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Applying QFD in the Development of Sensible Brassiere for Middle Aged Women

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QFD(품질 기능 전개도)를 이용한 중년 여성의 감성 Brassiere 개발

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Abstract

Quality Function Deployment(QFD) is a product development tool which ensures that the voice of the customer needs is heard and translated into products. To develop a sensible brassiere for middle-aged women QFD was adopted. In this study the applicability and usefulness of QFD was examined through the engineering design process for a sensible brassiere for middle-aged women. The customer needs for the wear comfort of brassiere was made by one-on-one survey of 100 women who aged 30-40. The customer competitive assessment was generated by wearing tests of 10 commercial brassieres. The subjective assessment was conducted in the enviornmental chamber that was controlled at 28±1°C, 65±3%RH. As a results, we developed twenty-one customer needs and corresponding HOWs for the wear comfort of brassiere. The Customer Competitive Assessment was generated by wearing tests of commercial brassiere. The subjective measurement scale and dimension for the evaluation of sensible brassiere were extracted from factor analysis. Four factors were fitting, aesthetic property, pressure sensation, displacement of brassiere due to movement. The most critical design parameter was wire-related property and second one was stretchability of main material of brassiere. Also, wearing comfort of brassiere was affected by the interaction of initial stretchability of wing and support of strap. Engineering design process, QFD was applicable to the development of technical and aesthetic brassieres.

Key words: QFD, Customer needs, Technical language, Customer competitive assessment, Technical competitive assessment; 품질기능 전개도, 소비자 요구, 기술적 언어, 소비자 경쟁평가, 기술적 경쟁평가

I. Introduction

Textile industries that produce fibers, yarns, fabrics, garments and finished goods rely heavily on the ability to sell products that people want, yet there is no clear solution that covers the product development process in depth.

As a methodology of product development process, an engineering design process, QFD(Scheurell, 1994)was adopted to translate customer needs into product design requirements and manufacturing operation requirements. Design elements was ana-

lyzed and synthesized based on psychopysical results between design parameters and human response at each stage of design process.

Quality Function Deployment(QFD) is a product development tool which ensures that the voice of the customer needs is heard and translated into products. To develop a sensible brassiere for middle-aged women QFD was adopted. QFD provides a multifunctional team with information necessary to design and manufacture a successful product(Scheurell, 1994; Day, 1993). The process that a project team goes through to organize this information also provides the basis for making decision 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. In this study the applicability and usefulness of QFD was examined through the engineering design process for a sensible brassiere for middle-aged women.

II. Methodology

The customer needs for the wear comfort of brassiere was made by one-on-one survey of 100 women who aged 30-40. It carried out at the locker room of the swimming center in Taejon. Once, the customer needs identified called WHATs, a questionnaire for the importance rating of each customer need was conducted using thirty women to find which items are critical, and which could be traded off for other attributes or benefits. Some of the needs that customers have may be in direct competition with or opposition to others.

In order for the developer to make rational tradeoffs, we must first identify the area of conflict or area of mutual reinforcement among customer needs. A detailed comparison of each customer need against every other customer requirements was made by experts. The analysis was documented in the side roof on the left of the WHATs in the House of Quality.

HOWs were the translation of customer needs into technical language. The format that was taken was to put the technical language into the form of tests that best provide empirical data directly measuring each WHAT. The empirical data were obtained from the 3D shape measurement using the phase-shifting moire topography. Also, we could get the subjective responses by wearing test, mechanical properties using KES-FB system.

The relationship matrix between the WHATs and the HOWs was established by research team based on the collected data. These relationships were designated as strong(worth 9 points), medium(3 points), or weak(one point). When there was no relationship, the matrix cell was left blank. The next process to be developed was the correlation matrix between different HOWs. It used the same symbolism as the side roof. The customer competitive assessment was generated by wearing tests of 10 commercial brassieres. Middle-aged women who aged 30-40 were asked to evaluate the brassieres using the descriptors for customer requirements. Each 10 commercial brassieres were rated on a 7 point scale for WHAT, with 7 being the highest rating and 1 being the lowest. The enviornmental condition was controlled at 28±1°C, 65±3%RH.

III. Results

1. WHATs & Their Importance Rating

The consumer needs were grouped into categories called primary WHATs as shown in Table 1. Fit/reformability, aesthetic property, pressure sensation, displacement of brassiere due to movement were extracted by factor analysis. We included strap-related property, overall sensation and other miscellaneous properties along with the upper five categories. The actual voice of customers is in the second column in Table 1. They are called the secondary WHATs. As it can be seen consumers rated over 4 points in the following voices, which are "good stretchability", "shape of bra matches shape of breast", "wire is comfortable", "good overall wear comfort". There are several things to be aware of an conducting these kinds of customers needs studies. First, customers rarely tell you about basic requirement, such as "the brassieres are available in my

size" 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 WHATs such as "basic safety features" and "basic workmanship standards". That way, the project team doesn't forget about them. Second, customers rarely can tell about new ideas or features, because they just don't conceive of them. Customers might be very excited about a new brassiere. Yet it is unlikely that they would mention that. These types of attributes are called "delight" or "excitement" features. 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 with little vertical integration, 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 "stretchy fiber" would want to know that a person wearing a brassiere made out of the new fiber felt more supportable. But the fiber manufacturer also has to be sure that the downstream fabric manufacturer can process the fiber, and the brassiere manufacturer won't have difficult sewing a fabric made with it. This can be handled in the House of Quality by having more than one "needs" section(in this project, user needs, manufacturer needs). The importance rating of the WHATs are found in a column to their right in the house of Quality. 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 wear comfort of brassiere, a questionnaire was developed, and women who aged 30-40 were participated. They used a five point scale where 5 was equal to a "must

Table 1. Customer Needs and Important Ratings for Wear Comfort of Brassiere.

Primary WHATs	Secondary WHATs the "Voice of the Customer"	Importance Rating
Fit	Good Stretchability	4.04
	Shape of bra matches shape of breast	4.19
	Does not spill over	3.52
	Wire is comfortable	4.17
Reform shape of breast	Push breasts together	3.52
	Reduces breast vibration	2.96
	Volumes well up	3.70
Aesthetic properties	Sexy	2.56
	Design is beautiful	3.07
Pressure Sensation	Does not compress armpit	3.59
	Does not irritate at bra tape	3.22
	Does not compress breast	3.33
Displacement of bra due to movement	Does not slide up in front of bra	3.70
	Does not slide up in back & sides of bra	3.30
Strap-related Properties	Does not slide down strap of bra	3.52
	Strap is supportable	3.07
	Little compressed feeling on shoulder due to strap	3.26
Miscell.	Not warm & humid	2.81
Overall sensation	Good overall wear comfort	4.09
	Good tactile sensation	2.89
	High quality	2.63

have-most important" down to 1 equal to "not a consideration-not at all important". The results can be seen in (Table 1).

2. Side Roof

The analysis is documented in the side roof on the left of the WHATs in the House of Quality as shown in (Fig. 1). 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 opposition to others. They may be mutually exclusive. In other for the development team to make rational tradeoffs, they must first identify the areas of conflict or area of mutual reinforcement among customer needs. QFD provides a methodology to identify, and therefore potentially remedy situations where conflicts results. While the method is potentially tedious, it ensures that each customer requirement is given by 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. In the wear comfort of brassiere, the need for brassiere to be "volume up" may be in direct opposition to several other important customer requirements. If the project team decides to focus it's product development activities on providing sensible and comfortable brassiere, it will be important for them to consider all of the other customer needs like "does not compress breast", "wire is comfortable", "does not spill over" that are related to this requirement. The side roof results for the brassiere can be seen in (Fig. 1).

The symbolism used shows a filled circle is a strongly positive relationship, an open circle is a positive relationship, and a "#" is a strongly negative relationship. From an analysis of the information found in the "side roof" of (Fig. 1), it appears that

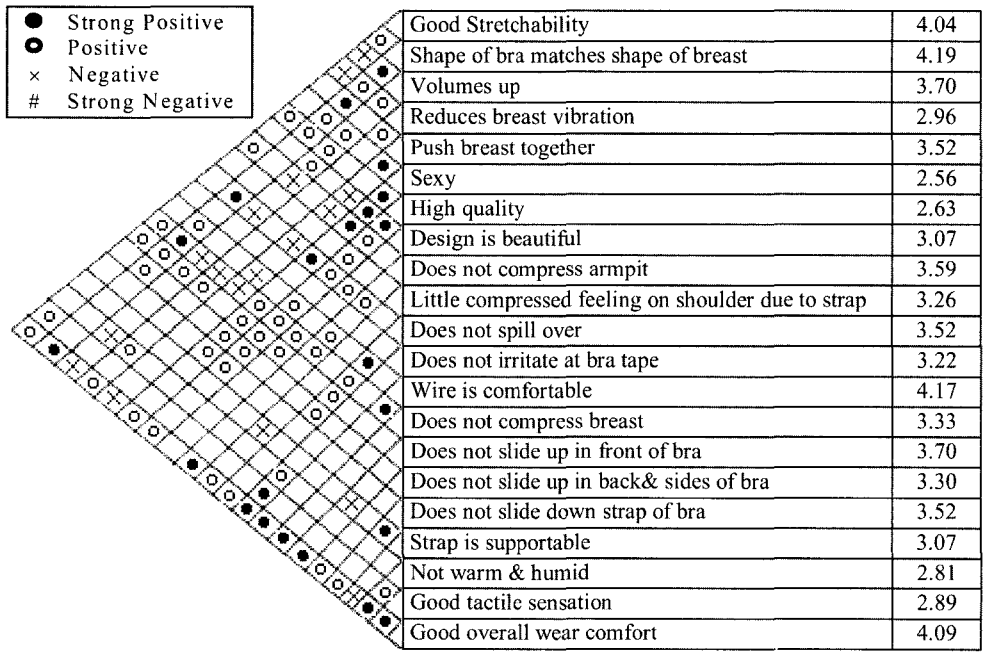

Fig. 1. Customer WHATs, Importance Ratings and "Side Roof" for Wear Comfort of Brassiere.

"push breasts together" has negative relationship with "good overall wear comfort", "does not compress breast", "does not spill over". Also "good stretchability" has negative relationship with "reduce breast vibration", "push breasts together". It has a positive relationship with "shape of bra matches shape of breast", "does not compress armpit", "does not compress breast", "good overall wear comfort", "shape of bra matches shape of breast" has strong positive relationship with "volume up", "push breasts together", "does not spill over". "does not compress breast", "good overall wear comfort".

From the important ratings, it is clear that customers find most of these features desirable and one to be a high consideration(rating equal to very important:4), "good stretchability", "shape of bra matches shape of breast", "wire is comfortable", "good overall wear comfort". In the brassiere example, our project team has decided to focus on "shape of bra matches shape of breast" and "wire is comfortable" in our first entry into the market and will focus later on brassiere for "volume up", "push breasts together".

A logical product objective is to find a way to provide comfort as well as aesthetic properties. This is easier to address if our project team has taken enough of the brassiere manufacturing process into our process. They can choose a specific fabric to provide this attribute(such as high stretchy or ultra supportable fabric) or a specific pattern with fit and reform. At this point in the analysis, the team should not be narrowing in on solutions, but identifying potential conflicts.

3. HOWs and Relationship matrix

<Table 2> shows how some of the customer require-

Table 2. Matching Customer Requirements with Technical Language/ Tests for Wear Comfort of Brassiere.

WHAT: Customer requirement	HOWs: Technical Tests
Good Stretchability	Tensile Property: Load cell(50kgf, Crosshead speed(100mm/min)
Shape of bra matches shape of breast	Measurement of volume & shape for breast, Pattern
Volume up	Analysis for shape of breast using 3D moire
Reduces breast vibration	Physical property of material, Measurement for vibration of breast by an accelerometer and a motion analyze
Push breast together	Analysis for shape of breast using 3D moire
Sexy	Subjective Assessment
High quality	Subjective Assessment
Design is beautiful	Subjective Assessment
Does not compress armpit	Measurement of pressure
Does not irritate at bra tape	Mechanical properties(KES-FB system)
Does not compress breast	Measurement of pressur
Does not slide up in front of bra	Wearing Test, Measurement of displacement
Does not slide up in back & sides of bra	Wearing Test, Measurement of displacement
Does not slide down strap of bra	Wearing Test, Measurement of displacement
Strap is supportable	Measurement of pressure
Little compressed feeling on shoulder due to strap	Measurement of pressure
Not warm & humid	Temperature & humidity of microclimate
Good overall wear comfort	Subjective Assessment
Good tactile sensation	Surface properties(KES-FB system)
Wire is comfortable	Measurement of pressure, Strain & stress analysis, Curvature analysis
Does not spill over	Analysis for shape of breast using 3D moire

ments in the wear comfort of brassiere can be described by technical tests. Some of HOWs require the development of a test method, such as determining low pressure sensation or aesthetic property. Basically, we could conduct a controlled wear test to find relationships between customer need and HOWs in terms of subjective evaluation. However, when any physical test method is available, we attempted a corresponding experiment. For example, curvatures of wires were measured and their relationship between the wearing comfort and the curvature of wires was examined . The results indicated that the brassiere with good wearing comfort had less change in the curvature of radius.

The relationship matrix and the target for the HOWs in the wear comfort of brassiere were illustrated in (Fig. 2). 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. We selected some of customer needs and conducted experiment to find relationships in detail. For example, stretchability of the main material of brassiere and wire-related properties were critical design parameters for the overall wear comfort(Kim, Lee & Hong, 2000). There were also negative relationships between overall wear comfort and the differences in skin temperature. As the level of pressure due to the wing of brassiere increased, blood pressure and skin temperature increased(Hong, Lee, Sung & Sohn, 2002). Reformability of the breast after wearing various brassieres was observed using phase-shifting moire topography. We could find significant difference the dimension of the width and height of breast depend-

Design Requirements (HOWs) / Requirements For Wear Comfort of Brassiere(WHATs)		Importance (1-5)	3D Moire Data	Mechanical Property (StrechabilityLT, WT)	Mechanical Property (Wire, Strap)	Subjective Assessment of Aesthetic Property	Physiological Property (EEG, HF, HRV)	Pattern	Measurement of Pressure
Customer Needs	Overall Wear Comfort	5		9	9		9		
	Fitting, Reformability	4	9						
	Displacement of Bra Due to Movement	2							
	Pressure Sensation	3					9	9	9
	Physiological Property	3					9	9	
	Aesthetic Property	3							
	Strap-related Property	2							
Targets									
Technical Competitive Evaluation									
Absolute Importance									

Fig. 2. Relationship Matrix.

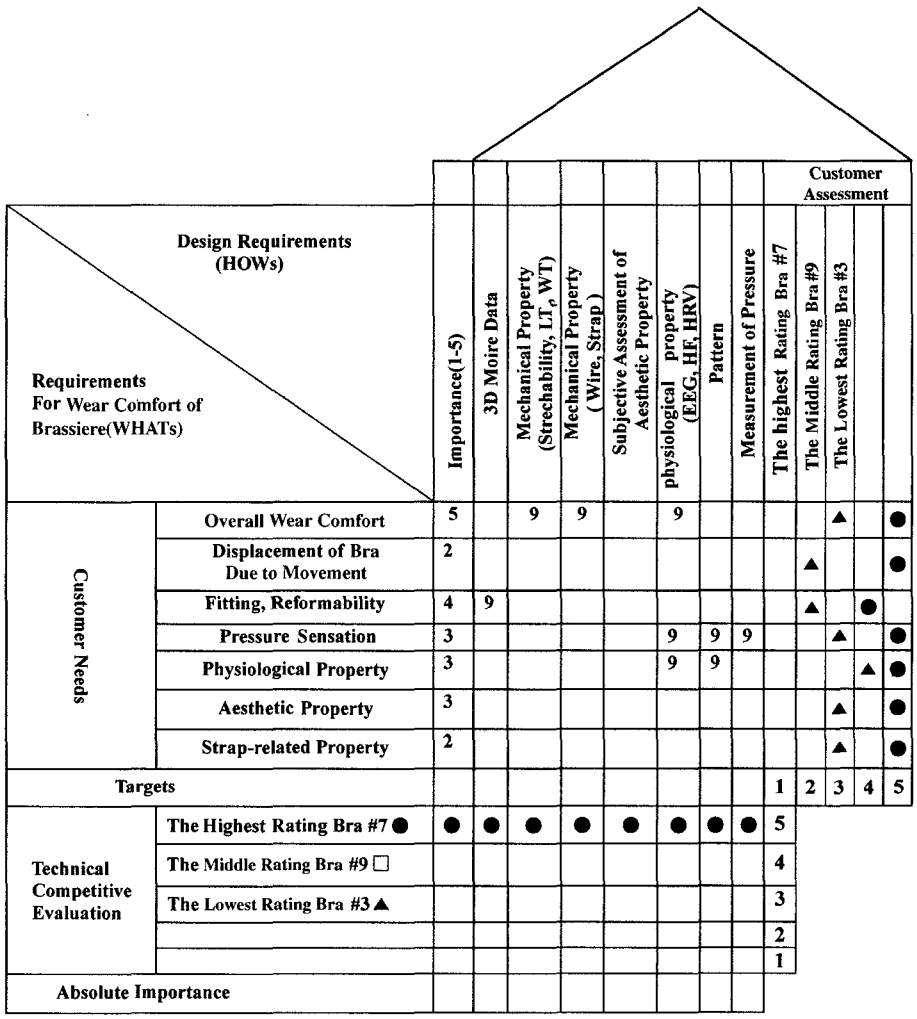

Fig. 3. House of Quality for Customer Competitive Assessment and Technical Competitive Assessment.

ing on the type of brassiere. Whenever we found a strong relationship between the customer needs and corresponding experiments, the value of 9 were given on the relationship matrix as shown in (Fig. 2).

When a WHAT is strongly related to a given HOW it should be used as a part of the product specification system to ensure that the customer is provide 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. This is the basis for developing the product specifications. The Relationship Matrix and the Target for the HOWs in the wear comfort of brassiere can be seen in <Fig. 3> Since "overall wear comfort" is strongly related to the mechanical property of main fabric, wire, strap and physiological property, the relationship matrix shows a value of 9 in the intersection of those two items.

Also, "pressure sensation", "physiological property" are strongly related to the physiological property and pattern, the relationship matrix shows a value of 9 in the intersection.

4. Correlation Matrix (Roof)

The roof shows where there are negative or posi-

tive interactions between different HOWs. They also indicate area where it would be useful to do technology development. Criteria for the selection of appropriate test methods and the direction of physical properties should be based on the absolute importance. More studies are required to figure out the correlation matrix on the roof. The next room to be developed is the Correlation Matrix or "roof". It used the same symbolism as the side roof. Places where there are negative interactions can cause the project team to make trade-offs in benefits.

Recall from the wear comfort of brassiere on the side roof in <Fig. 1>, that "does not compress breast" had a negative correlation with "volume up", "reduces breast vibration", "push breast together". In <Fig. 3>, these customer requirements(WHATs) translated into "pressure sensation" and "pressure measurement" for HOWs.

These negative interaction between the two HOWs for these WHATs (seen as the highest "x" in the roof) shows that it is useful to think about some means of increasing overall wear comfort of a brassiere, aesthetic property without increasing it's pressure.

Patents or new product ideas often come from solving these negative interactions.

5. Customer Competitive Assessment and Technical Competitive Assessment

The Customer Competitive Assessment was generated by wearing tests of commercial brassiere. The results are shown in <Fig. 3> on the right hand side of the matrix. In this chart, the results for the wear comfort of brassieres from the hightest rating bra was represented by a filled circle, while the middle rating one was represented by a rectangle, the lowest rating one was represented by a filled triangle. The highest rating brassiere(#7) was rated 5(best possible rating) for "overall wear comfort". Since that WHAT is the most important (receiving a 5 on the Importance Rating Column), it would be important for the company product to do on that WHAT, and so the filled circle is shown in the box representing 5 for that customer rating.

The Customer Competitive Assessments are especially helpful in determining where to put research efforts. If the company product is bit a worse than the competition on one attribute, but the customer rating of the attribute is not high, then it may not be cost effective to spend resources improving this attribute. Three brassieres rated high, middle, low in customer assessment coincided with the results by technical competitive evaluation. A comparison of the physical test evaluations in the Technical Competitive Assessment and the consumer evaluation in the Customer Competitive Assessment will tell a project team through the Relationship Matrix, whether they have identified the right HOWs.

IV. Conclusion

We developed twenty-one customer needs and corresponding HOWs for the wear comfort of brassiere. Customer Competitive Assessment is evaluation of the company's products versus competitive benchmarks based on consumer feedback. The Technical Competitive Assessment is an objective evaluation(physical testing) of the same product. The Customer Competitive Assessment was generated by Wearing tests of commercial brassiere. The subjective measurement scale and dimension for the evaluation of sensible brassiere were extracted from factor analysis. Four factors were fitting, aesthetic property, pressure sensation, displacement of brassiere due to movement. The most critical design parameter was wire-related property and second one was stretchability of main material of brassiere. Also, wearing comfort of brassiere was affected by the interaction of initial stretchability of wing and support of strap. Engineering design process, QFD was applicable to the development of technical and aesthetic brassieres. Design elements was analyzed and synthesized based on psychophysical results between design parameters and human response at each stage of design process. Various 3D measurement techniques using phase shifting moire topography was also developed to have more reliable 3D data for women's breast, which would be a valuable

DB for innerwear industry. However, the completion of the house of quality requires more DB. Refinement of measurement technique and standardization of test method are also necessary. As results, it is hoped that final products as well as engineering design process developed in this project would enhance the competitiveness of underwear industry.

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요 약

QFD(Quality Function Deployment: 품질기능 전개도)는 상품개발과정에서 소비자의 요구가 손실되지 않고 최종제품의 생산에 반영되고 시장에 투입되도록 고안된 상품개발 기술의 일종이다. 본 연구에서는 착용감이 우수한 brassiere를 개발하는 과정에서 필요한 모든 정보를 획득하기 위하여 소비자가 요구하는 제품속성과 이 제품속성을 제품 기능에 반영할 수 있는 구체적인 연구 방법론을 제시하기 위해 QFD를 이용하여 그 효율성과 타당성을 검토해 보고자 하였다. Brassiere 착용쾌적성에 대한 소비자 요구 조사를 위해 30-40대의 주부 100명에게 설문조사를 실시하였다. 소비자 요구들 중 중요 항목을 선정하기 위해 중요도 순위 조사를 5점 척도로 조사한 후, 소비자 요구 항목들은 기술적 언어로 전환되었다. 제품에 대한 소비자의 주관적 평가인 소비자 경쟁 평가를 위해 10가지 시판 brassiere에 대한 착용실험이 28±1°C, 65±3% RH로 조절되는 인공기후실에서 실시되었다. 소비자 경쟁 평가치는 기술적 경쟁 평가의 물리적 평가치와 비교함으로써, 적절한 기술적 언어를 발굴해 냈는가를 검증할 수 있었다. 결과적으로 쾌적성 있는 중년 여성의 brassiere를 개발하기 위해 도출된 소비자 요구는 종합적 착용 쾌적감, 맞음성-체형보정성, 움직임에 의한 브래지어의 위치 이동성, 압박감, 생리적 특성, 심미적 특성, 브래지어의 어깨끈 관련 특성 등 7가지로 나타났다. 이를 제품에 반영하기 위한 기술적 언어로는 3D측정 Data, 소재의 물리적 특성, 심미적 특성, 생리적 측정치, 패턴, 압력 측정치 등으로 도출되었다.