TRANSACTIONS FROM
THE SYMPOSIUM ON QUALITY FUNCTION DEPLOYMENT

QFD™

Driving QFD with ISO 16355

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Abstract

QFD is a quality approach to new product development with the goal of increasing customer satisfaction and value by designing it in (rather than inspecting it out) from the earliest stage possible in the product realization process. While the most well known driver of QFD is from the customer requirements stage, in many projects the drivers may be strategic planning, technology evolution, competitive market space, regulatory changes, cost reduction, etc. The draft ISO 16355 QFD standard will include these other drivers both in their historical context as well as modern applications. This paper will introduce these with examples.

Key words

Reverse QFD, Technology-driven QFD, Cost-driven QFD, Competitor-driven QFD, Regulatory-driven QFD, Manufacturing-driven QFD, Executive-driven QFD, ISO 16355

Historical perspective of QFD drivers

Using different deployment sequences to drive product development from various stages was first introduced by Yoji Akao, one of the creators of the QFD method, in 1986 to describe a comprehensive system of quality deployment (Akao 1986, 1988, 1990). Figure 1

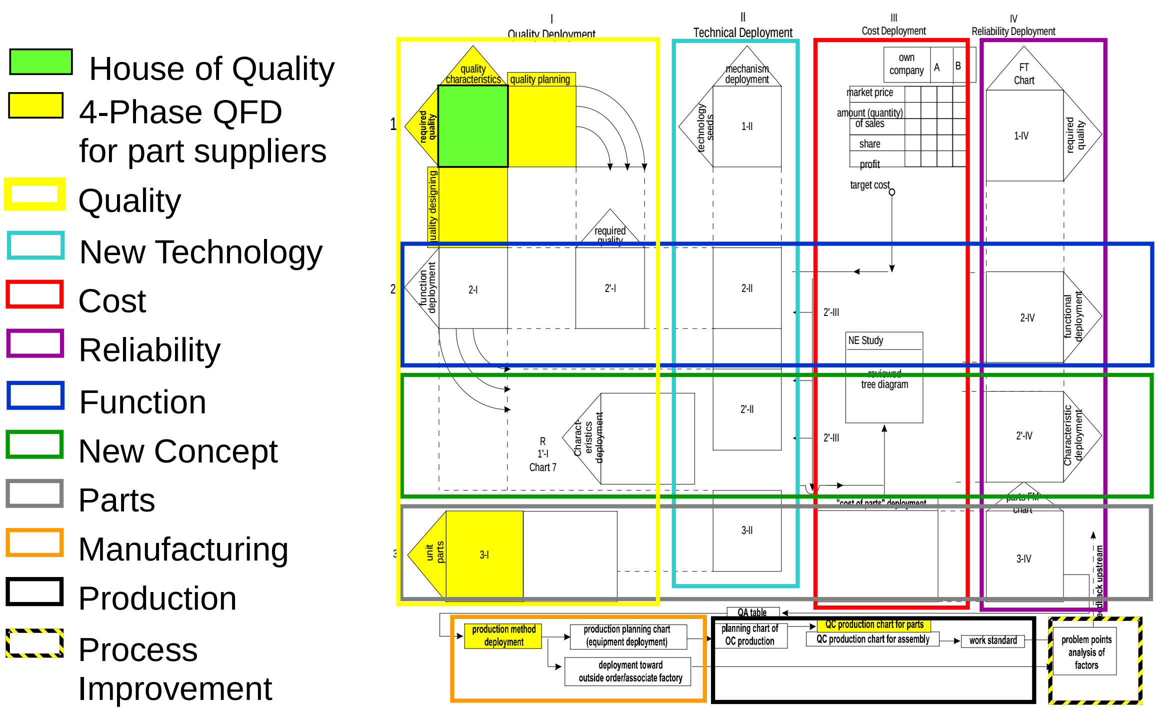

Figure 1 Comprehensive QFD diagram (adapted from Akao 1990)

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In Akao's Comprehensive QFD diagram, there are several deployment flows linked by arrows indicating how information outputs from one chart become inputs to the next chart. The vertical deployments are labeled quality, technology, cost, and reliability. The starting point of these vertical deployments are independent, meaning that information related to quality goals, technology concepts, cost targets, or failure modes can originate elsewhere using other methods and tools. These deployments can then be linked using the horizontal flows of customer needs, functions, parts, and processes usually from the upper left to the lower right. They can also initiate QFD analyses according to what is driving the project - quality, technology, cost, reliability, and more recently schedule, regulatory change, sustainability, security, safety, and other concerns.

In 1987, Bob King at GOAL/QPC and one of Akao's first non-Japanese disciples, "filleted" this diagram into its component charts called the Matrix of Matrices (Figure 2) and identified useful paths to link the charts according to the project concerns. For example, to analyze customer demands, the recommended path was A1, B1, D1, E1 or to set cost targets B1, C2, C3, C4 was recommended. (King 1987)

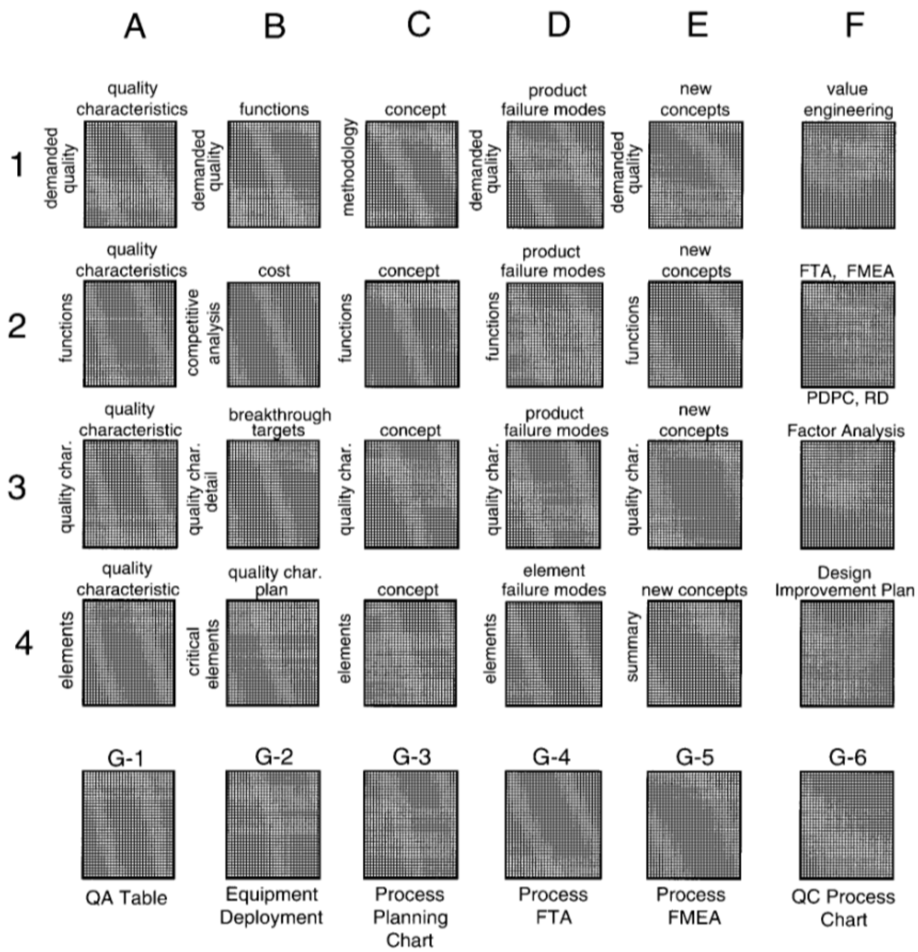

Figure 2 Matrix of Matrices (King 1987)

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Unfortunately, much of the power of these analytic models was lost to the more well-known 4-Phase QFD model championed by automotive parts suppliers building to print. This model began with the House of Quality (customer needs x functional requirements or the A1 matrix) and followed a shortcut quality deployment path to parts, manufacturing setup, and production processes. The 4-Phase QFD model bypassed design, function, technology, cost, reliability, and the other deployments Akao had laid out. This made it difficult to use for end-product producers, service and information applications, and business process improvement. In recent years, most companies including auto parts suppliers have all but abandoned the manufacturing and production matrices as being too time consuming, and rarely go beyond the House of Quality.

Modern Blitz QFD® developed by the QFD Institute has tried to bridge both the Comprehensive and 4-Phase QFD models by offering all the comprehensive deployments but saving time and effort by limiting them to a few high priority customer needs. The matrices are summarized or replaced by the Maximum Value table (MVT), which includes columns for quality assurance information derived from each of the matrix axes in the Matrix of Matrices. Maximum Value tables are custom tailored to the project, and may include special columns related to physical characteristics, service processes, information or software data, etc. To limit their size, MVTs usually deploy no more than three to five customer needs as shown in Figure 3 (Zultner and Mazur 2000).

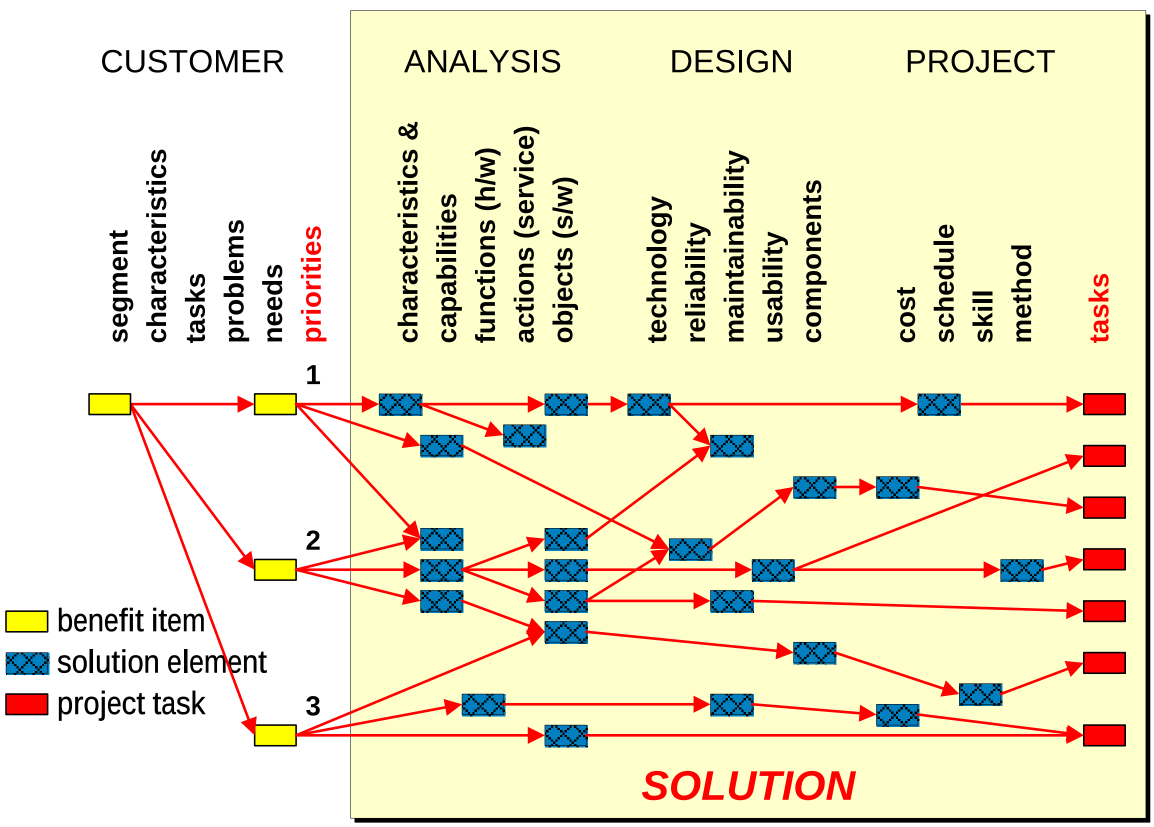

Figure 3 Maximum value table (Zultner and Mazur 2000)

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What all three models (Comprehensive QFD, Matrix of Matrices, Maximum Value table) were initially used for was to assure that in addressing customer needs, other constraints such as technology readiness, target costing based on market pricing, and reliability of selected subsystems and components were also examined in the product development process. The 4-Phase model did not address these constraints.

Non-customer drivers of QFD

In 1990, an opportunity to begin with a downstream constraint and work in reverse to the customer need presented a new way to use QFD. What if the customer need were already satisfied and there were no market complaints, but other factors were pressing for a new product? Could QFD be adapted to a "reverse" deployment?

Regulatory-driven QFD

In the 1970s, Mario Molina and F. Sherwood Rowland, two chemists who would eventually receive Nobel Prizes for their research, discovered the long-term atmospheric damage caused by the use of chlorofluorocarbons (CFC) as a propellant in common household products such as hairspray (UC Berkeley 2007). In the early1990s, regulations were enacted to ban the use of CFCs in aerosol propellants and air conditioning systems, forcing producers to develop substitutes.

In 1990, one of the first to address this regulatory change by using QFD was a supplier of the resin component of hairspray. Their concern was that when the hairspray manufacturer changed the propellant, how would their resin interact with it? Would the holding properties of the hairspray degrade so that currently satisfied customers would become dissatisfied and either change brands or force the hairspray manufacturers to seek out a new resin supplier? Since the resin supplier did not make the end product or other components in the hairspray, how much control could they exert?

The first step was to understand the role the resin played in the hairspray. To do this we examined ten structural properties of the resin including solids content, solvent absorbency, evaporation rate, and film formation and how strongly they correlated to four resin functional requirements of finishing time, interfiber lubricity, humidity resistance, and spray pattern. These two data sets, resin structural properties and functional requirements were examined in a QFD matrix in reverse order, shown in Table 1. At this point, the matrix was unweighted because we did not know the importance to the customer.

The second step was to understand the role the resin functional requirements played in the hairspray functional requirements (our customer's product) including curl retention, atomization diameter, droplet size, and drag with a wet comb. These two data sets, resin functional requirements and hairspray functional requirements were examined in a QFD matrix in reverse order, shown in Table 2. At this point, the matrix was still unweighted because we did not know the importance to the customer.

The third step was to understand the role the hairspray functional requirements played in satisfying consumer needs (our customer's customer) including my hair stays styled, my hair springs back when touched, my hair feels clean, and my hair feels natural. These two

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data sets, consumer needs and hairspray functional requirements were examined in a QFD House of Quality matrix in reverse order, shown in Table 3. This matrix was created in a joint meeting between our product chemists and the hairspray manufacturer's product specialists.

Table 1 Reverse QFD matrix of resin structural properties x functional requirements

Resin Functional Requirements \ Resin Structural Properties	Solids content	Solvent absorbency	Evaporation rate	Film formation
Finishing time	●	◑	◑	◕
Interfiber lubricity		·		◕
Humidity resistance			·	◑
Spray pattern	◔	○		·

Table 2 Reverse QFD matrix of resin x hairspray functional requirements

Hairspray Functional Requirements \ Resin Functional Requirements	Finishing time	Interfiber lubricity	Humidity resistance	Spray pattern
Curl retention (humidity proof)	·	·	●	◑
Atomization diameter	◔	·	·	◑
Droplet size	◑	·	·	◔
Drag - wet comb	◔	●	·	·

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Table 3 Reverse QFD matrix of hairspray functional requirements x consumer needs

Consumer Needs \ Hairspray Functional Requirements	Curl retention (humidity proof)	Atomization diameter	Droplet size	Drag - wet comb
My hair stays styled	●	◑	·	·
My hair springs back when touched	◑	○	·	·
My hair feels clean	·	◔	○	·
My hair feels natural	·	·	·	◑

The fourth step was to have the hairspray manufacturer ask their consumers to prioritize their needs, and then forward re-deploy those priorities to determine which resin structural properties were most critical to consumer satisfaction and to reformulate to protect those from interactions with the replacement propellant. The now-weighted matrices in forward QFD deployment are shown in Table 4.

Table 4 Forward QFD matrix flow for hairspray

Consumer Needs \ Hairspray Functional Requirements	Consumer priority	Curl retention (humidity proof)	Atomization diameter	Droplet size	Drag - wet comb
My hair stays styled	0.519	● 0.519	◑ 0.139	· 0.000	· 0.000
My hair springs back when touched	0.201	◑ 0.054	○ 0.014	· 0.000	· 0.000
My hair feels clean	0.201	· 0.000	◔ 0.027	○ 0.014	· 0.000
My hair feels natural	0.079	· 0.000	· 0.000	· 0.000	◑ 0.021
Absolute Weight		0.573	0.180	0.014	0.021
Hairspray FR weight		72.7%	22.8%	1.8%	2.7%

Hairspray Functional Requirements \ Resin Functional Requirements	Hairspray FR Wt.	Finishing time	Interfiber lubricity	Humidity resistance	Spray pattern
Curl retention (humidity proof)	0.727	· 0.000	· 0.000	● 0.727	◑ 0.194
Atomization diameter	0.228	◔ 0.031	· 0.000	· 0.000	◑ 0.061
Droplet size	0.018	◑ 0.005	· 0.000	· 0.000	◔ 0.002
Drag - wet comb	0.027	◔ 0.004	● 0.027	· 0.000	· 0.000
Absolute Weight		0.039	0.027	0.727	0.258
Resin FR weight		3.7%	2.5%	69.2%	24.5%

Resin Functional Requirements \ Resin Structural Properties	Resin FR Weight	Solids content	Solvent absorbency	Evaporation rate	Film formation
Finishing time	0.037	● 0.037	◑ 0.010	◑ 0.010	◕ 0.019
Interfiber lubricity	0.025	0.000	· 0.000	0.000	◕ 0.013
Humidity resistance	0.692	0.000	0.000	· 0.000	◑ 0.185
Spray pattern	0.245	◔ 0.033	○ 0.017	0.000	· 0.000
Absolute Weight		0.070	0.027	0.010	0.217
Resin Structural Properties weight		21.6%	8.3%	3.1%	67.0%

Technology/Solution-driven QFD

The R&D function of an organization holds several responsibilities in the new product development process. Chief among these are creating solutions in response to unmet customer needs in Customer-driven QFD and creating solutions in advance of unexpressed customer needs. Creating new solutions in response to customer needs is the technology deployment column in Figure 1 and is a type of forward QFD. Creating new solutions in advance of customer needs can follow either the technology deployment in Figure 1, but in reverse, or can be done using the Blitz QFD® Customer Voice table (CVT) in reverse.

An example of the Reverse Blitz QFD® CVT was presented by Florida Blue (formerly Blue Cross Blue Shield of Florida), a health insurance provider (Hines and Mazur 2007). The project was initiated to encourage Florida Blue employees of various ethnic backgrounds to ideate ways to increase health insurance subscribers in their communities by offering programs with unique touch points. The overall process is shown in Figure 4. The concepts were generated internally and then mapped back into customer needs, which were then prioritized by customers using the analytic hierarchy process (AHP) (Saaty 1990). Once key needs were identified, they were used 1) as criteria to select which concepts to pursue, and 2) to fine-tune the new concepts for usability and better market acceptance.

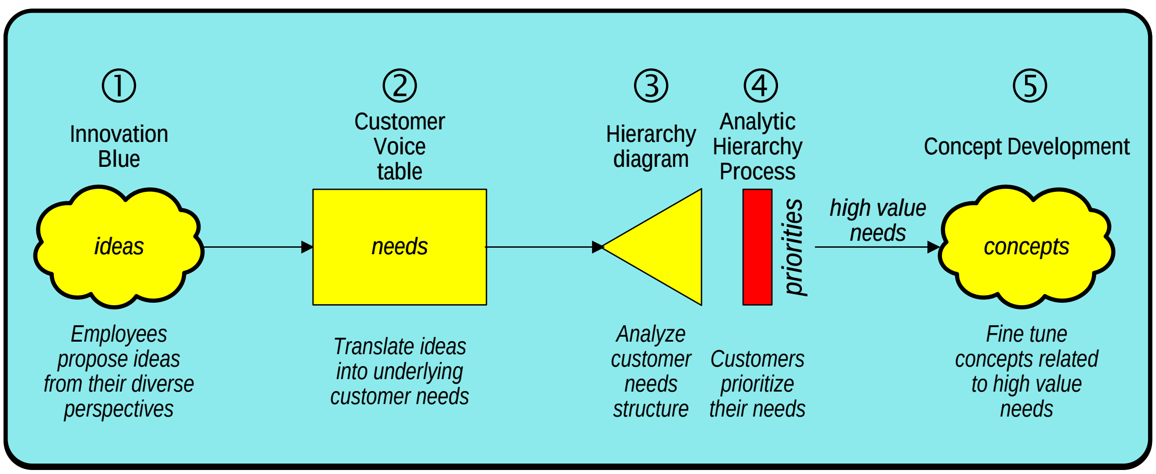

Figure 4 Solution-driven reverse QFD flow (Hines and Mazur 2007)

Called "Innovation Blue" by a group vice-president, the goal was to assure that employee-generated ideas would be heard and were in fact vital to the future of the business. One employee-generated idea was to include health club membership as an insurance benefit. These ideas were then examined in a CVT to translate back into customer needs. Health club membership (a technology solution) had the capability to hold members accountable for their own physical activity, which addressed the customer need of "I need help with appropriate physical activity." This CVT analysis helped understand that the customer would not benefit from health club membership unless it encouraged activities that were appropriate for their physical condition and that the encouragement was sustained over time. A health club membership card was not enough. An example of other ideas analyzed is shown in Table 5 Customer voice table translates technology/'solution concepts into customer needs (Hines and Mazur 2007) The selected

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concepts were fine-tuned to the needs of the various ethnic communities and became the basis of targeted marketing programs.

Table 5 Customer voice table translates technology/'solution concepts into customer needs (Hines and Mazur 2007)

customer needs	characteristics & capabilities	functions	reliability	technology	information	commun-ications
I need help with appropriate physical activity.	member accountability for their physical activity			health club membership		
I need help with appropriate nutrition.	member accountability for their nutrition			diabetic nutrition education (Josylin)		
I need to know the progress of my condition.	diabetes progress reportability	patient self-reporting AIC		incent patient A1C reduction		
I need up-to-date information on my condition.				provide free testing supplies for 3 months		
I need to know do's and don't's to stay healthy.	healthy lifestyle compatibility	provide healthy lifestyle compliant programs				
I need to know the progress of my condition.			Don't penalize patients for diagnosis			

Executive-driven and Strategy-driven QFD

Senior management sits high enough in the organization to see far into the future. QFD drivers that take advantage of this vision are Executive-driven QFD and Strategy-driven QFD. Executive-driven QFD often begins when a senior manager believes there is a market opportunity for a new product, new technology, or a new application. Existing information may not yet support this, but they believe strongly enough to want to commit resources to develop it. The product development team can use QFD to validate this belief, as demonstrated in a project at Fusion UV Systems, Inc. (Delgado, Okamitsu, Mazur 2001). The gist of this project was an executive-level decision to introduce a quality upgrade to the product. The QFD analysis showed that in high volume production lines, this upgrade would negatively impact process throughput for the customer. As a result, the high volume market was abandoned and the product was repurposed towards low volume customers.

Strategy-driven QFD often begins with a management directive to develop a response to external influences such as changes in governmental and public policy. Florida Blue (formerly Blue Cross Blue Shield of Florida) does regular environmental situation analyses (ESA) combined with information about competitors to identify high level threats and opportunities (Hepler and Mazur 2008). At the beginning of the 2008 US presidential primary campaigns in 2007, several candidates were evaluating healthcare concerns for both individuals and businesses as part of their political platforms, ranging from moder-

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ate tweaks to universal healthcare options. Florida Blue executives were asked to brainstorm various scenarios likely to develop depending on who won the presidential election. AHP was used to assess the likelihood of each scenario by asking each executive to make his or her best judgment. These scenarios were evaluated against future population shifts predicted in the Florida market so strategic investments could be made to build appropriate capabilities. A forward Blitz QFD® was then performed for each of the most likely scenarios. As the presidential primaries reduced the number of candidates, scenarios were reevaluated and the QFD studies adjusted accordingly.

Cost-driven QFD

The original approach to cost deployment illustrated in column three of Figure 1 was to look for ways to cut costs during customer-driven QFD. It examined the cost impact that new functions and performance levels would have at the system, sub-system, component, and build stages. But driving down cost while maintaining current levels of customer satisfaction is also another use of the model, and there are several design methods to support this (Ross and Mazur 2009) including:

1. Initial product functionality reduced by design with cost deployment and reverse QFD
2. Reduced initial product performance by design with cost deployment and reverse QFD
3. Reduced reliability and durability of function over time by design
4. Reduced parts cost, and comparing parts cost vs. system cost by design, including commonization and reuse of parts, volume purchases
5. Value Analysis/Value Engineering (VA/VE)
6. Reduced assembly cost by design
7. Managing variation in design and manufacturing
8. Managing variation in customer usage through better understanding of scenarios, user training, built-in monitoring (performance, maintenance, service)

Value analysis will be discussed here. When incorporated into cost deployment, value analysis and value engineering allow you look at cost from an end users perspective and from an engineering point of view (Dimsey and Mazur 2002). This helps identify potential part reductions and possibly combine part functions to keep cost in line with value.

The theory behind value analysis is to put cost into the parts that have the most value to the customer. The value analysis takes the parts percentage cost based on the total system part cost and distributes it against the value of the part derived from the quality characteristic x parts matrix such as shown in the brake example in Table 6. Value Engineering helps in determining which functions might be best combined into a single part. The VE analysis takes the parts percentage cost based on the total system part cost as a ratio of the parts percent function in the system. This can then be graphed to see where function/cost mismatches present opportunities for cost reduction efforts (Figure 5). Parts that have function-to-cost ratios above the diagonal line indicate that the cost is higher than the functionality and are therefore candidates for cost reduction efforts, including commodity and communization as mentioned above.

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Table 6 Quality characteristics x parts matrix (Dimsey and Mazur 2002)

Quality Characteristic / Front MC Parts				Mc Body	Clamp	Clamp Screws	Lever	Pivot Pin	Bushing (lever pin)	Retaining Ring (lever)	Sight Glass	Cover Gasket	F
Quality Characteristic	Physical	Lever	Ratio				⦿						
			Width				⦿						
		Other	Resistance lever apply force				⦿	△	○				
			MC weight	⦿	○	△	⦿	△	△	△	△	△	
	Performance	Lever	Lever force vs Travel	⦿			⦿						
			Lever dead stroke	⦿			△						
		System	Force vs Pressure	⦿			⦿						
			Stroke vs Deceleration (leve	⦿			⦿						
		Oth	Lever reach	⦿			⦿						
Absolute Weight				2.60	0.10	0.10	3.50	0.10	0.01	0.01	0.10	0.30	0.1
Part Weight				23.90	0.52	0.50	31.74	0.61	0.34	0.01	0.50	2.59	0.

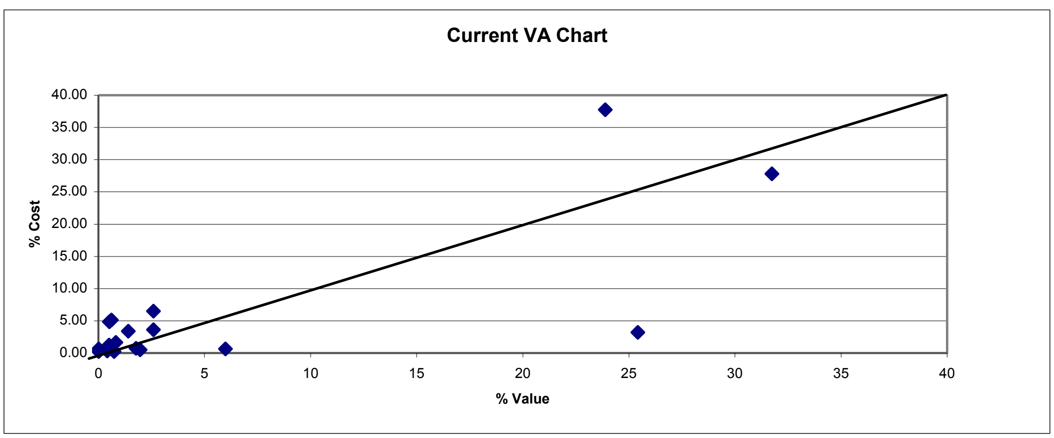

Figure 5 Value analysis of ratio of current master cylinder parts cost to value of customer needs (Dimsey and Mazur 2002)

ISO 16355

In 2009, QFD experts in Japan recommended this author to convene a working group to write a standard for QFD. The process began with a QFD study to understand the needs of standards users in various industries and to use that information to assemble a team of QFD experts (Mazur 2012). The resulting ISO 16355 is currently in draft and consists of eight parts:

Part 1. General principles and perspectives of the QFD method
Part 2. Acquisition of VOC/VOS – non-quantitative approaches
Part 3. Acquisition of VOC/VOS – quantitative approaches
Part 4. Analysis of non-quantitative and quantitative VOC/VOS
Part 5. Strategy and Translation of VOC into engineering solutions and cost planning
Part 6. Optimization – robust parameter design
Part 7. Optimization – tolerance design
Part 8. Guidelines for commercialization and life cycle

Various QFD drivers as outlined in this paper are planned for Part 5 of the standard. The purpose is to demonstrate that QFD is more than a House of Quality. It is a highly adaptable *system* of analyses and tools to assure that customer satisfaction and value are inviolate regardless of the project and what drives it. Without customer satisfaction, products will fail and neither the customer nor the company will enjoy its benefits.

Conclusion

While most widely used QFD projects begin with customer-driven or forward QFD, the method can be used with many other drivers according to the project charter and scope. This paper has shown that QFD can be used in reverse and when combined with other methods, can be used to drive projects from the perspective of regulatory change, technology or solution, executive directive or strategy, and cost. Other drivers can include reliability, safety, competition, sustainability, and other that have not yet been identified. It is hoped that readers will continue to push the boundaries of QFD thinking to further the benefits to customers and organizations in the future.

About the author

Glenn H. Mazur has been active in QFD since its inception in North America, and has worked extensively with the founders of QFD on their teaching and consulting visits from Japan. He is a leader in the application of QFD to various industries and products, conducts advanced QFD research, and is the Conference Chair for the annual North American Symposium on Quality Function Deployment. Glenn is the Executive Director of the QFD Institute and International Council for QFD, retired Adjunct Lecturer on TQM at the University of Michigan College of Engineering, President of Japan Business Consultants Ltd., and is a senior member of the American Society for Quality (ASQ), and the Japanese Society for Quality Control (JSQC). He is a certified QFD Red Belt® (highest level), one of two in North America. He is a certified QFD-Architekt #A21907 by QFD Institut Deutschland. He is honorary president of the Hong Kong QFD Association. He is convenor of the ISO Working Group 2 of the Technical Committee 69, Subcommittee 8 to write the international standard ISO 16355 for QFD and a member of the Technical Committee 176 responsible for ISO 9000 series standards. He is an Academician and Secretary-Treasurer of the International Academy for Quality. Additional papers and related topics: www.mazur.net

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