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Value Based Product Development - Using QFD and AHP to Identify, Prioritize, and Align Key Customer Needs and business goals

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Abstract

In order to separate ourselves from the competitive pack, it is becoming increasingly important to seek a deeper understanding of value-driving customer needs during the early stages of product/process development. In this case-study, TRW Automotive has utilized QFD and augmented it with the Analytical Hierarchy Process (AHP) to develop a working model for project leaders to prioritize and focus their design effort effectively. This Blitz QFD® model enables product/process design managers to comprehend, prioritize, and merge the various goals of the business (both corporate and project) with the derived needs of the customer. Further, it serves as a central, clarifying centerpiece of project direction and remains fluid - so if priorities are challenged, the model can be used to recalibrate the design focus.

Key Words

Blitz QFD®, AHP, VOC, DFSS, brake sensor

Introduction

This paper presents an application of modern QFD to the design & selection of an TRW Automotive brake system sensor. We will show how the methodology, which goes well beyond basic requirements analysis, was instrumental in assuring that the highest priority needs of the customers and stakeholders were delivered in the final solution. In doing so, we can also see how the application of modern QFD can also aid project managers to keep the development team on the correct path without deviations or distractions which often lead to cost over-runs, design iterations, and missed project milestone deliverables.

Quality Function Deployment began in the Japanese automotive industry with the first reported application by Bridgestone Tire in 1966.[1] At that time, the goal was to assure the quality of a new a tire during the development stage by understanding key quality requirements and how they were positively and negatively affected by process and material design. This was a shift in quality control strategy from solving problems after they occurred to preventing them before they occurred by understanding the correlations between product requirements and process requirements. Since then, the Japanese automotive industry has been on a relentless pursuit of customer satisfaction by starting the process further and further upstream.

In 1983, Dr. Yoji Akao, one of the co-founders of QFD, published an article in *Quality Progress*[2] and taught the method at a seminar in the United States. Among the earliest adopters were the Big-3 North American auto companies (General Motors, Ford Motor Company, Chrysler Corporation) and their tier-1 suppliers. As key auto companies continue to press for market advantage in a global economy, QFD tools and techniques have grown more powerful by providing value in the form of a better understanding the key needs of their customers.

Traditional QFD vs. Modern QFD

The engineering community in mid-20th century Japan was quite different. Lifetime employment was a social guarantee, work hours were long, college graduates were hired instantly in employment campaigns each spring, the abacus was a common desk top tool, and customers were generally considered the next step in the process. What this meant was that a product development team had the time and resources to do a comprehensive analysis of the quality requirements and how to resolve them. While manufacturing was moving towards "lean," the technical side of the business was anything but.

The attention to detail was well repaid. Pull-through benefits from a thorough analysis of design issues helped Toyota Auto Body reduce start up costs by 61% from 1977 to 1984[3] (Figure 1). Akira Fukuhara, the quality assurance manager at that time, attributed this not only to the improvements resulting from repeated application of QFD to the product line, but also to the increased awareness of how all product quality issues drive customer satisfaction. The Lite Ace minivan project documented this detail by identifying four major improvement opportunities in steering, rust, sliding doors, and a moon roofs. The rust study (actually a reliability study and not a QFD), deployed to 16 levels of matrices and took some two years to complete.

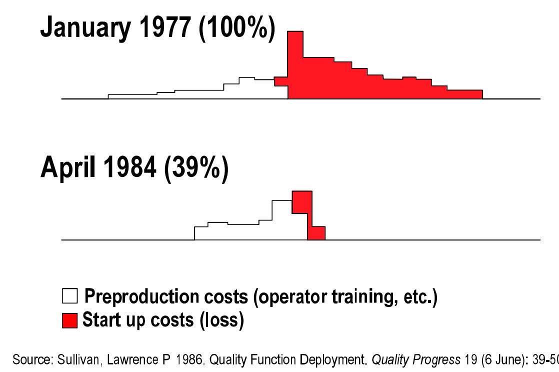


Figure 1: Toyota reduces startup costs with QFD

The purpose of the QFD matrix is to transfer the priority of some input data into priority of some output data. That output is then linked (i.e., deployed) as the input for the next level down, and so forth. Thus, any priority changes to the inputs of the first matrix (customer needs) could be reflected in changed priority of all the subsequent linked matrices. This Toyota example applied this technique in the most comprehensive way by deploying the customer needs from design all the way through to process control with a total of 16 matrices.

The first of the 16 matrices showed 42 tertiary customer needs (there were about 800 needs in eight hierarchical levels) deployed to tertiary quality characteristics. The second matrix expanded just one of the tertiary needs to its 53 eighth-level needs and deployed these to eighth-level quality characteristics. The third matrix identified critical operation environments in which different kinds of rust occurred and accelerated test conditions to mimic the environment. The fourth matrix deployed the impact of the tests on body structure. The fifth matrix deployed the body-in-white structure to manufacturing facility conditions. The sixth matrix deployed manufacturing facility conditions to operation standards. The seventh matrix deployed sealing conditions to process equipment. The eighth matrix deployed operation standards to work control conditions. The ninth matrix deployed operation standards to operation control conditions. The tenth matrix deployed process operation conditions to work control conditions. The twelfth matrix deployed quality characteristics into dip surface treatment conditions. The thirteenth matrix deployed intermediate coating conditions into equipment conditions. The fourteenth and fifteenth matrices deployed equipment conditions into operation standards, and finally, the sixteenth matrix deployed operation standards into work control conditions. In other words, this comprehensive approach goes end-to-end, from design to process control. This is the *hallmark* of assured quality.

This study became one of the foundations of automotive supplier QFD in the U.S. and elsewhere, but its magnitude was hard for beginners to grasp. A Fuji-Xerox study[4] that used just four matrices was adapted by American automotive suppliers to address common reliability concerns, and what became known as the "4-phase" model of QFD was born. The first of these phases, the House of Quality, evolved to become synonymous with QFD, and practitioners eagerly grew these charts to sizes that approach one million intersecting cells. Dr. Akao, when first showed one of these charts, struggled to bless the efforts of one automotive team by praising "how straight the lines were." (Japanese charts were typically drawn by hand at that time and this was one of the first to be printed on a plotter.)

The straight forward 4-Phase deployment of

- product requirements to quality characteristics (similar to Toyota's 2nd matrix above),
- quality characteristics to part parameters (3rd matrix),
- part parameters to operation conditions (5th matrix), and
- operation conditions to process control (10th matrix)

is logical and easy to learn. As a result it quickly became THE way to do QFD in nearly every country outside Japan.

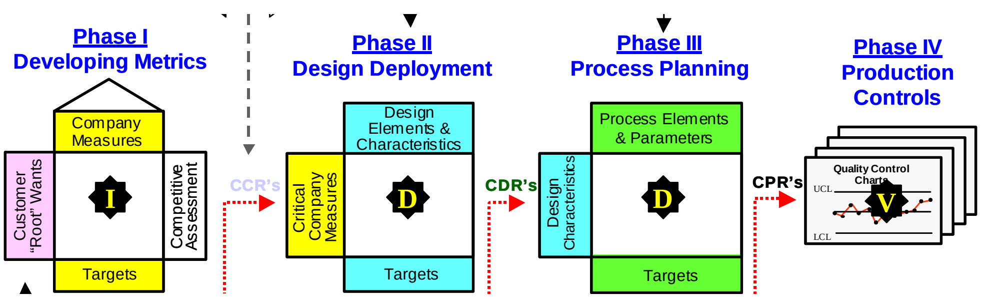


Figure 2: Typical 4-Phase QFD model

Unfortunately, not all companies using QFD are auto part suppliers building to specifications from an OEM auto maker. Many companies make end products, services, software, food products, etc. Even first and second tier auto part suppliers have major design responsibility. In such cases, the 4-Phase QFD model may not cover all the necessary deployments, that is, it does not go end-to-end to assure quality.

The better approach, used in modern QFD, is to custom tailor a subset of the QFD matrices and other tools that represent the most effective and efficient use of team members' time.

Modernizing QFD

Modern QFD, utilizing the Blitz QFD® approach, offers a more efficient use of time by replacing most if not all matrices with more efficient tables, that track only a small number of the most critical customer needs end-to-end through the analysis, design, development, and build phases. The House of Quality matrix, on the other hand, is only the deployment of the analysis phase into design (Figure 3.) Additional matrices may be needed to deploy prior and following product development issues.

The automotive supplier base was reliant on their OEM customer to understand their customers' needs and priorities. Unfortunately, this was not always the case and so even suppliers with well developed components suffered if the finished vehicle did not sell well. Thus, a stronger front end analysis of the value chain and market segments was added in modern QFD.

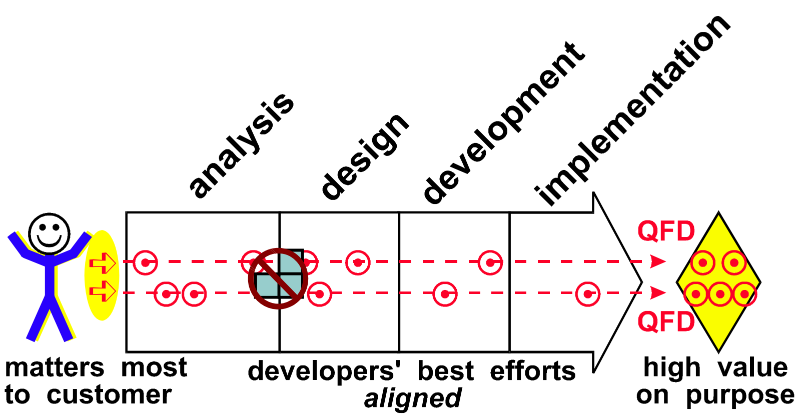


Figure 3: Blitz QFD® and House of Quality

Traditional QFD, as it developed in 1960s Japan in the pre-calculator and personal computer age, was done by hand. To do the math, a simple five rating point scale was adopted that could be calculated with an abacus. Although it resembles the familiar five-point Likert Scale often used in market research, the QFD scale is used to determine importance and correlation, not agreement with a statement. Because the five-point scale is an ordered scale, that is the interval between 1 and 2 is not necessarily equidistant to the interval between 4 and 5, statistical analyses are limited to mode and median calculations. This means that many of the math operations in traditional QFD violate this limitation and the results have questionable meaning. The better approach, used in modern QFD, is to develop ratio scale numbers using the Analytic Hierarchy Process (AHP).[5]

Finally, since the 1960s and especially today, "right-sizing" has lead most organizations to cut staff to the leanest possible levels. Add to this the pressures of rapidly advancing technology, global competitors, multi-tasking on several projects, and compressed time-to-market demands, and new product development teams are hard pressed to find time to do all the QFD they should. To help address the most critical needs first, modern QFD has included Blitz QFD® as a matrix-free approach to first deploy only the most important needs of the customer, end-to-end throughout all the quality assurance phases. In the Toyota rust study, for example, Blitz QFD® would include only the critical few concerns of all 16 matrices.

Brake Sensor Case Study Demonstrates Modern QFD Tools

Many automotive suppliers, such as TRW Automotive, tried using QFD only in terms of the 4-Phase model above, or even as only the first phase, the House of Quality Matrix with limited success. As pressures to infuse "lean" methods into the product development process have increased, the value of these matrices has come into question; engineering and program management are continually overwhelmed with managing all the product requirements that customers consider highly and equally important. Engineering teams and program managers lose interest in QFD very quickly when product delivery schedules are impacted. They typically default to a "we know what the customers want" mentality often based on the loudest and most frequent demands, only to find later that some things were missing or that they had lost sight of the original project priorities. That is because there is no project-wide, deep understanding of customer needs or a structure in which to think about or comprehend them. Many individuals may each carry a bit of this deep knowledge, but it cannot be leveraged for the team until it is collected, organized, and prioritized by business and project goals.

To gain this understanding, TRW Automotive applied the Blitz QFD® approach to the design of a brake system sensor. Blitz QFD® focuses only on a small number of the most critical customer needs unlike the traditional matrix-QFD where all customer needs, quality characteristics, functions, bill of materials, processes, etc. are comprehensively analyzed. Thus, it is crucial that these needs be identified correctly. <u>This requires some upfront clarification of what makes a need important</u> (Figure 4). The voice of customer (VOC) analysis tools used in Blitz QFD® are a powerful way to identify key customer needs. The brake sensor study will be used to demonstrate some of these tools.

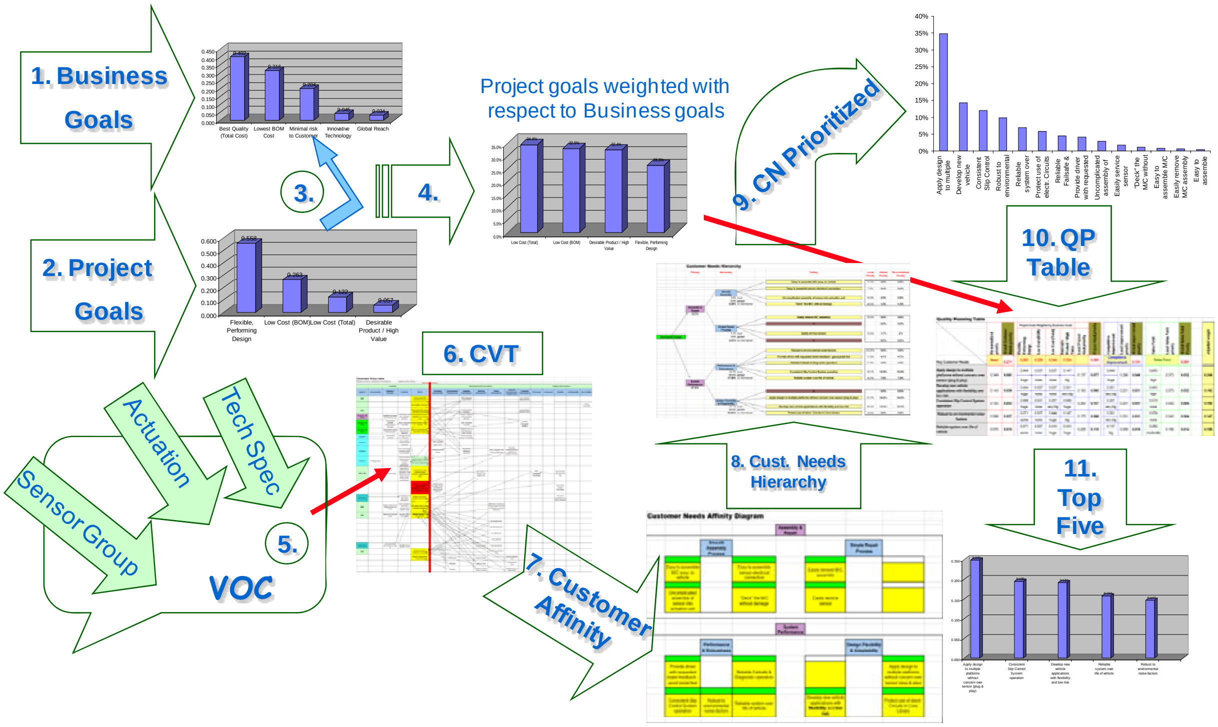


Figure 4: Blitz QFD® steps

1. Business Goals

The first step towards a stronger focus on key customer needs is to clarify and prioritize the goals of the business. These priorities assure alignment of the business with the most critical customer messages. There are many stakeholders and customers that must be considered. A key objective was to deliver a "core" sensor design that offered the most value and largest positive impact with respect to key stake-holders: the TRW business, TRW engineering groups for actuation, slip control, and sensor development, TRW assembly, and OEM engineering & assembly. Table 1 defines some of the business goals.

Table 1: TRW business goals

Goal Statement	Description
Best Quality	Engineering development, DVPR & 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 & 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 & products that add value for our customers. TRW is uniquely **positioned to be a leader in active and passive safety technologies**

2. Project Goals

It is common in today's global automotive market for a project to be given to engineering with the singular goal of "low cost." But what does that mean and where does that goal stand with respect to quality, innovation, market penetration, or saleable to multiple customers? Too often, the words "low cost" are interchanged with "low price." This clarification is very important and it must be communicated to all stakeholders of the project.

Project goals are, by definition, more specific to the project than business goals (Table 2). They help clarify how a project will lead to the more general business goals and strategies. QFD and other cross-functional team members often serve, and are evaluated by, different organizational bosses, however. Thus, team objectives and priorities could differ from individual performance evaluation factors. Clarification of departmental and team goals is important so that neither customers nor team members are caught in the crossfire of internal battles. For example, engineering has the goals of performance and bill of materials cost. Manufacturing has goals related to scrap and throughput. Quality is watching out for production and post-production related costs. Lest we forget, the customer wants a product that meets or exceeds their requirements. Obviously, in order to avoid a seriously suboptimal solution, some care must be taken to combine these various goals with the stated needs of the customer.

Table 2: Brake sensor project goals

Goal Statement	Description
Flexible design	Capable of being used on a variety of vehicle platforms. / Low Design Risk
Low BOM Price	Cost reduced from current sensor. Cost not to be passed on to other areas of the system.
Technology Leadership	Low error performance
Low Customer Risk	No loss in perfomance due to component variation or all-out failure, "adequate redundancy". No "Surprises" at SOP / Launch

3. Prioritizing with AHP

The business and project goals shown in Tables 1 and 2 describe the value of the project to TRW, not the customer. Not all goals are equally important and so they were prioritized using the Analytic Hierarchy Process or AHP (Table 3).

Prioritization in multi-criteria decision making was advanced by the research of Dr. Thomas Saaty in the 1970s at the U.S. Department of Defense and later at the Wharton School of Business at the University of Pennsylvania. Saaty found that decision makers facing a multitude of elements in a complex situation innately organized them into groups sharing common properties. He then organized those groups into higher level groups, and so on until a top element or goal was identified thus forming a hierarchy. When making informed judgments to estimate importance, preference, or likelihood, both tangible and intangible factors may be included and measured. The Analytic Hierarchy Process (AHP) was created to manage this process in a manner that captures the intuitive understanding of the participants and also yields mathematically stable results expressed in a numerical, ratio scale. A numerical, ratio scale is preferred for the following reasons:

1) Numerical priorities can be applied to later analyses to derive downstream priorities.
2) Ratio scale priorities show precisely how much more important one issue is than another. Ordinal scales only indicate rank order, but not the magnitude of importance.
3) Numerical scales can be tested for judgment inconsistency, sensitivity, and other properties.

AHP has been successfully applied in many government and industry decisions to clarify fuzzy and often emotional goals, and build consensus on the best ways to address them.

At TRW, AHP was used to realign the project team with key corporate objectives and priorities. The four business goals were examined via pair-wise comparison for relative importance on a verbal scale from "equal importance" to "extremely more important." These verbal comparisons were converted to a numerical scale of 1-9 in accordance with the AHP methodology. "Best quality" is considered equal to moderately more important than "lowest price" and so a "2" was entered into the grid shown in Table 3. Similar evaluations were made between all six possible pairings of the business goals shown in the center of the grid (goals compared to themselves and inverses are shaded yellow). Applying AHP, the results show the ratio scale percentage of relative importance in the rightmost column of the grid, labeled "row average." A significantly deeper level of comprehension of the business goals can now be communicated given the ratio-based relationship between Best Quality and Innovative Technology; relating 49% to 6% carries with it a significantly deeper meaning than 1st to 4th place.

Table 3: TRW business goals prioritized with AHP

Four	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 Ratio	0.00

4. Deploying business goals into project goals

Project goals must align with or be driven by the business goals. If they do not, the project runs the risk of delivering something to the customer that the overall business strategy cannot support. The business goals are generally stable but their respective priorities may change over time due to marketing strategies or fluctuations due to various economic pressures. If they do change, the relative (ratio-scale) priorities must be driven downstream in the product development process. That is, the strategies must be communicated through the business goals, on through the project goals, and ultimately into the product itself.

The mechanics of checking & aligning the project goals with the business goals are as follows:

1. Develop a relationship strength table with AHP derived priorities. The relationship strength between the Business and Project goals is indicated with the Modern QFD symbol set based on international weather symbols and quantified using AHP (Table 4). The weather symbols indicate the strength of the relationship between the business goals and the project goals –

specifically the degree to which each project goals helps to achieve each business goal. The strongest relationship is a fully filled in circle and then it decreases to an open circle as the weakest, and a simple dot to indicate there is not a relationship but it was at least discussed. These symbols are weighted using AHP to quantify them on a ratio scale (remember the ordinal scale in traditional QFD does not support the required math functions).

2. Ask the question of each intersection of business and project goals, "how strongly does projet goal X positively impact business goal Y?" For example, begin by asking the question for one of the intersecting pairs, "To what degree does the Project Goal of Flexible Design drive the Business Goal of Best Quality?" In the TRW sensor project, management's response to this question was that this was a weak relationship. This was indicated by an empty circle symbol and respectively an AHP derived weight of 0.035 (Table 4).

3. After the relationship symbols are determined, the row weights (business goal priorities) are multiplied by the symbol weights and the products are summed column by column. These are called the absolute weights in the second from last row (Table 5).

4. Normalize the absolute weight priorities such that they sum to unity. This method allows for as many as nine levels of relationships instead of the three in traditional QFD, and to score them in ratio scale instead of the limited ordinal scale. In these mathematical analyses, generally a minimum of five levels is preferred to assure statistical precision.

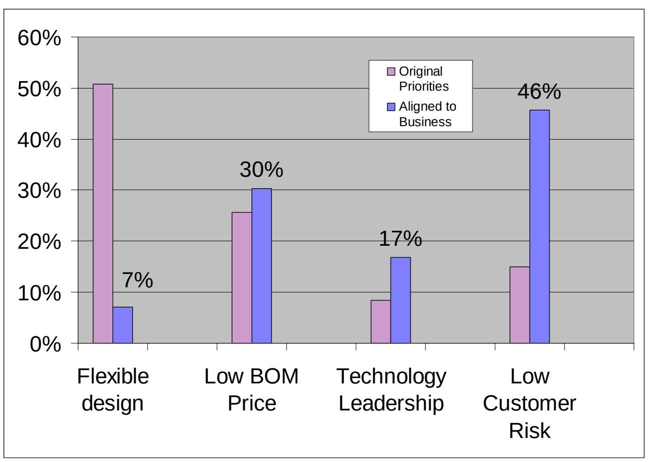
Referencing Table 5 again, the intent was to offer a comparison of perspectives between the original project goal priorities as engineering had comprehended them from the given requirements package and priorities that were deployed down from the business goals. The comparison made obvious some significant discrepancies from these two perspectives.

Table 4: QFD relationship strength with symbols

	Symbols	Priorities
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

Table 5: Business goal priorities deployed into project goal priorities

Business Goals	Adjusted Weight (Management priority)	Flexible design	Low BOM Price	Technology Leadership	Low Customer Risk
Original Project Goal Assumptions/Priorities =>		0.508	0.257	0.085	0.150
		Project Goals			
Best Quality	0.486	○ 0.035	· 0.000	◑ 0.134	● 0.503
Lowest Price	0.378	○ 0.035	● 0.503	· 0.000	◑ 0.134
Global Reach	0.071	◕ 0.260	◕ 0.260	◕ 0.260	◕ 0.260
Innovative Technology	0.064	· 0.000	· 0.000	● 0.503	· 0.000
Deployed (Absolute) Weights		0.049	0.209	0.116	0.314
Normalized & Aligned Project Goal Weights		0.071	0.304	0.169	0.457



Of particular interest in this specific deployment was how the project goal priorities were affected by the business goals. Notice that the project goal of Flexible Design was initially carrying just over 50% (0.508) of the project priority (Figure 5). However, after it was deployed across (i.e., aligned with) the business goal priorities, it fell to just over 7%. This is a very significant piece of (discrepant) information for the engineering and management teams! This activity of aligning with the business goals lead to increased awareness for both parties.

Figure 5: Project goal alignment by business goals

5. Voice of Customer

The most critical goals of this project were now clarified; *reduce risk to the OEM customer* and *achieve a low bill of materials price* as indicated by the above matrix. To achieve this, internal customers who make other design decisions that affect risk and cost needed to be included in the analysis. Thus, engineers within the actuation and sensor group were interviewed to learn their likes and dislikes with the current design, their wants and needs for a future design, and design process opportunities to work together more effectively.

6. Customer Needs

All interview verbatims and technical specifications were recorded and parsed into simplified statements for further analysis in the Customer Voice table (CVT). Table 6 shows how the CVT was used to map the "sensor requirements" back to the customer needs. Additional customer needs were derived from situations where there were previously identified problems. This tool increased the understanding of each voice of customer (VOC) input in the context of the customer's environment and language. Customer needs have a unique definition in QFD; they are positively worded, singular statements that describe a problem, opportunity, or in image concern from the customer's perspective. They are not about our product; they are about the customer's product or process.

The CVT activity helped surface the key customer needs such that they could be connected with project goals and, subsequently, prioritized on a ratio scale. This is a noteworthy point; the project manager can now comprehend the requirements (where everything is said to be of equal <u>and</u> high/utmost importance) on a ratio scale. When tradeoffs must (as they always do) be made in the product development, the project manager now has a <u>defensible</u> map to navigate and guide him or her to make the appropriate choice for the overall project success.

Table 6: Customer Voice Table (CVT) mapping voice of customer into true customer needs (partial)

Customer					Requirements (for the solution)						
Segment	Characteristics	Situations / Scenarios	Problems	Needs	Packaging Requirements	Environmental Requirements	Assembly Requirements	Electrical Requirements	Sensor Requirements	Failsafe & Fault-Detection Requirements	Connector Requirements
OEM				Easily remove M/C assembly for service			OEM clearance requirements				Low connector **removal force**
				Serviceable components							
OEM				Easy to assemble sensor **electrical connection**			overall package envelope				Low connector **insertion force**
Assembly Line **(TRW)**		Installation of sensor into actuation unit	complicated, multi-step installation process	Uncomplicated assembly of **sensor** into actuation unit			Robust to "rigorous" OEM assembly process				
Assembly Line (OEM)		During OEM assembly (Body/Chassis marriage)	Sensor vulnerable to damage	"Deck" the M/C without damage			"Self- Protected" assembly				(proper) **Connector location**
Assembly Line (OEM)		"giant hands" During OEM assembly	doesn't provide sufficient hand clearance	Easy to assemble M/C assembly to vehicle			Adequate room for line-workers to "Deck" the M/C				
Actuation		During OEM assembly	damaged during mc "decking"				Robust package design / no damage				

7. Customer Needs Affinity Diagram

Once the customer needs are defined, they must be prioritized so that we know where to concentrate our valuable engineering effort. In modern QFD, we use a sequence of three tools to do this. The three tools are affinity diagram to capture the customer's mental structure about their needs, hierarchy diagram to check the structure and discover unspoken needs, and the AHP to get the customers to easily and accurately prioritize their needs.

The affinity diagram is a grouping technique developed by a Japanese cultural anthropologist to uncover underlying structures in the belief systems of foreign cultures. In a sense, customers are a "foreign" culture to the development team, and this tool is very helpful in helping break existing paradigms. The customer needs are written on cards which customers then arrange into groups and super groups which they name, respectively, with more abstract header cards (Figure 6) .

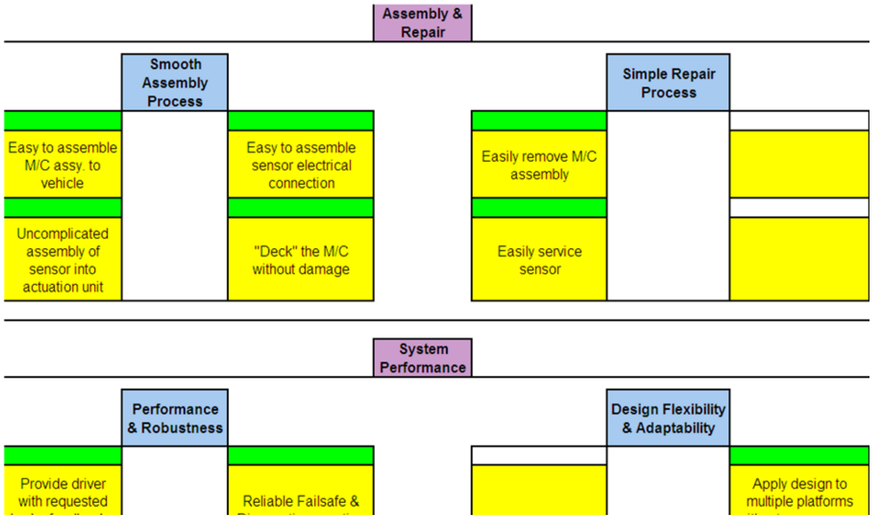


Figure 6: Affinity diagram of customer needs (partial)

8. Hierarchy Diagram

The hierarchy diagram is used to check the structural levels of the customer needs. (Figure 7) It is also used to discover additional missing needs. These two tasks are important to subsequent prioritization with AHP, where the accuracy of the results is improved when the items in the hierarchy are mutually exclusive and collectively exhaustive (MECE). For example, to compare the juiciness of an apple to an orange, one could establish that the orange was juicier and even determine the relative degree of juiciness on the AHP verbal scale of equal to extreme, explained above. However, if the hierarchy structure is incorrect, we might be asked to determine which is juicier, an apple or a piece of fruit. Since an apple is a piece of fruit (it is a subset of fruit), an accurate comparison cannot be made.

The second task of uncovering missing needs is done be exploring the groups in the hierarchy diagram. For example, if our "fruit" group includes apple, orange, banana, pear, and plum, we should ask if there are other fruits to consider, such as peaches and pears. For the sensor project, the affinity diagram outputs are rotated 90 degrees in order to illustrate the hierarchy.

9. Prioritizing Customer Needs with AHP

Once the customer needs hierarchy has met the MECE test, we ask the customers to tell us which needs are most important. The AHP, described previously, is easy for customers to evaluate and produces very accurate ratio scale results of relative importance. It is easy for customers because when there is a large number of needs, customers can use the hierarchical structure to their advantage to reduce the effort. They can begin the pairwise comparison at the primary level, and then only pursue the high priority branches to the secondary level, and so on. This can reduce the number of evaluations to less than one-third of all the items. In a traditional survey, however, customers must rate each of the needs on an ordinal scale, resulting in fatigue and numbers with limited usefulness later in the QFD. Table 7 shows the results of the prioritization of the customer needs for the TRW brake system sensor. Again, notice the impact of the ratio-scale importance values compared to the lesser information that a top-14 list with ordinal-based priority would provide. Only the top-5 customer needs of Table 7 are carried forth in the case study for the sake of brevity.

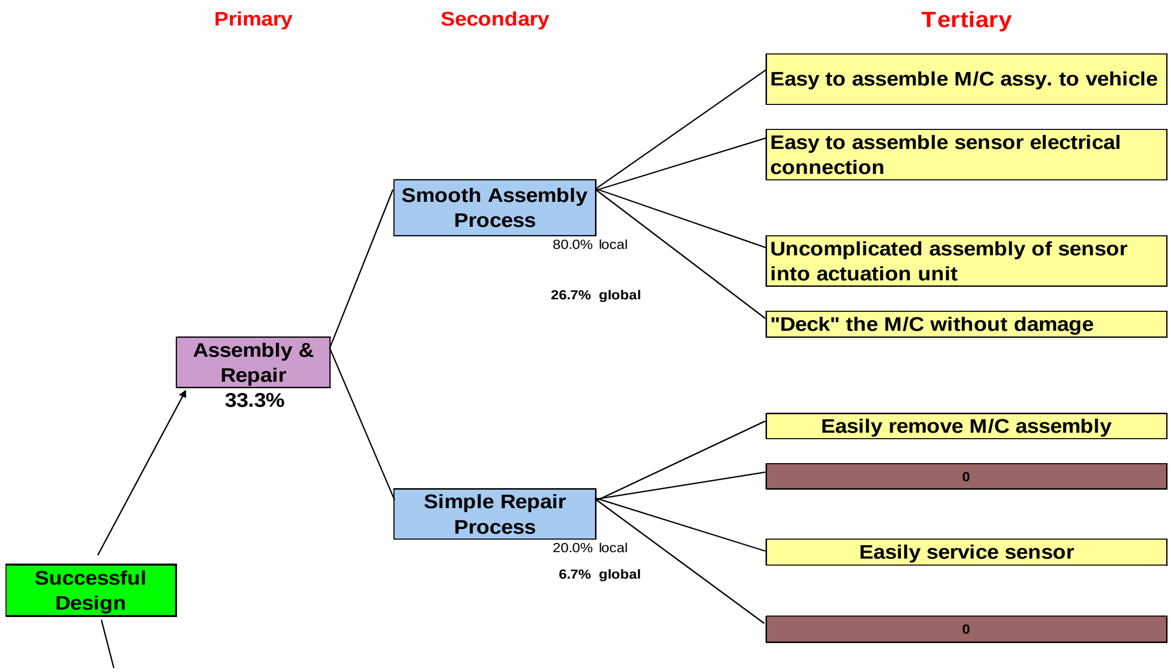


Figure 7: Hierarchy diagram of customer needs (partial)

Table 7: Customer needs priorities from AHP

Rank	Customer Needs		Cum%
1	Apply design to multiple platforms without concern over sensor (plug & play)	23.2%	0.23
2	Uncomplicated assembly of sensor into actuation unit	16.1%	0.39
3	Consistent System operation	9.8%	0.49
4	Develop new vehicle applications with flexibility and low risk	9.5%	0.59
5	Robust to environmental noise-factors	8.0%	0.67
6	"Deck" the M/C without damage	6.6%	0.73
7	Reliable system over life of vehicle	5.7%	0.79
8	Easy to assemble M/C assy. to vehicle	4.5%	0.83
9	Protect use of electr. Circuits in Core Library	3.9%	0.87
10	Reliable Failsafe & Diagnostic operation	3.6%	0.91
11	Provide driver with requested brake feedback - good pedal feel	3.3%	0.94
12	Easily service sensor	2.7%	0.97
13	Easy to assemble sensor electrical connection	2.1%	0.99
14	Easily remove M/C assembly	0.9%	1.00

10. Quality Planning Table to Weights for Competitive Benchmarking and Sales

Dr. Akao's model for comprehensive QFD allows adjustment of customer needs weights to account for competitive benchmarking and sales claims and effort. In traditional QFD, customer needs were prioritized, competitive products were benchmarked, and sales claims or sales points were identified and weighted using an ordinal 1-5 scale. However, when these numbers are multiplied to calculate an aggregate weight, this uses an improper math operation on ordinal numbers, thus yielding a result whose meaning cannot be determined. In modern QFD, this has been fixed (Table 7) by applying AHP once again to each of these categories.

Table 8: Quality Planning Table (QPT) using AHP derived relationship strengths

	Top-5	Global Customer Needs priority	Project Goals: Flexible design	Project Goals: Low BOM Price	Project Goals: Technology Leadership	Project Goals: Low Customer Risk	Project Goal priority	Customer evaluation of current product	Customer evaluation of competitor	Positioning Plan	Competitive Improvement	Local improvement priority	Improvement priority	Sales Point	Local Sales Point priority	Global Sales Point Priority
Top 5 Key Customer Needs	Need	0.271	0.071	0.304	0.169	0.457	0.490	Competitive Improvement					0.154	Sales Point		0.084
Apply design to multiple platforms without concern over sensor (plug & play)	0.232	0.063	0.444 huge	0.147 big	0.071 some	0.444 huge	0.278	They say about us	They say about them	Goal	0.444 huge	0.374	0.058	0.643 high	0.474	0.040
Uncomplicated assembly of sensor into actuation unit	0.161	0.044	0.444 huge	0.071 some	0.071 some	0.301 very big	0.174				0.071 some	0.059	0.009	0.283 moderate	0.208	0.018
Consistent System operation	0.098	0.027	0.444 huge	0.037 none	0.147 big	0.444 huge	0.194				0.301 very big	0.253	0.039	0.074 none	0.054	0.005
Develop new vehicle applications with flexibility and low risk	0.095	0.026	0.071 some	0.037 none	0.147 big	0.301 very big	0.143				0.301 very big	0.253	0.039	0.283 moderate	0.208	0.018
Robust to environmental noise-factors	0.080	0.022	0.071 some	0.037 none	0.301 very big	0.444 huge	0.212				0.071 some	0.059	0.009	0.074 none	0.054	0.005

The Quality Planning Table, or QPT shown in Table 8, is where all the "voices" come together to weigh in on the relative importance of the "customer" needs. One could take the view that if each of the key customer needs is not fulfilled, the project will be deemed a failure. The reality of physics often dictates otherwise; compromises and tradeoffs are always made. Further, if the customer needs are being fulfilled in conflict with the business plan and strategy, it is likely that a company won't be in business very long. Those points in mind, the key customer needs were deployed across the project goals, Competitive Improvement opportunity, and Sales Point opportunity. Again, in this example the top-5 customer needs from Table 7 were carried into the QPT for brevity.

Project Goals - A fair amount has already been said about the importance of the project goals. Thus far, they inherited their priority from the business goals. Here in the QPT they are deployed to the key customer needs.

Competitive Improvement – Here the key customer needs are deployed across the opportunity to position our product against the competition should we fulfill a specific customer need. If the fulfillment of a particular customer need would provide a significant competitive advantage, it should be given a slight increase in its relative importance.

Sales Point – Here the key customer needs are deployed across the opportunity to gain additional sales.

11. Adjusted Customer Need Weights

Ultimately, the process resulted in a prioritized list of customer needs that could then be used throughout the design process (Table 9).

Adjusted Customer Needs	Adjusted Weight (Management priority)	Sensor Type: Sensor A	Sensor B	Sensor C	Sensor D
Apply design to multiple platforms without concern over sensor (plug & play)	0.309	○ 0.035	◔ 0.068	◑ 0.134	· 0.000
Uncomplicated assembly of sensor into actuation unit	0.172	◑ 0.134	◔ 0.068	◑ 0.134	○ 0.035
Consistent System operation	0.186	◔ 0.068	◔ 0.068	◑ 0.134	○ 0.035
Develop new vehicle applications with flexibility and low risk	0.159	◑ 0.134	◑ 0.134	◑ 0.134	○ 0.035
Robust to environmental noise-factors	0.174	◑ 0.134	◔ 0.068	◑ 0.134	○ 0.035
Absolute Weight		0.091	0.078	0.134	0.024
Normalized Weight		0.278	0.239	0.410	0.073

Table 9: Top-5 deployed customer needs used in sensor design selection

Ultimately, the effort put forth to understand all the various customer needs and organizational motives was used in a concept selection exercise. Table 9 shows how the deployment process described previously was essentially repeated to select sensor design "C" by a significant margin. Given the clarity and traceability offered by the Blitz QFD® approach, the selection decision was both defensible and well documented.

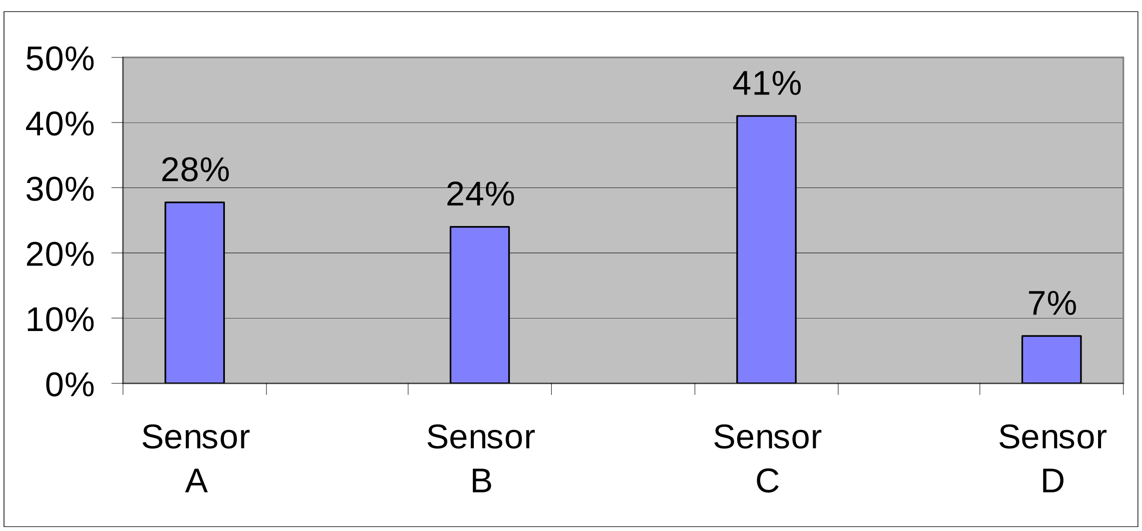


Figure 8: Sensor design selection results

Integrating QFD and PDP

TRW is embedding QFD and other Define for Six Sigma (DFSS) tools and methods into their product development process (PDP). This integration is beginning to pay dividends by adding value to the PDP; improving knowledge in critical areas that were typically drivers of design, build, test iterations and other forms of engineering waste. This is Value-Based Product Development.

Summary and Next Steps

Early adopters of QFD in the automotive industry have struggled to find the time and resources to do the large matrices that were taught beginning in the 1980s. QFD has modernized in response to the changing needs of its practitioners (customers) as companies have grown more "lean," faster paced, and more demanding of value-add at every step of the product development process. This example illustrated this adaptation by assuring that the product was what the customers wanted within the bounds of the clarified TRW business goals. More importantly, the alignment with the TRW business priorities assisted the project managers early in the project with keeping the valuable engineering effort focused on delivering the most important aspects of the design without distractions and unnecessary iterations. By adopting modern Blitz QFD®, TRW hopes to maintain its leadership as a key brake system supplier to auto companies across the globe.

Additional papers and related topics may be found by linking on the Internet through the following home page: www.mazur.net

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About the Authors

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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 service industries and consumer 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, Adjunct Lecturer on TQM at the University of Michigan College of Engineering (ret.), 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.