QUALITY FUNCTION DEPLOYMENT (QFD): A CASE STUDY

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Abstract

Quality Function Deployment (QFD) was conceived in Japan in the late 1960's, and introduced to America and Europe in 1983. This paper will provide a general overview of the QFD methodology and approach to product development. Once familiarity with the tool is established, a real-life application of the technique will be provided in a case study. The case study will illustrate how QFD was used to develop a new tape product and provide counsel to those that may want to implement the QFD process.

Introduction

Quality Function Deployment (QFD) was conceived in Japan in the late 1960's, and introduced to America and Europe in 1983. During the period between the late 1960's and early 1980's, the concept of QFD was evolved from the belief that Total Quality Control must include not only checking of the control points during production, but an understanding of the requirements prior to the design phase. In the late 1960's, Japanese companies were breaking from their post World War II mode of imitation and copying to a more original mode of product development[1], making design quality an important consideration. The need to understand the critical design issues prior to production was acknowledged and QC process charts were widely used to ensure that the design criteria were met during manufacturing, but there was no formal system to translate the customer's needs into the initial design and subsequent process control points. Thus, an opportunity was created for QFD to come to fruition as a method to check the design itself for adequacy in meeting customer requirements and to translate those requirements to production.

At this juncture, the quality chart as created by the Kobe Shipyards of Mitsubishi Heavy Industry (MHI) became known. The quality chart developed at MHI showed the relationship between customer needs and quality characteristics. Because the quality chart was first created at Kobe, it is often stated that QFD originated there. However, Akao states that "I first wrote about quality deployment, however, in an article published in April 1972, which described both the terminology and the procedure. This article was a compilation of what I had taught and experimented with at various companies over a six year period beginning in 1966. The writing of this article took place before the MHI quality chart was made public in May of 1978" [2]. In 1983, Akao published an article on QFD in Quality Progress, the magazine by the American Society of Quality Control, and began giving lectures and seminars to American audiences. It was at this time that QFD was brought to the American automotive industry and the QFD Institute was founded. Since then, QFD has been extensively utilized in many diverse applications and industries. Examples of this diversity include the use of QFD in developing education products for Northern Australia beef producers [3], designing the animatronics for the Triceratops Encounter at Universal Studios in Florida[4], exploring a new market for fresh pork sausage in southern Brazil[5], and improving the Ritz-Carlton's housekeeping system[6]. There have also been numerous QFD projects in the automotive industry including Visteon's power train control systems division work on fuel system components[7] and Ford Motor Company's project on automotive painting[8].

Benefits of QFD

The major advantage of the QFD process is that it encourages proactive product development instead of reactive product development (Figure 1). Proactive product development results in fewer and earlier design changes, decreased development time, fewer start-up problems, lower start-up costs, fewer field problems, and a more satisfied customer. A less obvious, though equally important, benefit of QFD is that it facilitates organizational knowledge transfer and establishes a proprietary knowledge base. The matrices that are generated during a QFD project make the logic flow obvious and act to preserve technical and customer knowledge. This affords others in the organization the opportunity to easily access and use the accumulated knowledge.

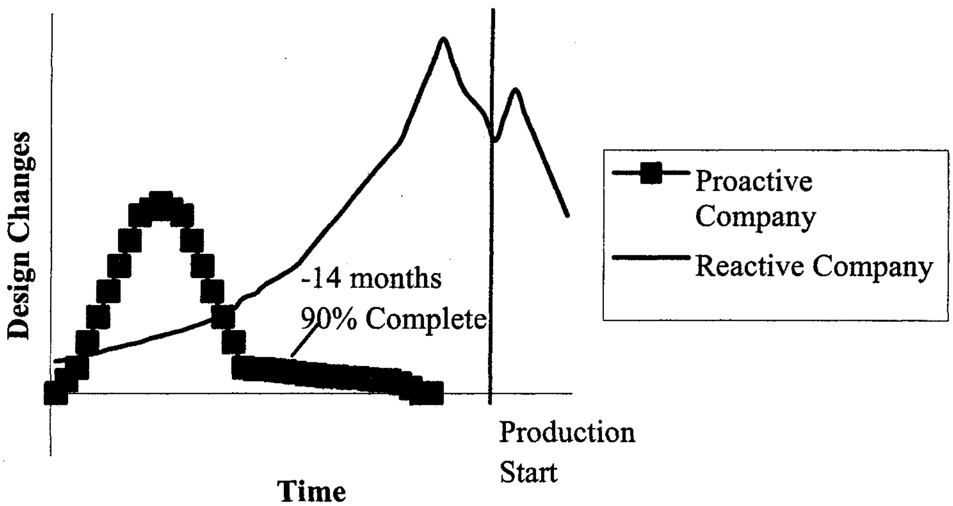


Figure 1. Change Comparison[10]

QFD Defined

As well as having several alternative translations (Table 1), the phrase Quality Function Deployment is a literal translation of the Japanese Kanji characters Hin Shitsu Ki No Ten Kai [9].

Table 1. Alternate Translations

Hin Shitsu	Ki No	Ten Kai
Quality	Function	Deployment
Features	Mechanization	Diffusion
Attributes	-------	Development
Qualities	-------	Evolution

The true meaning of the phrase QFD is customer driven product (or process or service) development. It is a system for translating customer requirements into appropriate company requirements at each stage, from research and product development, to engineering and manufacturing, to marketing/sales and distribution. QFD is a disciplined, systematic method that ensures the voice of the customer is heard throughout the development, manufacturing, and product launch processes. Some say that QFD is a way to "neutralize the voice of the executives or engineers". This rather sarcastic turn of the phrase has its roots in the idea that customer's needs are paramount and that what executive management or engineering thinks the customer needs or wants may not be reality. QFD forces a consideration and prioritization of needs based on the customer's own words, terminology, and actions.

Understanding Customer Needs

The Kano Model[11] is a useful tool in understanding customer needs (Figure 2)[12].

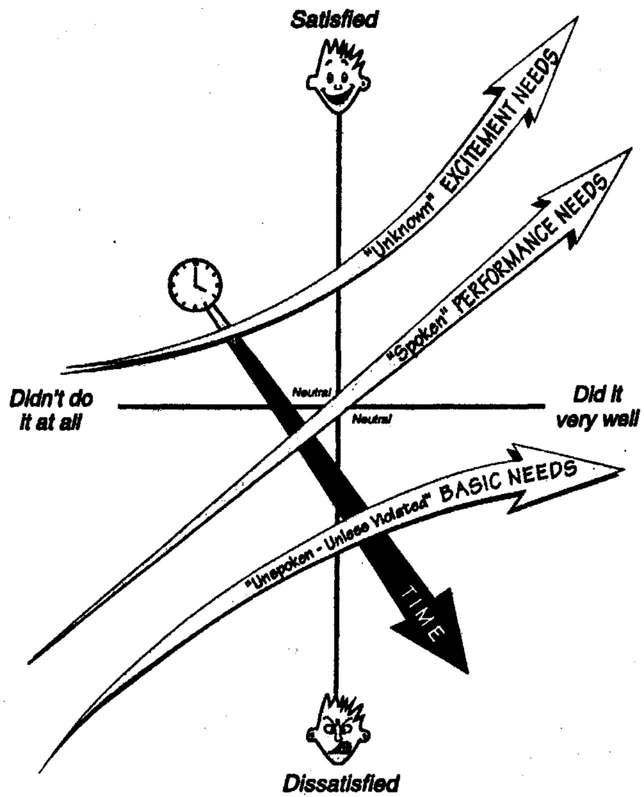


Figure 2. Kano Model

The Kano model categorizes customer needs into three groups: basic, performance, and excitement. This model must be applied to a specific market segment; for example, customer expectations for a commodity masking product are significantly different from those for a high temperature automotive masking product.

Basic needs are those that get a company in the market; they are not spoken unless violated. For example, at a hotel, you don't ask for a bed, you expect it to be there. If you show up and there is no bed, then you would speak the need (after it was violated). Basic needs, no matter how well done, can at best make the customer neutral. Continuing with our hotel example, if there are 3 beds in the hotel room and you are traveling alone, that doesn't make you any happier than if there was one bed. In terms of a tape product, if high temperature performance up to 300°F is required, and you give the customer a product that works up to 400°F, but his process never gets above 300°F, then the added temperature resistance does not increase his satisfaction. However, if the product does not function at 300°F (a basic need), then the absence of such need will be noticed. Sources of basic needs include complaints, industry standards, what your competitors are doing, and your own product expertise.

Performance needs are known as those that keep a company in the market. They are spoken by the customer and considered when purchasing decisions are made. Performance needs make the customer happy or unhappy, and the customer's happiness is proportional to how well the performance needs are met. For a pressure sensitive product, it is a basic expectation that it will stick to a surface with pressure. However, a performance need would be the amount of pressure required (i.e. the less rubdown pressure the customer has to apply, the happier he is). Other examples include delivery (the faster the better), express hotel checkout (the fewer the steps, the better) and the number of machines in the fitness center (the more the number and variety, the better). Performance needs can be gathered by market research, focus groups, surveys, clinic, interviews, and by contextual inquiry (asking questions while observing the product in use).

The last category of needs per the Kano model are those that afford the greatest opportunity in terms of becoming a market leader or innovator. These needs are known as excitement needs. Like basic needs, excitement needs are unspoken. However, unlike basic needs, which are expected and known, excitement needs are beyond customer expectations. For this reason, they are generally unknown and difficult to uncover. Some of the techniques used to uncover these needs include looking upstream and downstream in a customer's process, evaluating how a product has evolved with time, looking for unconventional uses of the product, and involving people from outside the industry. Excitement needs are pleasant surprises, leap improvements, "bells and whistles", and sources of customer delight. As such, if an excitement need is not fulfilled, it does not impact customer satisfaction. If an excitement need is fulfilled in any way, there is movement on the curve towards increased customer satisfaction. "Me too" companies do not address excitement needs; these needs are handled by innovative companies that are looking for the next generation product or service. Excitement needs for tape might include a protective tape that is pre-printed thus obviating the need for the customer to apply a separate identification label, or a masking tape that changes color after being subjected to a certain time/temperature cycle to indicate a paint has cured. Other examples of excitement needs include the cooler that is built into a recliner so the customer doesn't have to get up and go to the refrigerator, a fast food restaurant mixing the cream and sugar into a drive-through customer's morning coffee, and a wedding photographer posting a photo proof book on the internet for the viewing and ordering of copies by out of town friends and relatives. None of these things are expected and if they were lacking, a customer would not complain. However, the presence of them causes the customer to stand back and take notice.

Evolution of Needs with Time

An extremely important aspect of the Kano model is the idea that needs evolve over time. As time marches on, excitement needs become performance needs and performance needs become basic needs. The exciting and innovative needs get copied by competitors and become standard and expected. There are many examples of this in the auto industry where automatic transmission, cup holders, visors with clips, automatic windows, and airbags were once considered excitement needs and are now expected in a new vehicle. Express checkout at hotels, which used to be an excitement need is now considered a performance need and electronic ticket check in at the airport is moving from an excitement need to a performance need.

Voice of the Customer

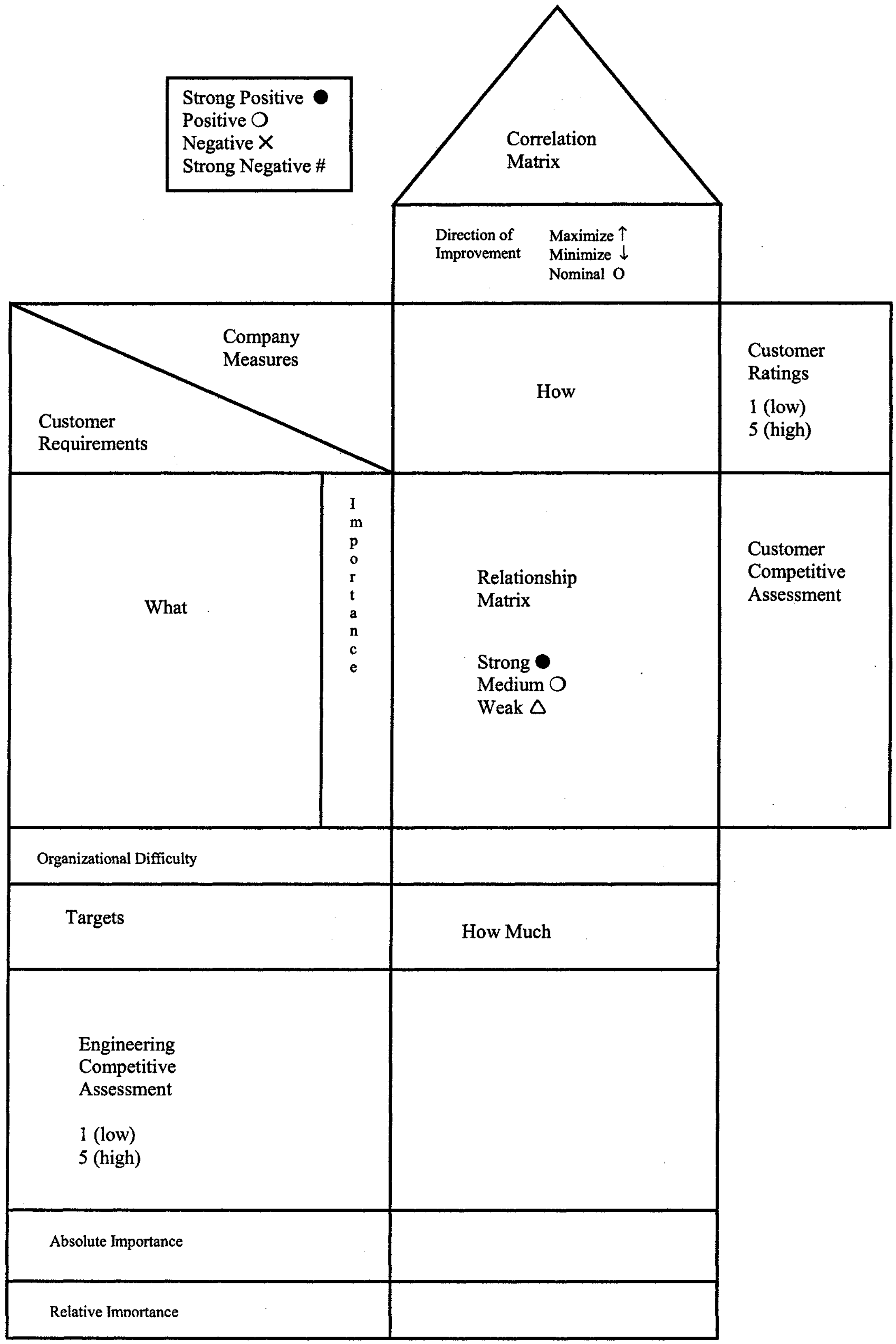
QFD is a tool that ensures the identified customer needs are considered in a design effort. The initial step in a QFD project is the gathering and analyzing of the voice of the customer; this step is vital in identifying potential opportunities in terms of excitement needs. The gathering of the voice of the customer can be done in many ways, including internal brainstorming, review of complaint and warranty logs, interaction at trade shows, focus groups, technology forecasting, and customer visits. Going directly to the end-use customer affords the opportunity for not only an interview regarding needs and wants, but also the chance to watch a customer use a product. This method helps the QFD team become focused on what the customer is actually doing with the product versus what the team thinks he is doing or what the customer says he is doing. It also requires the design team to think in the customer's terms and language, not in technical, engineering, or industry terms. This is achieved by a recording of the needs in the customer's exact words with follow up questions asked to clarify. However, a translation into technical terms does not take place until later in the QFD process.

QFD Methodology

QFD utilizes a series of matrices, referred to as the House of Quality (HOQ), to translate the voice of the customer through product design and manufacture. There are four phases of the process: Phase 1-Product Planning, Phase 2-Design Deployment, Phase 3-Process Planning and Phase 4-Production Control. The HOQ provides a direct link from phase to phase. The four key elements of each HOQ are what (customer needs), how (company measures), relationship (between what and how), and how much (target value). The company measures (how) of one phase become needs (whats) of the next phase. Target values (how much) are carried over from phase to phase to ensure the objective values are not lost. The cascade process continues until each objective is refined to an actionable level. In order to keep the process manageable, the funneling of critical items to the next phase is necessary.

In addition to the four key elements mentioned above, extensions of basic QFD are used as required for specific projects. The correlation matrix is the "roof" of the house and establishes the relationship between the hows. This allows for conflict identification early in the process. Conflicts can be used to generate excitement qualities since competitors may also have the conflict. A tape example is the need for high adhesion to backing and low high speed unwind. Competitive assessment, which depicts each item (either the customer needs or company measures) in terms of the current product and the competition, is another extension of the HOQ. For the customer needs (whats), the customer's perception of the current product versus the competition is determined and a Customer Competitive Assessment added to the house. For the company measures (hows), an analysis of competitive products takes place and a Technical Competitive Assessment added to the house. The technical assessment can be useful in establishing values for the target values.

Another useful extension of basic QFD is the addition of importance ratings for the customer needs. The ratings must truly represent customer beliefs rather than internal company beliefs; therefore, they are based on a customer assessment or prioritization. The importance ratings for the customer needs are then correlated to importance ratings for the company measures. Additional extensions include service complaints, organizational difficulty, service repairs, service cost, and regulatory and company requirements. See Figure 3 for HOQ with extensions.


Strong Positive ●
Positive ○
Negative ✕
Strong Negative #
Correlation Matrix
Direction of Improvement
Maximize ↑
Minimize ↓
Nominal O
Company Measures
Customer Requirements
How
Customer Ratings
1 (low)
5 (high)
What
Importance
Relationship Matrix
Strong ●
Medium ○
Weak △
Customer Competitive Assessment
Organizational Difficulty
Targets
How Much
Engineering Competitive Assessment
1 (low)
5 (high)
Absolute Importance
Relative Importance

QFD for the Development of a Heat Activated Tape Product

Intertape Polymer Group began using QFD in late 1997. A team consisting of representatives from Purchasing, Marketing, Process Engineering, Research and Development, and Quality Assurance was formed to use QFD to develop a heat activated tape product. An interview guide with questions designed to elicit performance and excitement needs was developed and visits to several customer sites arranged. Two members of the QFD team, along with an IPG sales representative, participated in the customer interviews. The survey questions were asked of several employees at each facility and their answers recorded verbatim. Employees were also observed as they processed the product through their operation. Those observations were documented on the survey as well. After all of the interviews were conducted, the customer needs, in the customer's own words, were organized and consolidated by the QFD team via an affinity diagram. This process of grouping similar needs together helped in terms of organization; however, even more importantly, it gave the team members who did not participate in the interviews a chance to better understand the customer needs.

The initial customer participants were then enlisted to complete a customer competitive survey and importance ranking of the identified needs. All of this information was subsequently entered on the HOQ chart (Figure 4) along with other items that the team felt were important but had not been mentioned by the customer. These were grouped together under the "design/tech" heading. The next step was the establishment of the company measures. The company measures were organized into groups and entered into the HOQ. In our project, the customer need of "once activated, stays adhered" was measured by the lead pull force test. A technical competitive benchmark study was performed on competitive products and that data added to the chart. Any conflicts between the customer competitive survey and the engineering survey were discussed and resolved at this point.

Next, the team developed the relationship matrix between the customer needs and the chosen company measures. In some cases, there was a blank row or a blank column. A blank row meant that a customer need did not have a company measure associated with it. In those cases, a company measure or new test was developed. A blank column indicated that a company measure was in place that did not relate to a customer need. These tests were removed from the matrix.

The team then developed the preliminary targets for the company measures. This was done based on an understanding of the competitive technical assessment results as related to the customer competitive assessment. In our specific case for example, a target for lead pull force was based on Competitor 2's test results since the customer rated Competitor 2 as superior for the need "once activated, remains permanently adhered".

Once the target values were developed, the correlation matrix (roof) was developed to determine the relationship of the company measures to one another. The team evaluated each company measure (how) by asking "if I optimize this 'how', does it help or hurt his 'how'". For our project, it was determined that optimizing lead pull force helped "visual test after activation" but hurt "probe transfer at X°F". The analysis of the roof leads to discussions about how to deal with conflicts. One option is to turn strong negative relationships into either strong positives, positives, neutrals, or at least negatives. These transformations are achieved by design or technology changes. Other options for dealing with roof conflict are to compromise by adjusting target value or ignore them. In our example, a compromise was achieved that was acceptable to the customer.

The final steps in the completion of the Phase 1 HOQ were determining the degree of organizational difficulty, and establishing the absolute and relative importance of each company measure. In our project, we found it would be difficult to achieve the target of 0 set for "number of splices per roll", but relatively easy to achieve the target set for lead pull force. Thus, the corresponding entries for organizational difficulty reflect this. The absolute importance weights were calculated by multiplying the degree of the importance of a need to the customer by a value assigned to the strength of the relationship between the need and measure. This is best illustrated by an example. Looking at our chart, lead pull force has a medium relationship (3-point weight) to customer need of "holds components without bridging" which has a 5-point weight of importance to the customer. 5 times 3 gives 15 points. Lead pull force also has medium relationship (3-point weight) to "good conformability around components" with a 5-point importance for another 15 points. Lead pull force is strongly related (9 points) to "once activated, remains adhered" which has a 5 point weight of importance to the customer for another 45 points. Finally, lead pull force has a weak (1-point) relationship to "holds components in place without burst through" which also has a high (5) customer importance ranking. This results in an additional 5 points for a grand total of 80 (15+15+45+5) for absolute importance. From the absolute importance, a relative importance can be calculated.

The importance ranking, in conjunction with other criteria, is used to determine which company measures should be deployed to Phase 2. In addition to highly ranked items, some of the other items to consider for further deployment include things that can be used as sales points, things that are new and different, things that are difficult to achieve (means that it is also difficult for the competition), things that will improve competitive position, things related to previous complaints, and in some cases, the team's gut instinct.

For our QFD project, Phase 2 and Phase 3 were combined into one as both material and process characteristics directly influence the end product characteristics. The choice to combine phases is project or process dependent. The first step in our combined Phase2/3 (Figure 5) was to enter the Phase 1 "hows" (company measures which were chosen based on factors described above), their targets, and importance ranking from Phase 1 into the second HOQ. These now become, instead of customer requirements, design requirements. At this point, the R and D team began the design work with the customer needs and established requirements foremost in their minds. The team used Design of Experiment to determine the best combination of ingredients and process conditions to achieve the objectives on the HOQ. Once the material and process parameters were optimized, the "how" section and the corresponding target values, and a measure of manufacturing difficulty were completed for the second house. The relationship matrix was completed in the same manner as the first house with the question being "if I control this process or ingredient parameter, how will it impact or satisfy the design requirement"? In our case, the control of several process and ingredient characteristics, such as coating weight, resin type, and resin level, was found to strongly impact the design criteria for lead pull force. The chart was analyzed for blank rows or blank columns to make sure all of the design requirements had a corresponding ingredient/process characteristic and that all of the ingredient/process characteristics were related to a design requirement. The team also performed a reality check to confirm that the ingredients and process characteristics were measurable and controllable.

Phase 4 of QFD is production planning. This is the step that translates the initial customer requirements to the shop floor, quality assurance, maintenance and other departmental work instructions. After the importance analysis of the Phase2/3 chart is complete, the selected ingredient/process characteristics, along with their target values, are entered into a fourth chart. The team then determines the systems, procedures, instructions, training, and control mechanisms that need to be put in place to ensure that the specified ingredient/process characteristics will be met. These are entered on the fourth chart (Figure 6). Phase 4 deployment will vary depending on specific company practices and systems;

however, the goal of ensuring that the voice of the customer is carried through to the operating personnel is the same for every company. In our example, coating weight, which related to lead pull force, was carried to Phase 4 and specific production requirements put in place. The appropriate process control instructions for the on-line weight control monitor were established, the troubleshooting guidelines updated, and a calibration schedule established. If a QFD project is done correctly, each control mechanism put in place in Phase 4 will be easily traceable back to an original customer requirement found in Phase 1. In this case, a specific calibration requirement can be traced back to the customer's spoken need ("once activated, remains permanently adhered") which was discovered during initial interviews.

Summary

Attaining higher levels of customer delight, increasing the speed and efficiency of the product development process, and increasing profits are goals that all of us strive to achieve while developing new products or improving current products. Intertape Polymer Group has found QFD to be a valuable tool to help quickly understand and integrate customers' needs into our products. The process affords IPG the ability to develop market-winning products by ensuring that all phases of product development are integrated together to satisfy the voice of the customer.

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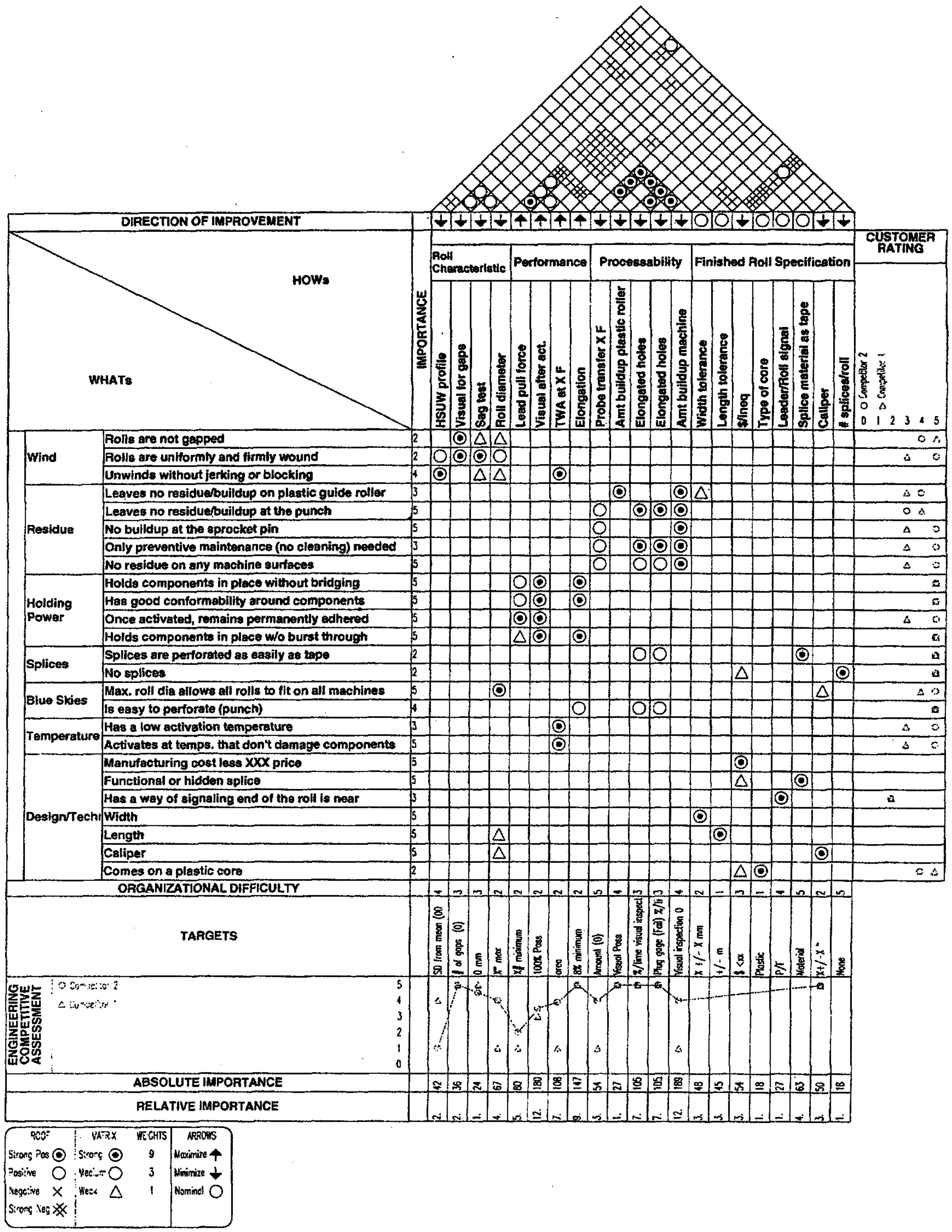

Figure 4. Phase 1 QFD Chart

Phase II and III Ingredients and Process Planning
January 4, 1999

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R. St. Coeur

Design Requirements / Material (Ingredients) Characteristics (Hows)		Customer Targets	Importance	Adhesive											Backing					Release coat		Slit/Pack		
				Coat wt. across web	Coat wt.	Roll length	Film condition (speed)	Resin type	Resin level	Adhesive type	Finished adhesive solids	Loop tack	Peel to ss	Shear	Elongation	Total Caliper	Caliper across web	Type	Basis weight	Type	Weight (w/barrier coat)	Winding tension	Core type	Splice construction
Roll Characte	Visual for gaps	# of gaps =0	3	◉	○												◉					◉	○	◉
Roll Characte	Roll diameter	X" max	2	△	◉	◉										○		△	○			◉		
Performance	Lead pull force	>X#	2		◉		○	◉	◉	◉		◉	◉	◉	△			○						
Performance	Visual after act. (bridging)	100% pass	2		○		○	◉	◉	◉		○	○	○	◉	△		○	△					
Performance	Elongation	X% min	2												◉	△		◉	△	△	△	△		
Processability	Amt buildup plastic roller	Visual pass	5																	◉	◉			
Processability	Elongated holes	Visual (0%)	3		○		○	◉	◉	◉		○	○	○										
Processability	Amt buildup machine	Visual (0)	4		○		○	◉	◉	◉		○	○	○						○	○			
Finished Roll Specification	Width tolerance	X+/-X	2																					
Finished Roll Specification	$/ineq	<$X conw	3		◉			○	○	○	○					○		○					○	
Finished Roll Specification	Leader/Roll signal	Present	4																				○	
Finished Roll Specification	Splice material as tape	Mat'l Desc.	5															△			△			◉
Finished Roll Specification	Caliper	X+/-X"	2	○	◉		○									◉	○	◉	◉		△			
Manufacturing Difficulty				4	2	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Part Characteristic Values				+/-X#/ream	X+/-X#/ream	As specified	X ypm max	X	Xphr	X	X+/-X%	X#/in	X#/in	X# >Xhrs	X% min	X min	Variance +/-X	X	X	X	X oz/yd2	X	X	X
How Importance				35	117	18	39	108	108	108	9	45	45	45	38	37	33	64	28	59	66	47	30	72

MATRIX	WEIGHTS
Strong ◉	9
Medium ○	3
Weak △	1

Figure 5. Phase 2 and 3 QFD Chart

Phase IV Production Planning
January 8, 1999

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R. Rawlings-Quinn
P. Rhude
R. St. Coeur

Material (Ingredients) Process Characteristics		Production Requirements	Part/Process Values	Accuracy WI B unit	Accuracy Recipe	In-Process Guide	Calibration	Formulation	C of A	Vendor Specification	QC Specification
	Adhesive	Coat wt. across web	+/- X#/ream	⊙	△	⊙					
	Adhesive	Coat wt.	X +/-X#/ream		⊙	⊙	⊙				
	Adhesive	Resin type	X					⊙	⊙		
	Adhesive	Resin level	X phr					⊙			
	Adhesive	Adhesive type	X					⊙			
	Adhesive	Loop tack	X#/in						⊙	⊙	
	Adhesive	Peel to ss	X#/in						⊙	⊙	
	Adhesive	Shear	X# >Xhrs						⊙	⊙	
	Backing	Type	X						⊙	⊙	⊙
	Backing	Elongation	X% min						⊙	⊙	⊙
	Release Coat	Type	X						⊙	⊙	
	Release Coat	Weight (w/barrier coat)	Xoz/yd2						⊙	⊙	

MATRIX		WEIGHTS
Strong	⊙	9
Medium	○	3
Weak	△	1

Figure 6. Phase 4 QFD Chart

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