Developing Environmental Quality Deployment for Designing Environmentally Friendly Product

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Abstract

This study proposes Environmental Quality Deployment (EQD) by combining an instrument for measuring customer satisfaction (ENVIROQUAL) with a standard tool of product design in manufacturing called quality function deployment (QFD). The EQD presents the conceptual map of House of Environmental Quality as a means to implementation to help a company know what customers perceive as important in making environmentally friendly product and provide a framework for the translation of customer satisfaction into identifiable and measurable conformance specifications for environmentally friendly product design.

1. Introduction

Manufacturers and service providers are increasingly facing new challenges. They no longer design products as they perceive customers needs but also must integrate customers in reaching design decisions. Therefore, their decision-making authority is increasingly shared with their customers and other potential groups that can influence the survivability of their businesses. Manufacturers and service providers must, therefore, listen to the voices of their customers and use that vital information to produce goods and services that meet the needs and expectations of the customers.

Some ways that are used to listen to the voice of the customers include market surveys either through field experimentation or questionnaire designs. Hence, many companies include customer survey questionnaires as inserts when they package their products. These surveys are used to identify ways to better serve their customers. The responses obtained from the customer surveys, however, need to be analyzed to identify the critical factors that influence customer satisfaction. Such surveys are analyzed using statistical techniques. Statistical analysis provides information in this context as to which factors are significant in influencing customer satisfaction. Those factors become the basis for the company in deciding areas for continuous improvement or for design changes in order to continue to provide quality services to its customers.

In dealing with environmental quality issues, the company is faced with several interest groups notably customers, communities, regulators, employees, and others. The company has a responsibility to listen to the voices of these groups and develop ways of satisfying them. Some factors as well as standards that must be met may already be specified by regulators. Many others may not be clearly stated or obvious until a survey is done with the other interest groups. Statistical analysis helps in this case to identify the critical or significant factors that must be focused on. There are different statistical methods for analyzing survey information. This study, therefore, will not discuss the specifics because each survey is different and the application of statistics depends on its nature and construction. In this study, we assume that appropriate statistical methods have been applied and that critical factors to enable the organization achieve its environmental quality goals(called ENVIROQUAL) have been identified through those means.

The objectives of the study are to propose an approach called Environmental Quality Deployment(EQD) by combining a tool for measuring customer satisfaction (ENVIROQUAL) with a standard tool of product design in manufacturing called quality function deployment(QFD), to present the conceptual map of House of Environmental Quality as a means to implementation, and to help a company know what customers perceive as important in making environmentally friendly product and provide a framework for the translation of customer satisfaction into identifiable and measurable conformance specifications for environmentally friendly product design.

2. Quality Function Deployment(QFD) Revisited

In an effort to provide customer input at the product design stage, a process called quality function deployment(QFD) was developed in Japan and used extensively by Toyota and its suppliers. The process results in a matrix, referred to as a house of quality, for a particular product that relates customer attributes to engineering characteristics. The central idea of QFD is the brief that products should be designed to reflect customers desires and thus the quality related functions of a firm need to work together. The house of quality provides a framework for the translation of customer satisfaction into identifiable and measurable conformance specifications for product or service design(Behara and Chase 1993).

3. Building "House of Environmental Quality"

3.1 Environmental Quality Criteria

Environmental quality determinants identified by methods such as literature review, customer survey questionnaires and interviews. The statistical methods such as factor analysis can be applied to identify ENVIROQUAL instruments.

Suppose that through the customer survey and the application of statistics, seven important attributes have been identified that must be present in the products and services provided to customers in order to the manufacturer to satisfy their needs. These attributes are as follows:

Q1: product safety
Q2: price
Q3: low emission of pollutants
Q4: energy efficiency
Q5: recycled parts
Q6: ease of maintenance and recycling disposal
Q7: use of renewable materials

These attributes are self-explanatory. However, for clarity, I will briefly describe them. Q1 deals with product safety. The product should be used under normal circumstances without endangering the well being of the users or others. For example, a car whose breaks fail under normal usage will endanger the well-being of people and may lead to destruction of property. Q2 deals with the price of the product. The price should be reasonable and competitive. Q3 deals with low emission of pollutants. For example, a car that has a high emission of hydrocarbons and nitrogen oxides pollutes the environment. Q4 deals with energy efficiency. Most of the worlds supply of energy comes from nonrenewable resources such as gasoline, and its continued exploitation creates further pollution of the environment. Q5 deals with recycled parts. the use of recycled parts helps to conserve resources. Q6 deals with the ease of maintenance and recycling disposals. Consumers must be able to get quality maintenance and service of the product when needed. Also, it is not enough to design products that supposedly recyclable. Customers must also know how the product can be effectively disposed of at the end of its life so that it can be recycled. That is, there must be outlets for collecting expired products for recycling purposes. Q7 deals with renewable materials. Emphasis should be on the use of renewable products to

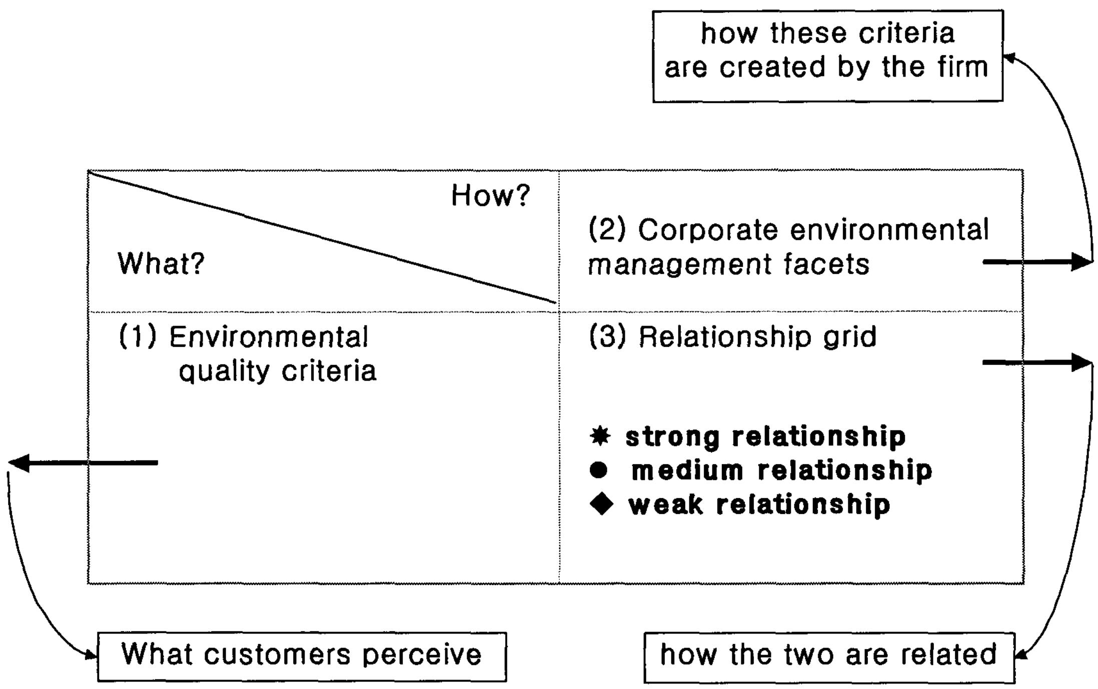

Figure 1: Environmental Quality Relationship Matrix

provide quality goods and services rather than on the use of nonrenewable materials.

3.2 Corporate Environmental Management Facets

The planning, procedures, and personnel aspects of the environmental management system can be identified through methods such as literature review, customer survey questionnaires and interviews.

Suppose that customer attributes have been translated into operating corporate actions, because the necessary actions needed to respond to each customer attribute must be identified. In this study, we assume that the following operational corporate actions have been identified:

A1: Work with suppliers on environmental issues.

A2: Encourage R&D to seek environmentally friendly or green products.

A3: Redesign manufacturing processes to reduce waste.

A4: Work with service delivery and distribution channels to reduce delivery wastes and environmental pollution.

A5: Establish internal environmental quality award program for suppliers, business units, and distributors.

A6: Educate employees, customers, and the community on the environment.

3.3 Relationship Grid

The strength of the relationship between environmental quality criteria and corporate environmental management facets is subjectively noted by symbols: strong relationship, medium relationship, and weak relationship.

3.4 Relative Importance ENVIROQUAL Scores

Ratings or rankings of ENVIROQUAL dimensions based on their levels of relative importance can be obtained by applying either the scoring system of 1 to 10 or AHP(Analytic Hierarchy Process) proposed in this study.

The attributes mentioned above are assumed that those identified by customers as the most critical by listening to the voices of the customers through questionnaires or the other survey methods and applying statistical analysis. However, to the customers, these attributes may have different priorities. They may not be viewed as equally important. We, therefore, need a structured means of ranking these factors based on their levels of importance. This is where the analytic hierarchy process(AHP) comes in. AHP is defined as a multicriteria decision model that uses hierarchic or network structure to represent a decision problem and then develops priorities for the alternatives based on the decision makers judgment throughout the system (Saaty 1987).

There are several advantages to the use of AHP(Madu and Madu 1993):

(1) AHP is based on a pairwise comparison of factors or attributes. This reduces the number of attributes that a customer will have to compare at a time, thus making it easier for the customer to be rational in his assessments.

(2) Both quantitative and qualitative information can be considered as factors in the AHP matrix.

(3) The quality of decisions reached can be measured through the consistency measure provided by AHP.

(4) Group decision making can be carried out, making it possible to reflect multiple opinions of the different interest groups.

Here, we have a goal, i.e., to satisfy customers needs and that goal is influenced by the seven attributes already mentioned. However, we want to be able to rank these attributes based on a priority scale. Suppose we create a square matrix and we ask the customers to conduct a pairwise comparison of these attributes and rate them in terms of

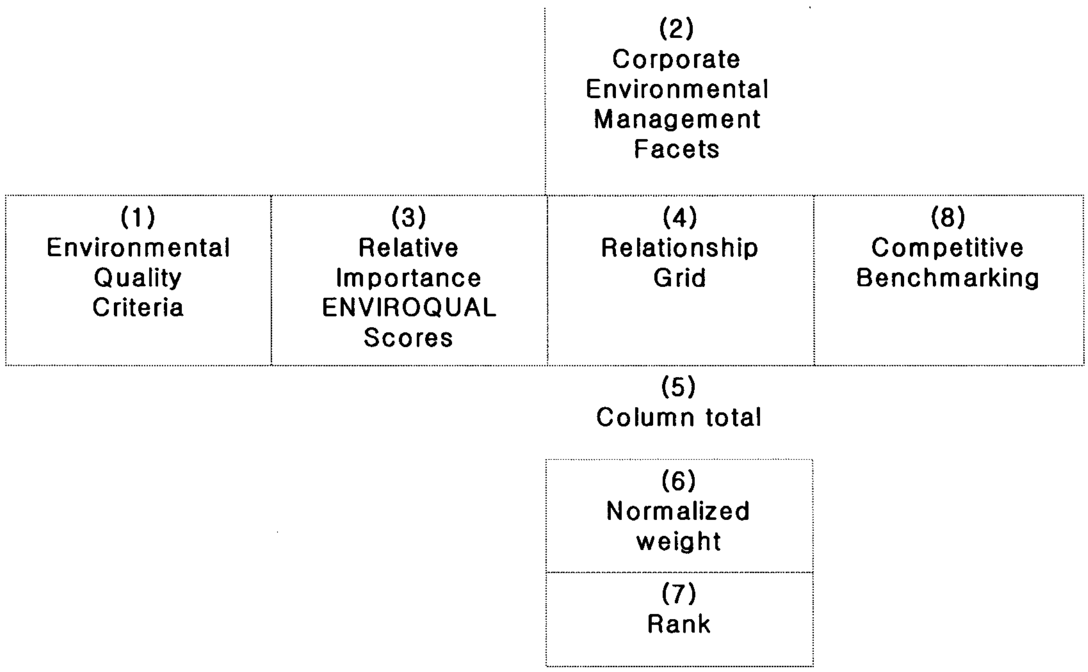

Figure 2: House of Environmental Quality

importance to achieving the specific goal. Then, we can get a set of matrices with customers respective rankings. There are different scales that can be used, but the following scales are commonly used:
1 = equal importance, 3 = moderate importance, 5 = strong importance, 7 = very strong importance, and 9 = extreme importance. the even numbers 2,4,6, and 8 are for compromise, while reciprocals are used to show inverse comparisons.

For example, we have a score of 3 when Q1 is compared to Q4, which implies that Q1 (product safety) is seen by the customer to have moderate importance over Q4 (energy efficiency). Other scores can be similarly interpreted.

The scores above table are for illustration purposes only. The scores may represent the score assignments of a single customer(e.g., EPA). However, multiple customers can be used. In this case, the geometric mean of their scores should be computed to reduce these matrices to a single matrix. The use of geometric means is necessary to preserve the reciprocal property of AHP(Aczel and Saaty 1983). The scores in the matrix can

Table 1: AHP Example

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Q1	1	1	4	3	2	5	2
Q2	1/1	1	4	4	2	5	2
Q3	1/4	1/4	1	1/2	1/2	2	1/4
Q4	1/3	1/4	2	1	1/2	4	1/3
Q5	1/2	1/2	2	2	1	4	1
Q6	1/5	1/5	1/2	1/4	1/4	1	1/4
Q7	1/2	1/2	4	3	1/1	4	1
total	3.783	3.7	17.5	13.75	7.25	25	6.83

be analyzed as follows to obtain the priority indices:

Step 1: Compute the column totals. The column totals for the exemplary table above are 3.783, 3.7, 17.5, 13.75, 7.25, 25, and 6.83, respectively.

Step 2: Divide each entry by its column total. For example, all the entries in column Q1 are divided by its column total of 3.783. the first entry in column Q1 is 1 and dividing it by 3.783 gives 0.264.

Step3: Take the average of each row. This average becomes the priority index and the sum of the priority indices for all the rows should be equal to 1. the following priority indices are, therefore, obtained: Q1=0.250, Q2=0.260, Q3=0.059, Q4=0.089, Q5=0.139, Q6=0.038, and Q7=0.165.

Based on the priority indices obtained for the seven attributes, we can conclude that Q2 (price) is perceived by the customer to be the most important attribute, followed by Q1 (product safety). Q6 (ease of maintenance and recycling disposal) is the least important attribute. The importance of these rankings is that it helps the manufacturer or service provider to know the major attributes on which to focus in order to satisfy customer needs. Moreover, since many business organizations have limited

Table 2: AHP Scores

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	total	average
Q1	0.264	0.270	0.229	0.218	0.276	0.200	0.293	1.750	0.250
Q2	0.264	0.270	0.229	0.291	0.276	0.200	0.293	1.823	0.260
Q3	0.066	0.068	0.057	0.036	0.069	0.080	0.037	0.413	0.059
Q4	0.088	0.068	0.114	0.073	0.069	0.160	0.049	0.620	0.089
Q5	0.132	0.135	0.114	0.145	0.138	0.160	0.146	0.971	0.139
Q6	0.053	0.054	0.029	0.018	0.034	0.040	0.037	0.265	0.038
Q7	0.132	0.135	0.229	0.218	0.138	0.160	0.146	1.158	0.165
									1.000

resources, they may not be able to pursue all the attributes identified by the customers at the same time. therefore, they can redistribute their resources to focus more on those attributes that are considered to be more important.

3.5 Relationship Grid

Customer attributes(ENVIROQUAL) are listed in row form, while corporate environmental management facets are listed in column form. In relationship grid, we evaluated the interrelationship between customer attributes and corporate environmental management facets and use the symbols to represent the correlation between them. Now, we will quantify the symbols according to the scale: strong relationship(9), medium(3), weak(1). For example, in our example, the interrelationship between them is assumed to be the following.

3.6 Column Total

Once the correlation between customer attributes(ENVIROQUAL) and corporate environmental management facets have been determined, the next step is to compute the total scores for each column attribute. They are calculated as

Table 4: Column Total

ranking		A1	A2	A3	A4	A5	A6	
0.250	Q1	1	9	9		9	9	
0.260	Q2	9	9	9	9			
0.059	Q3	9	9	3	1	9	9	
0.089	Q4	1	9	3		9	9	
0.139	Q5	1	9	3		9	3	
0.038	Q6			3	3	9	9	
0.165	Q7	9	9	3		9	3	
	column total	4.841	8.660	6.062	2.516	6.657	4.831	33.566

Table 3: Interrelationship Scores

	A1	A2	A3	A4	A5	A6
Q1	1	9	9		9	9
Q2	9	9	9	9		
Q3	9	9	3	1	9	9
Q4	1	9	3		9	9
Q5	1	9	3		9	3
Q6			3	3	9	9
Q7	9	9	3		9	3

Column Total =

(Relative importance ENVIROQUAL ranking * Correlation)

For example, the column total for A1 is computed as
[(0.250*1) + (0.260*9) + (0.059*9) + (0.089*1) + (0.139*1) + (0.038*0) + (0.165*9)] = 4.841.

3.7 Normalize Weight

Normalize the scores by finding the ratio of each column total to the sum of all column totals. Thus, the normalized score for column A1 is 4.841 / 33.566 = 14.42%.

Table 5 : Rank

	A1	A2	A3	A4	A5	A6	total
column total	4.841	8.660	6.062	2.516	6.657	4.831	33.566
normalized weight	14.42%	25.80%	18.06%	7.50%	19.83%	14.39%	
rank	4	1	3	6	2	5	

3.8 Rank

Rank corporate environmental management facets using the normalized weights. Therefore, the most important corporate environmental management facet in order to meet customers needs will be A2, which is to encourage R&D to develop environmentally friendly products. This facet is followed by A5, which deals with the establishment of award programs for environmental quality.

3.9 Competitive Benchmarking

Customers can compare a company's product to that of its competitors and position on a scale where the company falls. For example, if we assume that the present company is A and its primary competitor is Company B, then on a scale of 1 to 5 where 1 is the worst and 5 is the best Company A does better than Company B only in terms of price(Q2) but is worse off in all the other six customer attributes (ENVIROQUAL).

In terms of corporate environmental management facets, Company A does better than Company B only in terms of A4, which is to work with service delivery and distribution channels. Clearly, the present company is lagging behind its major competitor in many respects. Company A may, therefore, want to benchmark its competitor or surpass its competitor by stating new target values. These target values can be used to achieve some qualitative objectives. For example, an automaker wants to improve the energy efficiency of its compact car and states a target value of 30 miles per gallon of gasoline. However, the target value used here is in terms of rating in a scale of 1 to 5 on corporate environmental management facets. for example, a target to obtain a rating of 5 in R&D efforts to develop green products is similar to saying that Company A wants to be a leader in its industry in providing innovative green products to its customers.

Table 6: Competitive Benchmarking

	1	2	3	4	5
Q1			A	B	
Q2	B	A			
Q3		A	B		
Q4		A	B		
Q5			A	B	
Q6		A	B		
Q7			A	B	

4. Conclusion

QFD helps a company to achieve focus. The company is able to identify its customers environmental quality needs, develop a plan in terms of corporate environmental management facets to achieve those needs, and compare itself to its competitors. This helps the company to better satisfy its customers by producing the products and services that indeed meet their needs and by doing so, the company is able to compete effectively in the marketplace.

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