e) cloud based product functions;
- f) high rate of change due to requirements uncertainty and technology dynamics.

4.2.2 Effects of specific characteristics of digitalized products and services on the development process

These characteristics affect the development process of digitalized products and services.

- a) agile development as widely used paradigm for developing software;

NOTE There is no one common agile development model, Typical methods in practice are scrum, extreme programming (XP) or kanban. All models refer to certain core concepts going back to agile principles and values of the Agile Manifesto^[3].

- b) iterative development process for digital functions;
- c) incremental development process for digital functions;
- d) non-deterministic development and production process;
- e) negligible manufacturing cost;
- f) value co-creation through platform ecosystems.

4.2.3 Requirements change management in the development of digitalized products and services

Requirements change in every case and thus ways have to be found to deal efficiently with these changes. Agility stands here for the ability to handle these changes efficiently, aiming at a kind of balance between structuring and flexibility. According to ISO/IEC/IEEE 26515^[4], it is “based on iterative development, frequent inspection and adaptation, and incremental deliveries, in which requirements and solutions evolve through collaboration in cross-functional teams and through continuous stakeholder feedback.” It represents a countermovement to traditional, sequential development models in response to the increasing dynamics of change in requirements

4.3 Design guidelines for developing digitalized products and services

4.3.1 General

Based on the characteristics and the effects on the development process the following design guidelines form the framework for developing digitalized products and services with QFD^{[5][6]}.

4.3.2 Iterative and incremental development for digital functions

Development is in short time frames in which a set of features is developed, leading to a working product that can be demonstrated to stakeholders in order to incorporate immediate and intensive feedback to early product versions which contributes to the constant growth of the digital good and its functions.

4.3.3 Close collaboration, cooperation, and co-creation of customers’ and developers’ side

While requirements engineers and product managers increasingly use data analytics methods, experience shows that it is important to spend a significant amount of time in direct contact with customers to gain a deep understanding of the context in which the product is being used and of the customer needs.

Regular participation and engagement helps to keep abreast of issues and trends facing existing customers. Direct contact with customers by personal, face-to-face communication not only supports an analytical understanding of their problems but may also create empathy.

Collecting relevant customer data is only the first step to create insights. For digitalized products and services, the voice may not come from the customer itself but from data or other artefacts relevant for quality. Customers may be not only human but also digitalized actors (digital agents). Requirements engineers and product managers need to feed this data into discussions with stakeholders and use it for requirements analysis with QFD, as well as for business modelling.

Digitized products are often not monolithic products but the result of cooperation in platform ecosystems. An ecosystem is a set of actors with varying degrees of multilateral, non-generic complementarities that are not fully hierarchically controlled^[7]. For developing digitized products and services, this means not only having to understand the voice of the customer, but also to include the voices of additional complementary actors^[8].

4.3.4 Focus on essential activities and tasks

Not only is the focus on the highest priority customer needs and product requirements but also on minimizing non-purposive work efforts within the development process. There should be constant reflections at regular intervals within the development team to become even more efficient.

4.3.5 Consider all aspects of business value

While the focus in QFD as well as in agile development is on satisfying the customer through early and continuous delivery of valuable software, all aspects of business value may be taken into account. This means, for example, not only high-rated functions but also quality requirements and design constraints. In general, the developers are open-minded towards all (even late) changes when delivering higher value.

4.3.6 Sustainable and comprehensible procedure

Apply techniques and methods with comprehensible and reproducible sequence of activities. Such techniques and methods produce trustworthy results that are not regularly questioned or doubted by the involved stakeholders. Authentic and credible procedures and results which lead to increasing confidence and trust concerning job performance are important to deliver.

4.3.7 Foster commitment and motivation

Sustained motivation maintained so that work proceeds. Techniques and methods that are fun to use help the team stay motivated to apply them in the long term. Building development projects around these motivated individuals and giving them the support they need establishes a common understanding and commitment between all stakeholders of the product to be developed.

4.3.8 Use digital data analytics

By analysing the performance statistics or usage data, the development team experiments with different implementations of design and product concepts to focus on innovation and optimization despite uncertainty.

Data analytics methods are used to monitor online reports of market research agencies, blogs, and trade press for customer information, and data analytics software retrieves information about customer behaviour throughout the internet.

Data can also come from the (potential) user side covering how they behave in certain situations, or how much time they spend on which tasks. Data gathering methods may include both direct contact and analytics include customer observation, A/B testing, launching a beta version, and producing a minimum viable product (MVP) or a minimum merchandisable product (MMP) for evaluation.

NOTE A/B testing is randomized testing of two or more versions are shown to different market segments to assess impact and business metrics.

5 Basic concepts of QFD

5.1 Theory of QFD

ISO 16355-1:2021, 4.1 defines quality function deployment (QFD) as an "approach for ensuring quality throughout, but not necessarily, at each stage of the product development process, starting with the initial product concept. As a quality method, the aim is to assure that decisions regarding product development have a defined and repeatable process, are based on factual information, have definable and measurable targets, involve all relevant business departments, and focus first and best efforts where they matter most to customers. QFD should begin upstream in the product development process in order to assure that decisions are made in this way, as downstream rework can be costly in terms of money and delays."

5.2 Principles of QFD

QFD principles are to:

- a) prioritize information to focus;
- b) understand how to cause good quality;
- c) listen to the voice of the customer;
- d) observe the customer's situation;
- e) capture information from other sources;
- f) improve internal communications through the transformation of information between perspectives.

5.3 Spirit of QFD

ISO 16355-1 defines the underlying spirit of QFD as the commitment among all critical departments to work together for the benefit of the customer or stakeholder. A personal connection to the customer should be established. As a central principle, customer needs or requirements should be known or acquired and understood adequately by all relevant stakeholders. It should be validated if product requirements meet the needs of the customer or stakeholder.

6 Integration of QFD and the development of digitalized products and services

6.1 QFD support for product development methods in general

Integration of QFD into new product development processes is both desirable and possible. Successful integration has been accomplished with other product development methods such as Stage-Gate™¹⁾ and product development support methods such as design for six sigma, design for lean sigma, and others. This may be done at an enterprise level, business group level, project level, or technology level. This integration should be guided by a QFD expert familiar with these methods.

QFD is designed to link together the various phases of product development such as strategy, portfolio, marketing, competitiveness, systems, voice of customer, requirements analysis, concept development, optimization, change management, reliability, cost, safety, security, privacy, quality, testing, build, support, logistics, training, and other product development phases. This linking assures that priorities at each phase are supported by downstream phases and decisions at each phase can be viewed for their impact on upstream phases. In this way, QFD improves both the product or service and the process by which it is created.

NOTE 1 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 2 An applicable but not exhaustive tools list is included in ISO 16355-1:2021, A.1. They are meant to illustrate tools that have been effectively used in QFD. Other tools might also be useful according to the project.

6.2 The fit between the design guidelines and QFD

QFD and the development of digitalized products and services share a common spirit - a commitment among all critical departments to work together for the benefit of the customer and stakeholder, and to provide them the support they need to establish a common understanding between all stakeholders to the product to be developed.

1) Stage-Gate™ 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.

Table 2 visualizes the fit of the QFD principles and spirit in Clause 5 and the design guidelines of developing digitalized products and services in 4.3.

Table 2 — Fit between the design guidelines and QFD

QFD principles and spirit (Clause 5)	Design guidelines (4.2)
Process	
prioritize information to focus	focus on essential doings
understand how to cause good quality	sustainable and comprehensible procedure
validation if product requirements meet the needs of the customer/stakeholder	iterative and incremental development for digital functions
Information	
capture information from other sources	consider all aspects of business value
listen to the voice of the customer	use digital data analytics
observe the customer's situation	information about customer behaviour throughout the internet
People	
establish personal connection to the customer	Close collaboration/cooperation of customers' and developers' side
improve internal (and external) communications	Provide sustained motivating procedure of work

6.3 Flow of product development of digitalized products and services with QFD

The flow of QFD methods and tools may vary according to the organization and project requirements. Typically, they begin with broad concerns and through prioritization, flow down to specifics.

As in classical engineering, there are different product development approaches and flows in software engineering ranging from the waterfall model over iterative and agile development. However, when employing QFD, the basic flow of information from customer needs to product requirements should be similar. Figure 1 adapts a sample flow of QFD-related information.

NOTE 1 Sample QFD-flow based on the QFD process for the planning of software products following Herzwurm et. al. (2000a)^[9] supplemented by and combined with the software life cycle processes according to ISO/IEC/IEEE 12207^[10].

NOTE 2 In QFD, the information flows downstream through the entire product development are called deployments (ISO 16355-1:2021, 12.1). Such QFD flows imply pre- and post-traceability between the considered artefacts.

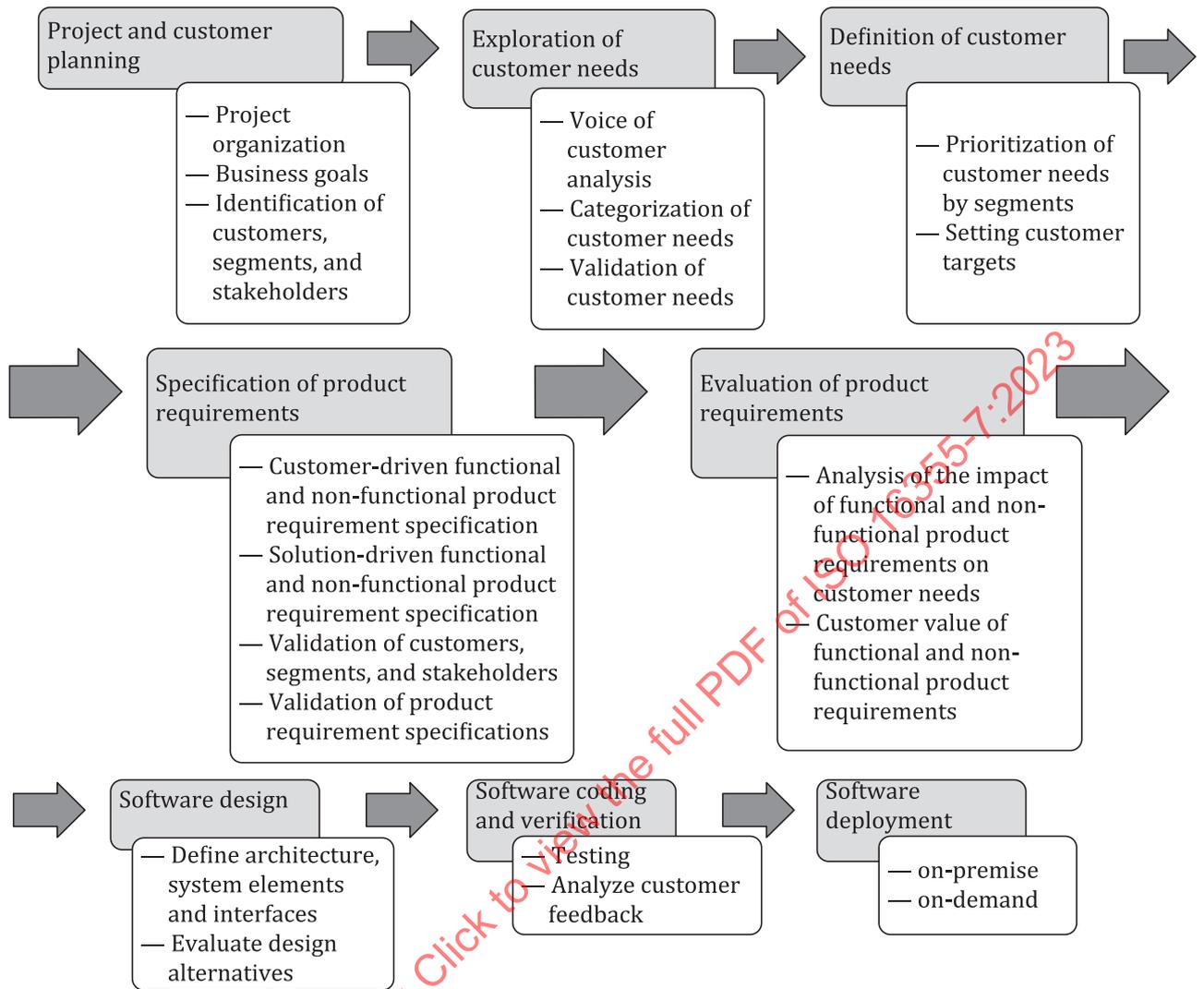


Figure 1 — Flow chart of product development of digitalized products and services with QFD in ISO 16355-7

Table 3 categorizes the flows into general aspects that may be mapped to any specific approach for digital product development with QFD. Furthermore, it references related clauses in the other parts of the ISO 16355 series standard that provide detailed guidance, methods, and tools as well as applicable case studies.

Table 3 — Mapping of flow chart to other clauses in ISO 16355 series standard

Aspect of the flow of information		Related chapter of ISO series standards
A	<p>Project and customer planning</p> <p>Project organisation</p> <p>Business goals, derived from hoshin kanri</p> <p>Identification of customers, segments and stakeholders</p>	<p>ISO 16355-1:2021, Clause 6</p> <p>ISO 16355-5:2017, Clause 7</p> <p>ISO 16355-2:2017, 9.1</p> <p>ISO 16355-2:2017, 9.1.2.8</p> <p>ISO 16355-2:2017, 9.1.3</p> <p>ISO 16355-2:2017, 9.1.4</p> <p>ISO 16355-2:2017, 9.15</p> <p>ISO 16355-2:2017, 9.2.1</p> <p>ISO 16355-2:2017, 9.2.2</p> <p>ISO 16355-2:2017, 9.2.3</p>
B	<p>Exploration of customer needs</p> <p>Voice of the customer and stakeholder acquisition and behavioural analysis in the customer gemba</p> <p>Categorisation of customer needs</p> <p>Validation of customer needs</p>	<p>ISO 16355-2:2017, 9.2.5</p> <p>ISO 16355-2:2017, 9.2.5.2.3</p> <p>ISO 16355-2:2017, 9.2.5.2.4</p> <p>ISO 16355-2:2017, 9.2.5.15</p> <p>ISO 16355-3,</p> <p>ISO 16355-4:2017, 9.2</p> <p>ISO 16355-4:2017, Clause 10</p> <p>ISO/TR 16355-8:2017, Clause 11</p>
C	<p>Measurement of customer needs</p> <p>Prioritisation of customer needs by segments</p> <p>Setting customer targets</p>	<p>ISO 16355-4:2017, Clause 11</p> <p>ISO 16355-4:2017, Clause 12</p>
D	<p>Specification of product requirements</p> <p>Customer-driven functional and non-functional product requirement specifications</p> <p>Solution-driven functional and non-functional product requirement specification</p> <p>Validation of product requirement specifications</p>	<p>ISO 16355-5:2017, 9.3.6.2.2</p> <p>ISO 16355-5:2017, 10.4.3.7.1.2</p> <p>ISO 16355-5:2017, 10.4.3.5.1.2</p> <p>ISO/TR 16355-8:2017, Clause 11</p>
E	<p>Evaluation of product requirements</p> <p>Analysis of the impact of functional and non-functional product requirements on customer needs</p> <p>Customer value proposition of functional and non-functional product requirements</p>	<p>ISO 16355-5:2017, Clause 9</p> <p>ISO 16355-5:2017, Clause 10</p> <p>ISO 16355-5:2017, 10.3.4.1</p>
F	<p>Software design^[10]</p> <p>Define architecture, system elements and interfaces</p> <p>Evaluate design alternatives (especially concerning non-functional requirements)</p>	<p>ISO 16355-5:2017, 10.4.3.7.1.1</p> <p>ISO 16355-5:2017, 10.4.3.6</p> <p>ISO/TS 16355-6,</p> <p>ISO/TR 16355-8:2017, Clause 11,</p>
G	<p>Software coding and verification^[10]</p> <p>Testing</p> <p>Analyse customer feedback</p>	<p>ISO/TR 16355-8:2017, Clause 11</p> <p>ISO/TR 16355-8:2017, 17.1</p>

Table 3 (continued)

		Aspect of the flow of information	Related chapter of ISO series standards
H	Software Deployment ^[10]	On-premises (installed base)	ISO/TR 16355-8:2017, Clause 13
		On-demand (cloud based)	ISO 16355-1: 2021, Clause 18 ISO/TR 16355-8:2017, 13.5.1 ISO/TR 16355-8:2017, Clause 14

6.4 QFD enhanced validation support to unified modelling language (UML) and systems modelling language (SysML)

6.4.1 General

QFD may support other software modelling languages.

6.4.2 QFD Support to UML

The unified modelling language (UML) described in ISO/IEC 19505-1, is a general-purpose, developmental, visual modeling language in the field of software engineering. UML was developed with the objective of providing system architects, software engineers, and software developers with visual tools for analysis, design, and implementation of software-based systems as well as for modelling business and similar processes. QFD provides direct support to the UML analysis by establishing clear relationships between customers, their needs, requirements, activities and priorities for development. This supports the validation and prioritization of the development of UML use case models and interaction diagrams captured in communication diagrams, interaction overview and sequence diagrams.

6.4.3 QFD Support to SysML

Systems Modelling Language described in ISO/IEC 19514, extends UML visual modelling approaches to help integrate modelling for systems containing both hardware and software elements. In particular the SysML extension includes the development of a requirements diagram that can be directly supported by QFD in the systematic validation of requirements, their traceability to customer and stakeholder needs, and the associated prioritization of those requirements. These are the aspects not systematically addressed within ISO/IEC 19514. UML and SysML have been used to establish systems modelling methods under the general heading of 'Model Based Systems Engineering (MBSE)' and is embedded in development frameworks for systems, particularly software-centric systems, and hence QFD provides appropriate requirements validation and prioritization critical to successful software-centric systems engineering development programs.

7 Types of product planning projects with QFD

The increasingly global and multidisciplinary nature of software development as well as the establishment of agile process models (especially Scrum) challenge science and practice to combine the principles of agile approaches with the circumstances of software development with digital and human elements. However, as pointed out above, the software part in today's business is mostly agile developed.

Thus, using QFD in an agile development serves as a kind of framework and mindset for the types of planning projects for digitalized products and services. A combination of the variants introduced below is possible in any case. In each variant, QFD concepts adapted to the agile environment have to be applied like handling matrix evolution methodologically, visual display of information to improve communication or the organizational fit in iterative and incremental^{[5][17]}.

Table 4 differentiates six different product planning approaches which serve as basic starting points (or application scenarios) for using QFD for digitalized products and services. Note that these approaches are not mutually exclusive and may be supplemented by concepts from the other approaches.

Table 4 — Product planning approaches with QFD for digitalized products and services

Life cycle phase	Requirements driven	Data driven	Technology driven
Existing product evolution	Requirements driven deployment	Data driven deployment	Reverse QFD
New product development	Dynamic software QFD	QFD for MVP/MMP development	Technology driven deployment

7.1 Requirements driven approach

7.1.1 General

This approach is used, for example for legal or regulatory requirements, commodity functionality and data requirements, and technology requirements. It is also applied in methods where hypotheses on customer needs, often referred to as customer problems and potential solutions are evaluated through qualitative and quantitative validation with customers, users and stakeholders.

7.1.2 Requirements driven deployment

Classical software QFD approaches applied in the context of further development of existing products referencing the focused QFD approaches that triangulate customer needs with functional and non-functional requirements^{[9][18]}. Modern QFD uses the maximum value table to focus on the highest priority to improve customer needs and define critical product requirements through to the build process and customer support^{[17][19][20]}.

7.1.3 Dynamic software QFD

Software QFD is applied iteratively in increments, virtually, especially under time pressure incorporating a certain amount of technical feedback on software designs and architectures. Usually starting in new product development, uncertainty is reduced through regular feedback. Feedback is also used in further development. Typical approaches include continuous and collaborative QFD^{[12][21]} and the twin peaks approach^{[22][23]}.

7.2 Data driven approach

7.2.1 Data driven deployment

Data-input-driven as well as data-analysis-driven product planning in general refer to data driven product development using data mining and analytics of past usage of existing products. Artificial intelligence (AI) and machine learning (ML) such as chat-bot data are examples where data is used as input for an ML engine to derive insights about directions for further development^{[24][25]}. Especially when handling a large amount of data in data-intensive applications, the raw data requires preparation, modelling and quality checking before usage^{[36][37][38]}.

7.2.2 QFD for MVP/MMP development

The product team may experiment with different implementations of design and product concepts and makes decisions based on the analysis of performance statistics or usage data. Data can also come from the potential user side covering how they behave in certain situations, or how much time they spend on what tasks. Such experimentation is a good approach when the focus is on innovation and optimization under uncertainty to learn and validate assumptions about a future product. Traditional development works toward developing a minimum viable product (MVP) or one that achieves basic function, but by

incorporating QFD in the learning cycle, the focus shifts toward developing a minimum merchandisable products (MMP) or one for which customers will pay.

7.3 Technology driven approach

7.3.1 Reverse QFD

Analysing an existing product or service (especially one which may have not been planned initially with QFD) is an approach to adding new product capabilities and characteristics, functions, and features. Often this is done when technology advancements make such functions and features possible or achieve a market-acceptable performance level. These are then mapped back to the customer needs that can be achieved or fulfilled if the technology is employed, and in what use cases by which customers. Then, the standard forward QFD process is used to determine how best to develop a business model, identify target customer segments and use cases, and then pursue their most important to improve customer needs. This improves the likelihood that the product will not only be technologically elegant, but will solve real customer problems, opportunities, and image concerns resulting in market success, profit, revenue, and other business goals^{[26][27]}.

7.3.2 Technology driven deployment

Evolutionary market innovations take place when a technology is close to market maturity but potential customers are not yet defined. QFD's voice of customer and stakeholder analysis provides the fuzzy front end for innovation management by including QFD to derive new business models^[6]. High market uncertainty with low technology uncertainty is strengthened with technology competence.

8 QFD team membership

8.1 General

The essential roles in a QFD team remain the same as described in ISO 16355-1:2021, Clause 7 and ISO 16355-5:2017, Clause 5. However, in software development and especially in agile environments, the role of a product manager (in scrum, the product owner) is responsible for profitability and serving as a communication interface between the development team and the customer or additional stakeholders and subject matter experts. This assures that the product manager will always consider the business interests of the company as defined by the voice of business as described in ISO 16355-2:2017, 9.1.

8.2 Core team membership

Core team membership is referenced in ISO 16355-1:2021, 7.2. Typical roles and tasks in QFD for digitalized products and services are shown in [Table 5](#).

Table 5 — Roles and tasks in QFD team for digitalized products and services

Roles in QFD teams	Tasks
Product manager with responsibility for profitability and close coordination with development team	Planning and coordination with voice of business
Process manager, method expert	Planning and moderation of workshops
Development team	Defining and implementation of product requirements
Customer, user, additional stakeholders (for example, software platforms)	Participation in workshops, bringing in the voice of the customer, involved in testing

8.3 Subject matter experts

Subject matter experts are referenced in ISO 16355-1:2021, 7.3. In the digitalized products settings additional experts for example, software platforms, complementary eco-system partners, contestants

for co-creation of services as well as users and customers capable of coding and designing should be involved. Primarily, their task is to bring their perspectives into the planning process.

8.4 QFD team leadership

Subject matter experts are referenced in ISO 16355-1:2021, 7.4. In the digitalized products settings, a process manager is a method expert (for example, a scrum master), and the QFD team leader is responsible for the planning and moderation of workshops. The QFD team leader should take a position of being function-agnostic so as to remain neutral to any business department or activity.

9 Techniques for applying QFD for developing digital products and services

9.1 General

Certain techniques are especially useful when applying QFD for developing digital products and services. Usually the described application of the techniques corresponds to one or more of the above design guidelines or one or more of the typical application scenarios of the above product planning approaches. How these fit as well as potential mutual dependencies (supplementation or conflict) of the techniques among themselves are important considerations. Supporting examples such as case studies and scientific evaluated papers are referenced which demonstrate the applicability of the approaches in more depth^[28]. The listed techniques are not exhaustive but comprise current best practices in agile development settings.

9.2 Fit with iterative procedures

According to the agile principles for continuous delivery of software^[3], an iterative approach in short cycles is used where the product grows incrementally. Thus, QFD techniques have to fit with iterative development, which represent a repeated use of concurrent planning, developing and verification activities^[4]. There are requirements refinement, iteration planning, requirements realization and review meetings into which QFD practices will fit. QFD serves in this setting especially as a managing, guiding and control tool through determining the needs and requirements to be fulfilled.

Using QFD in these settings incorporates planning meetings with external stakeholders, especially customers, to clarify details and to achieve an agreement and commitment on the next iteration's activities among all participants (especially developers). It results in a selection of product requirements (such extended user stories) to be implemented within the iteration. During the iteration, these requirements remain unchanged. Further refinement of needs and functional requirements using prioritization techniques and matrices may take place separately in so-called grooming meetings, both purely internally as well as with external stakeholders. In up to three grooming meetings within an iteration, estimates and assessments are updated and new solutions are sought to satisfy new or changed customer needs. In order to consider the feedback on the working product's performance directly in the next iteration, a mini-grooming is recommended immediately after the review meeting and before the start of the next cycle. The daily status meetings as well as the retrospective meeting on the experiences with the past iteration remain unchanged as in usual agile practice^[5].

Emphasized is the fit with design guidelines and QFD product planning types of iterative and incremental development for digital functions, close collaboration, cooperation, and co-creation of customers' and developers' sides, all of which fosters commitment and motivation.

9.3 Extended user stories

User stories are the main requirements representatives in agile contexts. In general, a user story refers to a product function that has a certain value for users or buyers of a software product. The focus is usually, but not always, on functionality, since software differentiates itself in most cases by its behaviour. The value directly corresponds to a higher business value from the perspective of the development organization. There is a widely used and established standard template for the formulation of a user story: "I as a (role) want (function or goal) so that (business value)"^[29]^[4]. From a

QFD perspective, this phrase can be restated as “As a (stakeholder) I want (functional requirement) to satisfy (customer need).” Or even more abstractly: “As (who) I want (what) to satisfy (why).”

A user story explains a moderate, strong, or higher relationship in a QFD house of quality L-matrix through this “why” component and its link to the “what” component. In the house of quality, the “why” component represents the customer needs in the rows and the “what” component represents the functional and non-functional requirements in the columns, as referenced in ISO 16355-5:2017, 9.3. However, because user stories only combine exactly one need with exactly one potential solution, the maximum value table in modern QFD better supports this. This is explained in ISO 16355-5:2017, 9.2. This one-to-one relationship between needs and solutions is not the usual case because product features rarely have a single effect on only one need because functions are often used in different contexts and by different customers. Just as needs can have alternative solutions, functional requirements, can satisfy several needs. Thus, many-to-many prioritization matrices like those used in classical QFD might be useful for downstream analyses. With its multiple effects on several needs each column of the prioritization L-matrix represents an extended user story not only focusing on one relation of a solution to one need but on many relationships to many needs.

Emphasized is the fit with design guidelines and QFD product planning types for close collaboration, cooperation, and co-creation of customers’ and developers’ sides which create business value, sustainable and comprehensible procedures, which are useful in requirements driven deployment and reverse QFD, (see [A.1](#)).

9.4 Visual display of information

Description: Especially within a development team, agile contexts demand for easy and quick access to information like the requirements to be realized within the next iteration. Additionally, assessments of risks, dependencies, difficulties, complexity and so on have to be intuitive and accessible. A prioritization L-matrix like the house of quality could serve as compact and well-arranged map of priorities of the needs and functional requirements to be addressed. It can be further reduced to its essential relations by selecting only the extended user stories (column-row-combination with highest relationships) or transforming it into a relations diagram like the maximum value table. In either case, the visualization serves as a management tool to guide the agile development.

These aspects can be seen to be aligned to the ways that modern QFD supports the validation and prioritization of aspects of visual software and system modelling and development approaches described in UML and SysML ISO standards, outlined in [6.4](#).

Emphasized is the fit with design guidelines and QFD product planning types to foster commitment and motivation. These visual displays help with incrementally growing and shrinking prioritization matrices, maximum value table, and assessing and prioritizing functional requirements^[5].

9.5 Categorization with the Kano model

Validation of the highest priority functional requirements from the house of quality L-matrix with survey results and categorization according to the Kano model as referenced in ISO 16355-5:2017, 10.3.4.4 increases the depth of analysis to determine if solutions meet only minimal expectations or will generate true excitement in the market. Additionally, judging the consequences on customer satisfaction when not realizing a requirement (and therefore not fulfilling corresponding customer needs) is valuable.

Emphasized is the fit with design guidelines and QFD product planning types of QFD for MVP and MMP development. This helps with assessing and prioritizing functional requirements^[11].

9.6 Maximum value table (MVT)

Modern QFD’s maximum value table as explained in ISO 16355-5:2017, 9.2 focuses on only the most important or urgent to improve customer needs and which functional requirements, non-functional requirements, design details, technologies, development and build activities and tasks, and customer support are essential. Due to this strong focusing on the relations with highest impact, the MVT directly

corresponds to the extended user stories. It further extends the linking between needs and solutions to one to five top customer needs to many dimensions of design, development, build, delivery, and support.

Emphasized is the fit with design guidelines and QFD product planning types with focus on essential activities and tasks, and requirements driven deployment based on extended user stories^[11].

9.7 Incrementally growing and shrinking prioritization matrices

Prioritization matrices in their standard form are often time-consuming to build due to the many possible relationships to be quantified between many rows and many columns. One way to tackle this problem is to let the matrix grow incrementally instead of trying to build it as a whole. Starting off, the matrices are pre-filled on the diagonal by the elements of the known user stories (and possible further dependencies). By letting the matrix grow row-by-row from a base of the most important needs in the top left corner of the matrix, potential new solutions can be added to the columns to the right. Even new needs may be added to the rows. The analysis progresses row by row, need by need. The critical question is how can the need be satisfied, or whether there is, among the existing solutions, one that contributes to its fulfilment already. The matrix grows through this row-wise approach of finding solutions for needs only below the diagonal. The matrix creation can stop after each step since the most important needs always are considered sufficiently because of the strong relationships. The matrices stay rather small because they aim only on deciding the requirements to be implemented in the next iteration. Extended user stories shown by the column-row-combinations could then be selected for realization in the next increment. After successful implementation, the prioritization matrix is shrunk on the basis of what was achieved and fully satisfied needs. The needs in the rows which have been fully satisfied are deleted as well as the corresponding solutions in the columns that have been already implemented in the product. The reduced matrix serves finally as a starting point for adding extended user stories in the form of new needs and further requirements.

Emphasized is the fit with design guidelines and QFD product planning types of iterative and incremental development for digital functions, focus on essential activities and tasks, sustainable and comprehensible procedures which foster commitment and motivation, and dynamic software QFD. Useful are extended user stories, fit to planning meetings and requirements refining meetings within iterative procedures^[5], (see A.2).

9.8 Prioritization with pairwise comparison

Especially when adding new needs as well as eliminating fulfilled needs, pairwise comparison, such as with the analytic hierarchy process (AHP), is used to easily judge the new needs in comparison with already prioritized ones. It is also used for other evaluation criteria such as difficulty, complexity, time, and needed resources. AHP applied to prioritizing customer needs is explained in ISO 16355-4:2017, Clause 11 and to other evaluation criteria is explained in ISO 16355-5:2017, 10.3.4.5.

Emphasized is the fit with design guidelines and QFD product planning types of iterative and incremental development for digital functions, and focus on essential activities and tasks. Useful for assessment and prioritizing functional requirements.

9.9 Assessment and ranking functional requirements

In very tight time schedules or with less motivated team constellations, simple symbolism and visualization could be sufficient to achieve a prioritization of the requirements on the basis of the ordinal ranking scale mostly used in agile contexts^[4]. If the needs are placed in a simple ranking according to their business value, all the effects listed in the upper lines of a prioritization matrix as well as a maximum value table are to be judged higher than the lower ones. The focus is on the strong and medium relationships; weak ones as also in classical prioritization L-matrices, are omitted as they do not help in the differentiation of the solutions.

The solution space consists of all possible kinds of functional requirements, especially product functions and quality characteristics. For further assessments of risks, dependencies, difficulties, complexities, efficiency and so on additional techniques like direct assessment or the pairwise comparison may be

used. Additionally, Kano categorization can support a sound and rational selection of requirements to be realized.

Emphasized is the fit with design guidelines and QFD product planning types: of focus on essential activities and tasks, consideration of all aspects of business value, requirements driven deployment, and dynamic software QFD. This is helped with the maximum value table, prioritization L-matrices, visual display of information, categorization with the Kano model, and prioritization with pairwise comparison^{[21][5]}.

9.10 Value proposition canvas

The value proposition canvas is a qualitative instrument for describing and visualizing a value proposition. This describes the benefits that a customer can expect from the product^[20]. It represents the fit between aggregated product features and customer benefits and forms one of the fundamental pillars of a business model. The mutual coordination, concretion, and abstraction of the value proposition canvas, a HoQ-like value proposition deployment matrix, and the minimum viable product (MVP) constitute the value proposition deployment (see [A.3](#)). By iteratively validating the value proposition in real settings, further central components of a business model like target customers, communication channels, potential revenue streams can be derived.

Emphasized is the fit with design guidelines and QFD product planning types of focus on essential activities and tasks, considerations of all aspects of business value, and technology driven deployment. This is useful with the maximum value table, prioritization L-matrices like the house of quality, and visual display of information, (see [A.3](#)).

9.11 Persona development

In case of unclear preferences of the customer, hypotheses can be made about their characteristics and the priorities derived from them. A combination of hypotheses about the intended customer is called a persona. Clear and detailed personae support the QFD team in product design. It is important to note that a persona is not the average customer but represents a specific target group whose requirements are to be met. The hypotheses may then be tested by developing a minimal viable product (MVP).

Emphasized is the fit with design guidelines and QFD product planning types for use of digital data analytics, QFD for MVP/MMP development, and technology driven deployment. It helps with identification of customer segments within project and customer planning, minimal viable products, extended user stories, prioritization techniques, and test of prototypes, (see [A.4](#)).

9.12 Software support

The incremental approach with frequent changes and the large amount of information to be included increase the complexity of development projects. This is intensified in distributed and highly scaled projects. Software can help to cope with this.

Emphasized fit with design guidelines and QFD product planning types for use with digital data analytics.

9.13 Test of prototypes

When uncertainty concerning needs exists, learning by early demonstration of possible solutions to external or internal customers is valuable. Possible solutions could be derived from a hypothesis of first user stories and their assessment.

Emphasized is the fit with design guidelines and QFD product planning types of iterative and incremental development for digital functions, use of digital data analytics, QFD for MVP/MMP development, and technology driven deployment. This fits with review meetings and requirements refining meetings within iterative procedures^[35].

9.14 Voice of engineer analysis (VOEA)

In coming up with potential solutions to provide benefit to customers there is not only an analytical part needed for transforming already known customer needs into functional requirements to be met by the product. Additionally, a creative part is essential for finding new innovative solutions and ideally real “break-through ideas” which potentially lead to even higher customer satisfaction. Hence, the Voice of Engineer i.e. of the solution developers have to be explicitly included and analysed. The procedure and potential tools used have similarities with those from the acquisition of the voice of customer (ISO 16355-1:2021, 8.2.7 to 8.2.11 and ISO 16355-2:2017, Clause 8) but are augmented with creativity methods like the 6-3-5-method, (reverse) brainstorming or remember the future. Already existing prototypes or even predecessor products can be used for consideration and as inspiration. The voice of engineer analysis can help to meet already identified customer benefits (requirements driven) or be the starting point for the development of new products and services (technology driven). Explicitly including the VoE is also important in order to identify exciting factors according to the Kano model, i.e. functional requirements that customers themselves would not have come up with.

Emphasized is the fit with design guidelines and QFD product planning types of focus on essential doings, requirements driven deployment, technology driven deployment and dynamic software QFD. This fits with the test of prototypes^[21].

9.15 Software house of quality (Software HoQ)

In the House of Quality matrix, weights quantify the relationship or contribution between customer needs and functional requirements (ISO 16355-1:2021, 13.1). The functional requirements cover the inherent performance of the product (often called quality characteristics) as well as actions the product accomplishes (see 3.5). As a digitalized product or service without such actions nearly offer no value to its customers, the focus within its development lies usually on product functions as solution characteristics. Thus, the software house of quality (Software HoQ) as an instance of an L-Matrix, also referred to as customer needs-functional requirements matrix (ISO 16355-5:2017, 9.3.6.2.3), comes to the fore. As non-functional quality characteristics relate to the product as a whole or to certain functions and subsystems, they are usually considered either as design constraints or are related to customer needs and product functions in a functional requirements-functions matrix (ISO 16355-5:2017, 10.4.2.4).

Emphasized is the fit with design guidelines and QFD product planning types of iterative and incremental development for digital functions, the focus on essential activities and tasks, and requirements driven deployment. Useful are extended user stories, fits to the visual display of information and incrementally growing, (see A.5).

9.16 Test coverage matrix

Digitalized products and services often work in environments where safety and security^[31], privacy, and societal issues^[32] are important. Thus, sophisticated methods of testing and certification for safe public usage are required. QFD supports the selection of relevant test cases by measuring their relevance according to the extent they cover customer needs. An L-Matrix mapping test stories as collections of test cases addressing a common business scope and user stories serves as a test coverage matrix^[33].

Fit with design guidelines and QFD product planning types of iterative and incremental development for digital functions, a focus on essential activities and tasks, and requirements driven deployment are emphasized. Extended user stories, fitting to the visual display of information, and the testing of prototypes are useful, (see A.6).

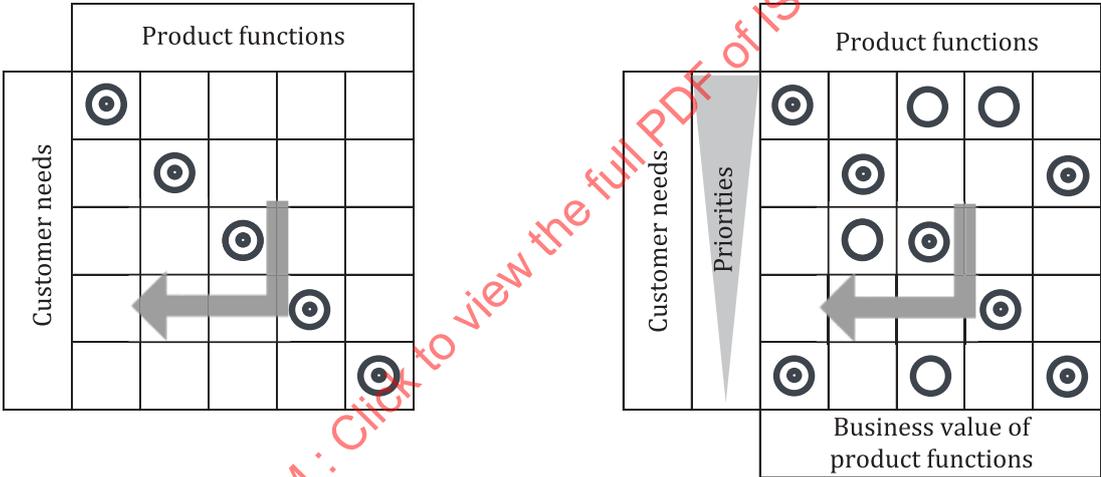
Annex A (informative)

Examples of applicable methods and tools

NOTE 1 Details of how these methods and tools are integrated and applied within QFD are explained in the cited books and papers. The examples below are from QFD application case study papers presented at conferences and in journals to illustrate how the methods and tools can be used in QFD.

NOTE 2 QFD can integrate with methods and tools from many product development methods. The methods and tools in this annex and in the Bibliography are not an exhaustive list. Some references are instructional and some show how they integrate with other methods and tools in QFD.

A.1 Extended user stories



a) User stories as L-matrix with 1:1 relationships of functions and needs b) Prioritization L-matrix with columns representing extended user stories

- Key**
- ⊙ strong impact
 - medium impact

Figure A.1 — User stories L-matrix

This figure illustrates extended user stories in b) versus user stories usually applied in agile contexts[5].