Applying Quality Function Deployment in the Apparel Industry

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Abstract

Quality Function Deployment (QFD) is a product development tool used to ensure that the voice of the customer is heard and translated into products. This paper shows the applicability and usefulness of this product development tool in the apparel industry by developing an apparel example and taking it through the four matrices that encompass a QFD process.

Key words: Quality Function Deployment, product development tool, House of Quality, downstream matrices, voice of the customer, apparel, travel garments.

Introduction

Fibers, yarns, fabrics, apparel and other textile based finished goods are all "products" for whoever purchases these items, whether for further downstream processing or final use. Thus product development is being done at all stages of these related industries. One specific team-based planning tool that is useful to product developers is QFD, or Quality Function Deployment[1,2].

The use of QFD in a particular industry is often not well documented, as this tool imbeds within it, information that most companies define as proprietary, such as specifications, and process settings. It would not be prudent for a company to publicly disclose their customer requirements, as this provides competitors access to information that took considerable time, effort and money to acquire.

So it is not surprising that one does not see many direct references to the use of QFD in the apparel and related industries. Articles on quality award winners BASF (textile and leather dyes and chemicals) and Milliken (textiles) provide glimpses of the importance of QFD in these companies' success[3,4,5]. A good review of the QFD process (although without specific QFD matrices) is found in a paper on the development of a textile structure in response to a military call for proposals[6].

There are a few QFD references in the literature citing hypothetical examples or case studies for fibers[7], textile dyeing and finishing[8], textile mill equipment[9], and ergonomics of safety shoes[10]. One paper references a hypothetical apparel example in the context of recommending that QFD and product development be taught in textile and clothing college curricula[11].

Other references recommend QFD in the context of a discussion of total quality systems in the textile industry[6,12]. And while it has been stated that apparel firms have little direct interaction with consumers due to retail firms acting as a filter for that information[13], apparel firms could still be using

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QFD to interpret the voice of their customer, which is the retail firm. Thus it is hard to gauge the extent to which this product development tool is used in the apparel industry, though it has been recommended in the literature[11,13].

QFD provides a useful framework for understanding, planning, and documenting product development. It does this by using a multifunctional team to capture all the information necessary to design and manufacture a successful product.

The process that a project team goes through to organize this information also provides the basis for making decisions on what product features and benefits should be incorporated into the product. These decisions are a function of what customers want, balanced by the company's limitations or needs (e.g. the technologies available to them, the degree of risk they are willing to assume, the amount of capital they have to invest, time to market, and a variety of other factors).

QFD is a product development tool that uses a series of matrices to ensures the "voice of the customer" is not lost as plans for changing a product or making a new one proceed from concept generation to production start-up. There are two main approaches to developing these matrices, one, a four phase process developed by Akashi Fukuhara and taught by the American Supplier Institute[14], and the other an expanded set of matrices developed by Dr. Yogi Akao[1,15].

This paper will use the Fukuhara / ASI four phase process that:

- translates customer needs into product design requirements (called the House of Quality),
- translates product design requirements into part requirements (called the Parts Planning Matrix),
- translates part requirements into process or equipment design requirements (called the Process Planning Matrix), and
- translates process requirements into manufacturing operation requirements (called the Production Planning Matrix).

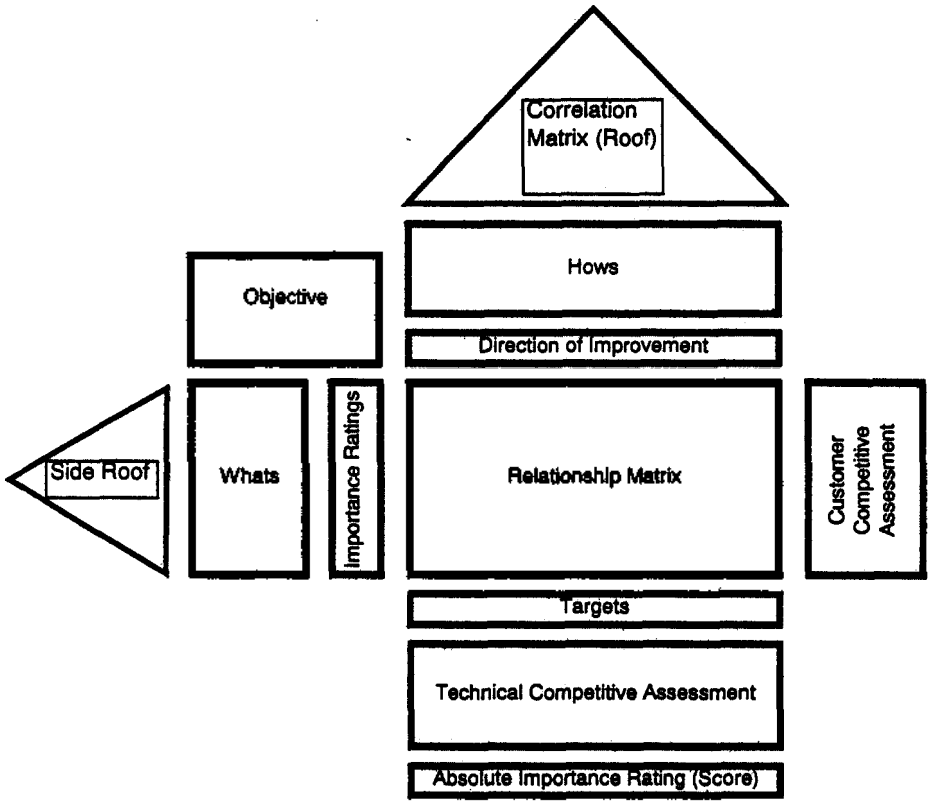
An Apparel Example

The first exposure to a full set of QFD matrices can be confusing. So to illustrate how QFD could be applied to the apparel industry, an apparel example has been developed and is discussed in the context of the part of the QFD process under review. The example assumes that an apparel firm would like to develop a line of women's clothing that might bring a higher profit margin than their current product line. They have noticed that more people travel, and would like to determine if they can market a line of clothing that has specific benefits and features that would cause women to buy it preferentially for travel.

Pilot data have been gathered on customer needs with their relative importance. A customer assessment of some garments currently marketed for travel was also piloted. Note that a larger number of women from a broader geographic area would have to be surveyed to statistically validate the pilot findings presented here. The purpose of this paper is to show the applicability of the QFD method to the apparel industry, not to focus on the data gathered.

House of Quality

The first matrix, or House of Quality, translates customer needs into product design requirements[2]. See Figure 1 for a basic framework. This matrix is called a "House" of Quality, because the information contained in it is organized into separate but connected "rooms". It provides the Product Developer with the information he needs to design a product with attributes that the customer wants. The matrix at it's simplest level is a list of the customer needs and wants, called WHATs down the left hand side, with the accompanying technical means of delivering



<Fig. 1> The basic framework for QFD House of quality showing component "Rooms".

those needs, called HOWs, across the top.

Most QFD efforts focus on the House of Quality. This step is critical, because it is the foundation on which the product is designed. The tasks include clearly defining the objective of the work, collecting and organizing customer needs and their relative importance to the target market, evaluating company products against competitive benchmarks, and translating customer needs into technical language. The next sections of the paper will review these rooms in detail.

House of Quality - Project Objective

The objective of the project must be stated as specifically as possible, so that the project team is in agreement with the objective, and clearly focused on only one task whose scope is clearly defined[2]. In the apparel example, the objective is determining the requirements for women's clothing to be purchased for a trip of four or more days. The objective is written just above the WHATs (see Fig. 1).

House of Quality - WHATs

The left hand "room" is a list of the customer needs for the product, in language used by the customer (thus the term, "voice of the customer"). These requirements are commonly called the WHATs. This section organizes the information collected in the first stage of the product development pro-

cess. It can be obtained in many ways, ranging from simple focus groups to very complex studies using sophisticated statistical methods of analysis.

The customer needs research for the apparel example was very straightforward. Women who traveled a minimum of 6 times per year on trips of 4 days or more for either work or pleasure were recruited. They participated in one-on-one interviews to develop the list of needs shown in 〈Table 1〉. The needs were grouped into categories called primary WHATs (easy to pack, easy to care for during travel, versatile, comfortable, and so on). The actual "voice of the customer" is in the second column in 〈Table 1〉. They are called the secondary WHATs.

There are several things to be aware of in conducting these kinds of customer needs studies. First, customers rarely tell you about basic requirements, such as "the garments are available in my size," "the dyes used in

<Table 1> Customer requirements and importance ratings for women's garments purchased for a trip of four or more consecutive days

PRIMARY WHATs	SECONDARY WHATs: the "Voice of the Customer"	IMPORTANCE RATING**
Easy to pack	Stays wrinkle-free in suitcase	4
	Takes up little space in suitcase	5
	Weight is light in suitcase	3
Easy to care for during travel	Can hand wash in hotel room	2
	Dries quickly when hand washed	1
	Stays wrinkle-free when hand washed	1
	Stays wrinkle-free when worn	4
Versatile	Can mix and match in several combinations	5
	Can use for business and casual events	5
	Modest enough for most cultures	4
Comfortable	Comfortable in hot environments	5
	Comfortable in cold environments	5
	Comfortable in both hot and cold environments	5
	Comfortable in windy environments	2
	Good fit: not binding	5
Security and organization	Provides secure place for valuables	2
	Helps me stay organized (e.g. pockets)	2
Purchase decision	Is a brand name I know and trust	1
	Can wear when not traveling - doesn't look travel specific	3
	Don't pay a premium for these benefits	3

** 5 = Must have, most important; 3 = is a medium consideration, is moderately important; and 1 = is not a consideration, not at all important.

the garments should not transfer to my skin," or "the seams are straight". They usually assume that the company knows this information. A QFD project team can draw attention to them in a House of Quality by adding a WHAT such as "basic safety features" and "basic workmanship standards". That way, the project team doesn't forget about them.

Second, customers can rarely tell you about new product ideas or features, because they just don't conceive of them. So, for example, customers might be very excited about a new garment that will "never absorb body odor - will always smell fresh". Yet it is unlikely that they would mention it spontaneously. These types of attributes are called "delight" or "excitement" features[1,2].

Third, a project team has to make sure they have thought about ALL of their customers as they put together this matrix. Especially with an industry like apparel that has a long supply chain, each supplier in the chain must think about the processing needs of all downstream operations as well as the final customer. For example, the manufacturer of a new "comfort fiber" would want to know that a person wearing a garment made out of the new fiber felt more comfortable. But the fiber manufacturer also has to be sure that the downstream fabric manufacturer can process the fiber, and the apparel manufacturer won't have difficulty sewing a fabric made with it. This can be handled in the House of Quality by having more than one "needs" section (in this example, user needs, garment manufacturer needs, and fabric manufacturer needs).

House of Quality - Importance Rating

The importance rating of the WHATs are found in a column to their right in the House of Quality (see Fig. 1). The reason for rating the importance of each customer need is to help the Product Developer and the project team understand which items are critical, and which could be traded off for other attributes or benefits.

For the customer needs identified in the apparel example, a questionnaire was developed, and women who travel for work or pleasure rated the importance of each. (Again note that a small sample size was used for this pilot study, so results may not be statistically valid.) They used a five point scale where 5 was equal to a "must have - most important" down to 1, which was equal to "not a consideration; not at all important". The results can be seen in 〈Table 1〉.

House of Quality - Side Roof

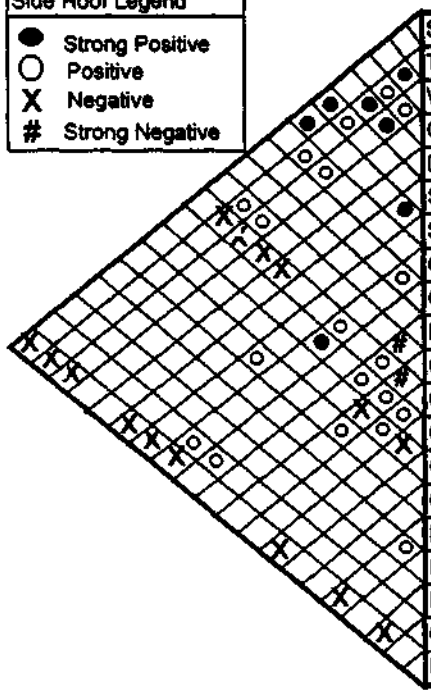
While the voice of the customer is often times loud, it does not always possess internal consistency. Some of the wants that customers have may be in direct competition with or opposite to others. They may be mutually exclusive.

In order for the QFD project team to make rational tradeoffs, they must first identify the areas of conflict or areas of mutual reinforcement among customer needs. QFD provides a methodology to identify, and therefore potentially remedy situations where conflicts result. While the method is potentially tedious, it ensures that each customer requirement is given due consideration and a reasoned evaluation. This is done by making a detailed comparison of each customer need against every other customer requirement. The analysis is documented in the Side Roof on the left of the WHATs in the House of Quality (Figure 1).

The Side Roof results for the apparel example can be seen in 〈Table 2〉. The symbolism used shows a filled circle is a strongly positive relationship, an open circle is a positive relationship, a blank is no relationship, an "X" is a negative relationship, and a "#" is a strongly negative relationship.

When a project team decides to focus it's product development activities on a specific problem, it will be important for them to consider all of the other customer needs that are

<Table 2> Customer WHATs, importance ratings and "Side Roof" for women's garments to be purchased for a trip of four or more consecutive days



Customer Requirement Relationship Matrix (Side Roof)	Customer Requirements (Whats)	Importance Rating
	Stays wrinkle-free in suitcase	4
	Takes up little space in suitcase	5
	Weight is light in suitcase	3
	Can hand wash in hotel room	2
	Dries quickly when hand washed	1
	Stays wrinkle-free when hand washed	1
	Stays wrinkle-free when worn	4
	Can mix and match in several combinations	5
	Can use for business and casual events	5
	Modest enough for most cultures	4
	Comfortable in hot environments	5
	Comfortable in cold environments	5
	Comfortable in both hot & cold environments	5
	Comfortable in windy environments	2
	Good fit; not binding	5
	Provides secure place for valuables	2
	Helps me stay organized (e.g. pockets)	2
	Is a brand name I know and trust	1
	Can wear when not traveling (appearance)	3
	Don't pay a premium for these benefits	3

related to this requirement, especially negative relationships.

For example, an analysis of the information found in the side roof of 〈Table 2〉, shows that "comfortable in cold environments" has a negative relationship with "takes up little space in the suitcase", "weight is light in suitcase", "can hand wash in hotel room", and "dries quickly when hand washed". It has a strongly negative relationship with "comfortable in hot environments". From the importance ratings, it is clear that customers find most of these features desirable and two to be MUSTs (rating equal to 5): "takes up little space in suitcase" and "comfortable in hot environments".

In this example, assume that the project team decides to focus on garments for cold environments in their first entry into this market. Therefore, they have to make a conscious decision on how to handle the negative relationships in the side roof. Assume that they decide to consciously ignore "comfortable in hot environments" for the time being, and will focus later on garments for hot environments once they can gauge their initial success in the marketplace.

Assume secondly that the QFD project team decides to specifically tackle the strong negative relationship between "comfortable in cold environments" and "takes up little space in suitcase". A logical product objective then, is to find a way to provide warmth without bulk. This is easier to address if the project

team has taken enough of the garment manufacturing process into their thought process. They can chose a specific fiber to provide this attribute (such as a "comfort fiber"), a fabric construction technique, or a specific garment style with less volume. They could consider offering layers and pieces to mix and match, or combinations of these solutions. They could even consider offering packing devices for "unbulking" bulky garments. At this point in the analysis, the team should not be narrowing in on solutions.

House of Quality - HOWs and Direction for Improvement

The next room of the "House" is the HOWs, though a customer assessment of products currently in the marketplace may be conducted first or concurrently. The HOWs translate customer needs into technical language. The format that is taken is to put the technical language into the form of tests that best provide empirical data directly measuring each WHAT. <Table 3> shows how some of the customer requirements in the apparel example can be described by technical tests.

These examples illustrate the point that the HOWs must be measurable. Some of the HOWs are based on a continuum, some are yes/no attributes, and some will require the development of a test method, such as

<Table 3> Matching customer requirements with technical language/tests for women's garments purchased for a trip of four or more consecutive days

WHATs: Customer Requirements	HOWs: Technical Tests That Predict Each Customer Requirement	Reference
Stays wrinkle-free in suitcase	Wrinkle recovery of Fabrics: AATCC Test Method 128-1994	16, pg. 213
Takes up little space in suitcase	Garment volume: cubic cm, compressed	
Weight is light in suitcase	Garment Weight: kg: modification of ASTM STM D3776-96	17, pg. 83
Can hand wash in hotel room	Garment Dimensional Change when washed: AATCC Test Method 150 (modified for hand washing)	16, pg. 264
Dries quickly when hand washed	Time to dry: hours	
Modest enough for most cultures	Develop survey to measure	
Can mix and match in several combinations	Garment colors (L,a,b) are same piece to piece: AATCC Valuation Procedure 6	16, pg. 369
Comfortable in cold environments	Fabric Clo value: ℃ m^2 hr /kg cal	18, pg. 17
Comfortable in windy environments	Fabric air permeability: ASTM STM D737-96	19, pg. 230
Provides secure place for valuables	Has a place for valuables: no/yes/number: develop test to determine ability of object to fall out or be removed	

determining if a garment is modest enough for most cultures.

Another feature of the House of Quality is the "Direction of Improvement" desired for each HOW where the directions are indicated by arrows pointing up (higher the better), down (lower the better), or by a circle containing a filled circle within it (indicating an optimum). This is shown in the row just above the HOWs and aides in developing the Relationship Matrix just below it (Fig. 1).

House of Quality - Relationship Matrix and Targets

The room at the center of the house (Fig. 1) is the Relationship Matrix between the WHATs and the HOWs. The relationship is established by asking

"Would this HOW be used to measure this WHAT?" or

"Can this HOW helps achieve this WHAT?"

Typically these relationships are designated as strong (worth nine points), medium (three points) or weak (one point). If there is no relationship, the matrix cell is left blank. The point system is designed to emphasize strong relationships. The weak relationship weighting is low enough that it can be used as an "argument breaker" when the experts who develop this matrix have differing judgements or conflicting data. Of course, the ideal would be to run experiments to confirm relationships that are in question.

When a WHAT is strongly related to a given HOW, that HOW should be used as a part of the product specification system to ensure that the customer is provided with the product they want. So one outcome of developing this room is a Target for each HOW, which is the row below the Relationship Matrix (Fig. 1).

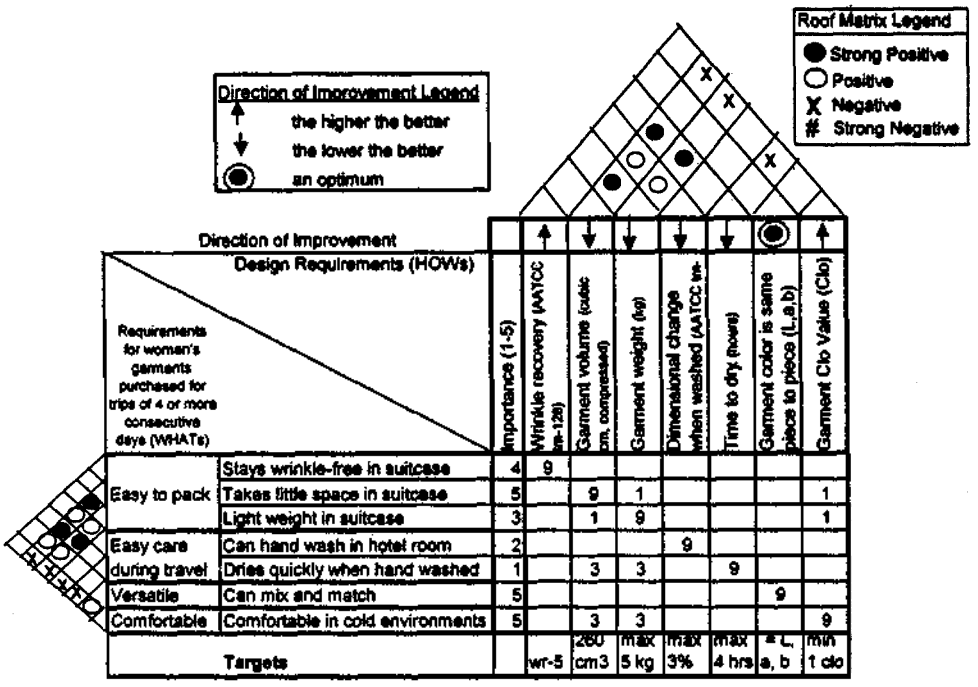
This is the basis for developing the product specifications.

An analysis of the relationship matrix reveals helpful information[14]. If a WHAT row shows no or only weak relationships with any of the HOWs, then the company takes a risk that it has no specification for a customer need. The higher the importance rating for that WHAT, the higher the risk that the company could disappoint the customer.

Conversely, if a HOW column shows no or only weak relationships with any of the WHATs, then a company is wasting valuable resources measuring something that has no relevance to the customer. (Note there are other reasons to create specifications besides the needs of the end-using customer, such as cost or the ability of downstream processes to convert materials. But as discussed earlier, these issues can also be incorporated into Houses of Quality and organized by segmenting the WHATs: user requirements, internal company requirements, converting requirements, etc. In the case of the apparel industry, this might be user requirements, logistics requirements, retailer requirements, etc.).

〈Fig. 2〉 shows all of the information discussed so far put together in one matrix. Note that only a portion of the WHATs and HOWs are used in this paper to show the applicability of the technique to the apparel industry. To show the full analysis would only add complexity that is not outweighed by the benefit of completeness.

The Relationship Matrix and the Targets for the HOWs can be seen in 〈Fig. 2〉. For example, "stays wrinkle-free" is strongly related to the AATCC Test Method for Wrinkle Recovery, so the relationship matrix shows a value of 9 in the intersection of those two items. The target wrinkle recovery value for the garment to be developed is wr-5, which, according to the AATCC Test Method is equivalent to no wrinkling[16]. At this point in the product development process, these targets represent an ideal based on what the project team would like to produce, not what they are capable of producing. This way, the voice of the customer is clearly heard without



<Fig. 2> Partial house of quality for women's garments to be purchased for a trip of four or more consecutive days.

being muffled by operational constraints.

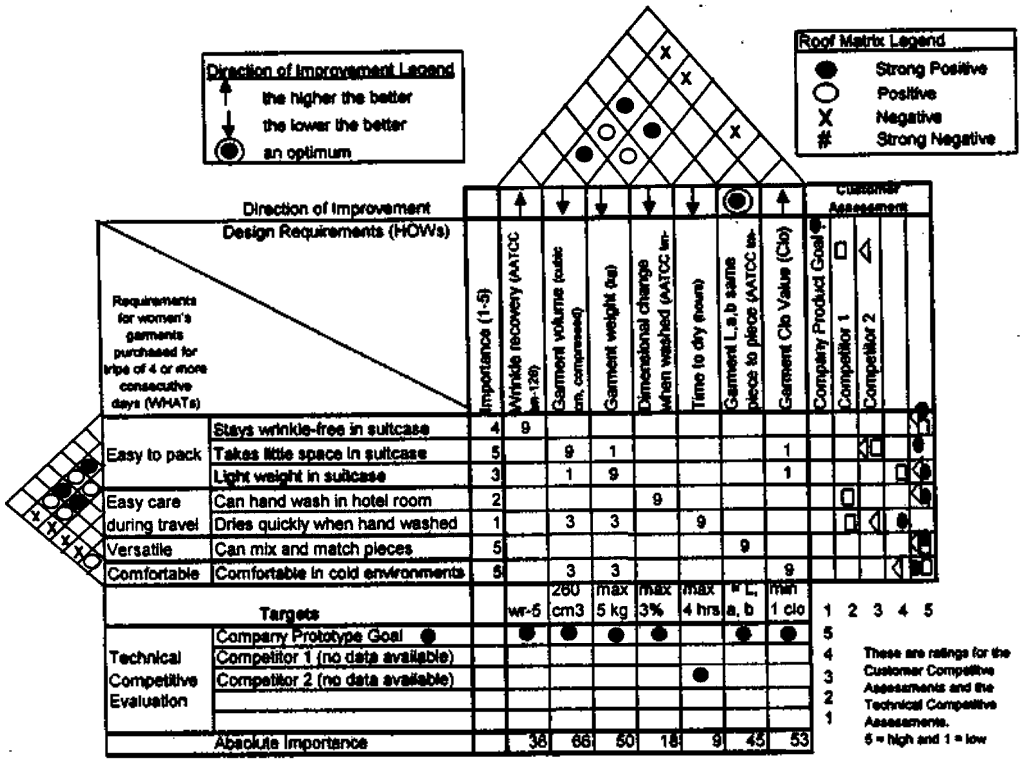
House of Quality - Correlation Matrix (Roof)

The next room to be developed is the Correlation Matrix or "roof". The roof shows negative or positive interactions between different HOWs. It uses the same symbols as the side roof. Negative interactions can cause the project team to make trade-offs in benefits. But they also indicate areas where it would be useful to do technology development.

Recall from the apparel example on the side roof in 〈Table 2〉, that "takes up little space in suitcase" had a negative correlation with "comfortable in cold environments". In 〈Fig. 2〉, these customer requirements (WHATs) translated into "garment volume" and "garment Clo value" for HOWs. The negative interaction between the two HOWs for these WHATs (seen as the highest "X" in the roof) confirms that same relationship. It shows the QFD project team that some means of increasing the warmth of a garment without increasing it's bulk for packing may provide a benefit that would be valued by the customer. Patents or new product ideas often come from solving these negative interactions.

House of Quality - Customer Competitive Assessment and Technical Competitive Assessment

There are two rooms of the "House" that show competitive evaluations. See 〈Fig. 3〉. To the right of the Relationship Matrix, is the Customer Competitive Assessment, which is an evaluation of the company's product versus competitive benchmarks based on con-



<Fig. 3> House of quality for women's garments to be purchased for a trip of four or more consecutive days.

sumer feedback. The Technical Competitive Assessment is an objective evaluation (physical or other objective testing) of the same products, and is located below the Targets on the House of Quality Matrix. The company product can be their current product, a new prototype(s), or a product goal indicating how well a new product must be evaluated against competitive benchmarks in order to be a viable entry into the market.

The Customer Competitive Assessment for the apparel example was generated by showing two catalog ads featuring travel garments to women from the target market. They were asked to evaluate the garments against the criteria developed as customer requirements, using the pictures and the ad copy. Each picture /ad copy combination was rated on a five point scale for each WHAT, with 5 being the highest rating and 1 being the lowest.

The results are shown in (Fig. 3) on the right-hand side of the matrix. The garments from competitor one are represented by a rectangle; competitor two is represented by a triangle. A prototype was not shown. Instead, the results are used to propose a company's goal product, represented by a filled oval. As an example, both competitive products were rated 5 (best possible rating) for "stays wrinkle-free in suitcase". Since that WHAT is fairly important (receiving a 4 on the Importance Rating column), it would be important for the company product to do as well as the competitive products on that WHAT, so the filled oval is shown in the box representing 5 for that customer rating. Note

that relative positioning within a box is not significant: the symbols were offset from each other so that they could be seen.

The Customer Competitive Assessments are especially helpful in determining where to put research efforts. If the company product is a bit worse than the competition on one attribute, but the importance rating of the attribute is not high; then it may not be cost effective to spend resources improving this attribute.

Extending this thought process to the apparel example where a product goal is being chosen, neither competitive benchmark does particularly well on "dries quickly when hand washed", receiving scores of 2 and 3 on the customer rating. But the importance rating of that feature is only a 1. So while the company product should do as well as or better than the benchmarks, the QFD project team should not trade-off other features to achieve it. Therefore it was positioned as requiring a 4 on the customer ratings as a goal.

On the other hand, if the company product is better than the competitive benchmark on an attribute that is especially valued by the customer but all products are poorly rated, it may be worthwhile to do even better on that attribute as a goal.

A comparison of the physical test evaluations in the Technical Competitive Assessment and the consumer evaluations in the Customer Competitive Assessment, will tell a QFD project team through the Relationship Matrix, if they have identified the right HOWs. If the physical measure shows that the company product is superior to the competition, yet the customer feedback says that the competition is better, then the HOW is not measuring that WHAT. Therefore the QFD project team will want to rethink the physical measure to be used for the product specifications.

For the apparel example, no data is entered for the Technical Competitive Assessment since no actual products were tested for this pilot study (Fig. 3, lower portion of the matrix). But again, the company product goal information is estimated which shows how well it must do to be a viable entry into the market. The rating system is the same as for the Customer Competitive Assessment, with each HOW being assessed on a 5 point scale, with 5 the highest rating a garment could receive on that physical test, and 1 the lowest.

House of Quality - Absolute Importance

The QFD project team can calculate the "absolute importance" of the HOWs and use them to determine the next steps in the product development effort. The absolute importance is derived for a given HOW by multiplying the relationship weighting by the importance rating for each cell and adding them. So, for example in ⟨Fig. 3⟩, under Wrinkle Recovery, $(9\times4) = 36$, and the value of 36 is entered in the bottom box in the row labeled Absolute Importance. Likewise, under Garment Clo value, $(1\times5) + (1\times3) + (9\times5) = 53$. The relative weightings of the HOW absolute importance give the QFD project team yet another clue on how to design the new product, by concentrating development efforts around the HOWs having the largest values.

Parts Planning Matrix

Some QFD project teams use just the information in the House of Quality to proceed without filling out any of the downstream matrices. If the risk of failure is low, this is prudent, since developing the other matrices does take time. However, if the risk is high (e.g., if the product is new to the company, if significant capital will be invested, or if a new process must be developed) then completing the downstream matrices is warranted. If the QFD process is continued, the next downstream matrix is the Parts Planning Matrix. A Parts Planning Matrix for the apparel example is presented in ⟨Fig. 4⟩.

Only the specific customer requirements

Design Requirements (What) \ Part Characteristics (How)		Importance (1-5)	fiber type	type of weave/knit	tightness of weave	fabric thickness	fabric weight	garment style	uniformity of fabric color
Design Criteria	Wrinkle recovery (AATCC tm-128)	2	9	9	3			3	
	Garment volume (cubic cm, compressed)	5		3	3	9		9	
	Garment weight (kg)	4		1	1	3	9	9	
	Time to dry (hours)	1	9		1	3	9	9	
	Garment L,a,b same piece to piece (AATCC tm-153)	3	3						9
	Garment Clo Value (Clo)	4			9	9	3	9	
Targets			washable; fine denier;	thermally warm non-wrinkling;small Z-direction profile	X yarns per square cm	X cm	X gm per square m	simple lines, not voluminous	less than X% difference piece to
Absolute Importance			27	37	62	96	57	132	27

<Fig. 4> Parts planning matrix for women's garments to be purchased for a trip of four or more consecutive days.

that need the most attention are taken to this next matrix, along with other customer requirements to which they are related. The HOWs from the House of Quality become the WHATs for the Parts Planning Matrix. It shows what parts or components are necessary to deliver the key elements of the product design that directly address the customer's needs. The team can use the absolute importance ratings of the HOWs in the House of Quality as a first cut on which ones should be used in the Parts Planning Matrix.

For the apparel example, 6 of the 7 HOWs from 〈Fig. 3〉 have been transferred to 〈Fig. 4〉 as WHATs. The absolute importance ratings in Figure 3 show that "garment volume" has the highest impact on the customer requirements in the House of Quality with a score of 66. The "time to dry" and "dimensional change when washed" have little impact overall, with scores of 9 and 18, respectively. Due to its low importance rating and the fact that it is not negatively correlated with any other HOW (Fig. 3, roof), "dimensional change when washed" was dropped from the downstream QFD process. This does not mean that the specification (target) related to that HOW is dropped, only that it is not high risk or important, and does not need to clutter up the downstream analyses. On the other hand, "time to dry" is retained in the Parts Planning Matrix (Fig. 4) even though it had a low absolute importance in the House of Quality because it is negatively correlated with "clo value" which is a feature of interest in the project (Fig. 3, roof).

When the 6 HOWs from 〈Fig. 3〉 are translated to WHATs in 〈Fig. 4〉, the overall importance ratings are normalized to a 1 to 5 scale. Thus relative positioning is maintained in the Parts Planning Matrix Importance Rating: "garment volume" has an importance rating of 5, while "time to dry" has an importance rating of 1.

The HOWs and Relationship Matrix for the

Parts Planning Matrix are developed much like those rooms in the House of Quality. For the apparel example, fiber type (HOW) was identified as having an impact on "wrinkle recovery", "time to dry", and "garment L, a, b is same piece to piece" (WHATs). Tightness of weave, fabric thickness, fabric weight, and garment style (HOWs) all impact garment Clo value (WHAT).

For an industry like apparel, the Parts Planning Matrix often defines the specifications for parts assembled into the final product, such as fiber type, weave, weight/m, and color of the fabric ordered from the fabric manufacturer, or the length, material, and color of the zipper from the zipper supplier. It provides the Supplier with the information he needs to produce parts that specifically meet the needs of the product customer. The apparel example shown in 〈Fig. 4〉 identifies seven key variables (HOWs) for this product, six of which will be locked in when the fabric is chosen (fiber, type of weave/knit, tightness of weave, fabric thickness, fabric weight, and uniformity of color). So in this example, the QFD project team would want to spend considerable time experimenting to define the fabric desired, and should work closely with the fabric supplier.

In many cases, the Parts Planning Matrix will show that a new part is required to be purchased or developed because the current one cannot achieve the targets required. The development of this new part may be difficult enough that the team will decide to transfer it to the next downstream matrix, the Process Planning Matrix, for further exploration[1].

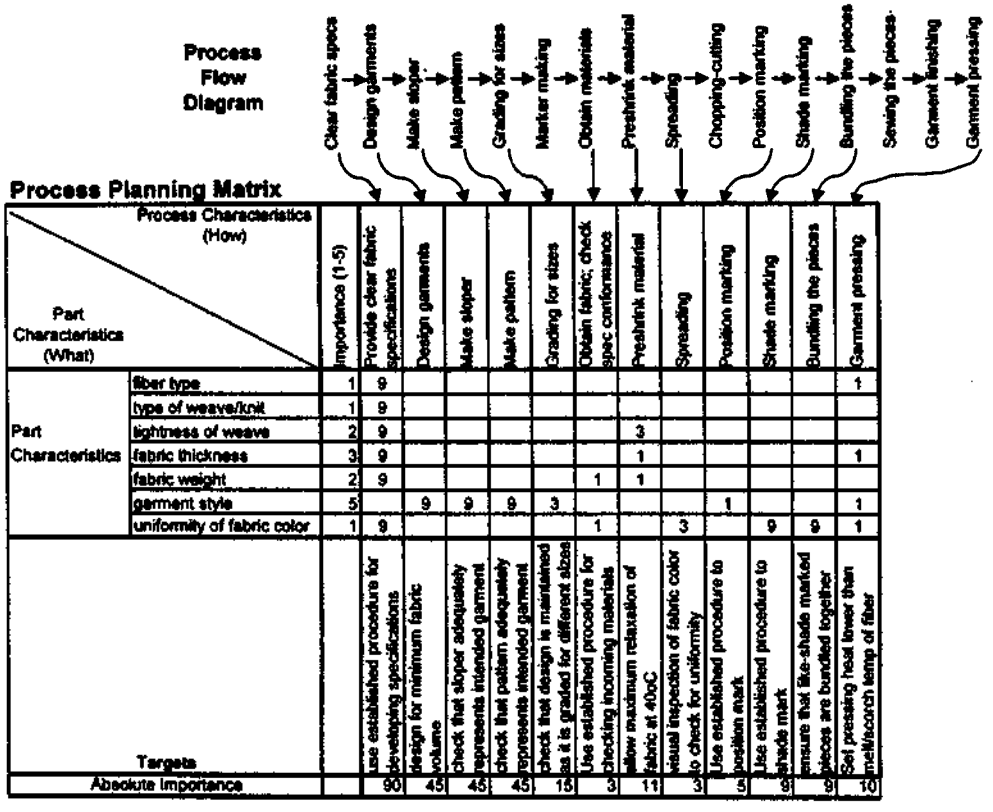
Process Planning Matrix

A Process Planning Matrix can be seen in 〈Fig. 5〉 for the apparel example. It translates the product/part requirements into the process or equipment design. Ordinarily, this is done only for those part requirements that are new to the organization, or known to be difficult to control[1]. It provides the Engineer with the information he needs to design the process or specify any new equipment that is necessary to produce the product or part. The HOWs from the Parts Planning Matrix (Fig. 4) become the WHATs for the Process Planning Matrix (Fig. 5).

During the development of the Process Planning Matrix, the QFD project team creates the process flow diagram, showing each step that is required to manufacture the product. The HOWs for the Process Planning Matrix are the process parameters listed in the process flow diagram that affect each WHAT or part requirement.

In the apparel example, all of the HOWs from the Parts Planning Matrix (Fig. 4) were transferred as WHATs for the Process Planning Matrix (Fig. 5). The absolute importance for the HOWs calculated in 〈Fig. 4〉, show garment style to be the key variable of interest, having a score of 132 compared to the next highest at 96. As these characteristics were transferred to become the Process Planning Matrix WHATs, they were normalized to a 1 to 5 scale so that their relative importance was maintained in the Importance Rating column to their right (Fig. 5).

The Process Flow Diagram for apparel production is shown above the Process Planning Matrix in 〈Fig. 5〉[20]. Ideally, the QFD project team would include more detail for each step[21]. (Note this and the next matrix were made up to show the applicability of the QFD process in the apparel industry, and do not reflect actual processes in a particular company.) The HOWs for the Process Planning Matrix are taken from the Process Flow Diagram (shown in 〈Fig. 5〉 by the arrows pointing from the flow diagram to the HOWs). Only those parts of the flow diagram that affect the WHATs are transferred. So, for the apparel example, the first five activities in the process (creating clear fabric specifications, designing the garments, making the sloper, making the pattern, and



<Fig. 5> Process flow diagram and process planning matrix for women's garments to be purchased for a trip of four or more consecutive days.

grading for sizes) affect the WHATs and were transferred to the HOWs. The next one, "marker making" did not, and so was not transferred to the HOWs.

Again, the relationship matrix is developed, which, in turn, is used to calculate an absolute importance for the HOWs using the importance rating for the WHATs as a multiplier. The composition of the team developing this relationship matrix would be more heavily skewed toward company engineers and operations personnel than earlier relationship matrices.

As was discussed before, the development of a clear specification for the fabric supplier is extremely important in the apparel exa mple, as much of the key product benefit is locked in when the fabric is chosen. This is verified by noting that the absolute importance in <Fig. 5> for "providing clear fabric specifications" is scored at 90, twice the amount of the next highest HOW of the process.

The Target section contains process centerline information for each parameter to achieve the product qualities desired[22]. It may also contain attribute checks (yes/no), or procedural checks measuring conformance to a standard operating procedure[1].

Production Planning Matrix

The Production Planning Matrix translates the equipment design into operations requirements. It gives information to Operations

Personnel on how to manufacture the product. HOWs from the Process Planning Matrix become the WHATs in the Production Planning Matrix. These could be the HOWs with high absolute importance ratings, or processes associated with new capital equipment, or other items of high risk as defined by the company. This is the final stage of the QFD process, where the voice of the customer meets technology and manufacturing. See 〈Fig. 6〉 for the apparel production planning matrix (made up as an example).

This matrix is organized somewhat differently from the prior matrices. It can include the important process requirements for a given process step, operational assessments of different types of risk, information on how the process should be controlled, preventative maintenance, and training information. This final matrix is highly customized to what the company wants to communicate to everyone in the organization down to the shop floor. Often the shop floor personnel are involved in the process of developing this matrix, leading to "ownership" of the result.

One specific section included in 〈Fig. 6〉 that is recommended in the literature[21], is the risk assessment of the process parameters. Typically this includes an assessment of the difficulty of controlling the parameter, the frequency with which the process parameter is likely to be out of control, the severity or consequences of that parameter being out of control, and the ability to detect when the process parameter has gone out of control. These are rated on a one to four scale (1 = little risk, 4 = severe risk) and multiplied to come up with a total risk score. Process parameters with high risk scores should be reviewed for ways to reduce the risk. For example in 〈Fig. 6〉, the Garment Pressing pressure requirement had the highest risk score of 256. The special note at the bottom of the matrix shows that a means of controlling the pressure with a sensor will be installed so as to reduce both the difficulty of

			Risk Assessment					Method to Control					Maintenance/Training Info				
Process Step	Key Process Requirement	Importance (1-5)	Difficulty of controlling	Frequency	Severity (Consequences)	Ability to detect	TOTAL RISK	Calibration	Checklist	Extensive operator training	Statistical Process Control	Supplier agreement	PM: times per month	Maintenance Instructions: SOP Number	Who to call in an emergency	Beeper number	Trainer for this Process
Provide clear fabric specifications	establish supplier partner relationships	5	4	1	4	1	80	yearly				X		#14			CEO
	gain agreement on key parameters	5	4	1	4	3	240					X		TBD			CEO
	purchasing dept issues PO with specs	1	2	1	4	1	8			X				#54	**Lisa	x4626	Lisa
Preshrink material	bring bath to 40oC: do not exceed	2	3	2	4	1	48	daily			X		2	#103	Mike	x4781	Mike
	leave fabric in bath for X minutes	2	1	1	2	1	4		X	X				#103	Mike	x4781	Susan
Garment pressing	set temp to a maximum of XoC	4	1	2	4	1	32	daily			X		4	#126	Jon	x4264	Jon
	Press for X seconds using light pressure	2	*4	2	4	*4	256	shift		X				#126	Jon	x4264	Susan
Special Notes	* Pressure control/sensor installed by 1/2000																
	**Lisa's back-up is Susan at x4033																
	All equipment is now Y2K compliant																

<Fig. 6> Production planning matrix for women's garments to be purchased for a trip of four or more consecutive days.

controlling the pressure and the ability to detect it when it is our of control.

Summary

This paper has shown the ability to apply QFD to the apparel industry. The whole QFD process does push the QFD project team to do detailed up-front planning. Apparel manufacturers may be concerned that this will lengthen the early stages of product development. However, QFD allows a reduction in the total time necessary to develop a product by one-third to one-half. This is accomplished by doing less redesigning in the latter stages of the product development cycle where redesign costs are typically much higher.

Other benefits seen by companies using QFD include improving communication among functions participating in the QFD process, less unscheduled down time and/or planned down time, improved product quality, lower start-up costs, lower capital costs, and more robust designs. It also provides greater operator involvement, improved relationships with equipment vendors, and documentation of the project that lives on after start-up to increase knowledge transfer for new personnel[22]. Most of these benefits should apply to the apparel industry as well. All of these benefits contribute to developing higher quality products delivered in shorter periods to the market place, which are concerns for all industries these days. This in turn, results in increased profitability and market share for the implementing company

References

1. Day, Ronald. 1993. *Quality Function Deployment: Linking a Company with Its Customers*, ASQC Quality Press, Milwaukee, Wisconsin.
2. Guinta, Lawrence and Nancy Praizler. 1993. *The QFD Book: The Team Approach to Solving Problems and Satisfying Customers through Quality Function Deployment*, AMACOM Books, New York.
3. Muller, Albrecht. 1995. "Applying Quality Management in Manufacturing at BASF," *Managing Service Quality* 5(2):33.
4. Caulkin, Simon. 1994. "The Road to Peerless Wigan," *Management Today* (Mar):28.
5. Jeanes, Clives. 1995. "Achieving and Exceeding Customer Satisfaction at Milliken," *Managing Service Quality* 5(4):6.
6. Rajamanickam, S. Park, and S. Jayaraman. 1998. "A Structured Methodology for the Design and Development of Textile Structures in a Concurrent Engineering Framework," *Journal of the Textile Institute* 89(part 3):44.
7. McLaughlin, Curtis and Jeffrey Stratman. 1997. "Improving the Quality of Corporate Technical Planning: Dynamic Analogues of QFD (Quality Function Deployment)," *R&D Management* 27(3):269.
8. Koksal, Guiser, and William Smith, Jr. 1990. *Quality Function Deployment: An Application Perspective for Textiles Dyeing and Finishing*, Institute of Textile Technology, July.
9. Temponi, Cecilia, John Yen, and W. Amos Tiao. 1999. "House of Quality: A Fuzzy Logicbased Requirements Analysis," *European Journal of Operational Research* 117:340.
10. Bergquist, Karin, and John Abeysekera. 1996. "Quality Function Deployment (QFD) - A Means for Developing Usable Products," *International Journal of Industrial Ergonomics* 18:269.
11. Hong, Kyunghi and Diane Scheurell. 1997. "Product Development Process for Clothing and Textiles," *Fiber Technology and Industry* 1(4):481.
12. Koksal, Gulser, William Smith Jr., and C. Brent Smith. 1992. "A System Analysis of Textile Operations: A Modern Approach for Meeting Customer Requirements," *Textile Chemist and Colorist* 24(10):30.
13. Little, Trevor, and Carol Carrere. 1992.

"Capturing Tomorrow's Customers," *Bobbin* 33(11): 86.

14. *Quality Function Deployment. 1989.* American Supplier Institute, Dearborn MI. Version 3.4.
15. Prasad, B. 1998. "Review of QFD and Related Deployment Techniques," *Journal of Manufacturing Systems* 17(3): 221.
16. *Technical Manual of the American Association of Textile Chemists and Colorists Volume 74,* Textile Chemist and Colorist, Research Triangle Park, NC. 1999.
17. *ASTM Standards, Section 7, Textiles 07.02,* American Society for Testing and Materials, West Conshohocken, PA. 1998.
18. Fourt, Lyman, and Norman Hollies. 1970. *Clothing Comfort and Function,* Marcel Dekker, Inc., New York.
19. *ASTM Standards, Section 7, Textiles 07.01.* American Society for Testing and Materials, West Conshohocken, PA. 1998.
20. Linton, G. 1973. *The Modern Textile and Apparel Dictionary, Fourth Ed.,* Bonn Industries, Plainfield, New Jersey.
21. Scheurell, D. 1992. "Taking QFD through to the Production Planning Matrix," Proceedings from the Fourth Annual Symposium on Quality Function Deployment, Novi MI. June.
22. Scheurell, D. 1994. "Beyond the QFD House of Quality: Using the Downstream Matrices," *World Class Design to Manufacture* 1(2): 13.