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RESEARCH ARTICLE

DESIGN OPTIMIZATION WITH ENTROPY USING QFD

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ABSTRACT

The awareness about the environment is increasing in customer segment day by day, which is one of the main reasons that the manufacturers are focusing towards the environment impact in their product. Now a day's customers are demanding the product which has less impact on environment. To integrate the requirement of the customer towards the environment a methodology is proposed in this research paper which combines voice of customer to the Green Quality Function deployment (GQFD). The specifications required by the customers in a product coupled with multiple criteria's are taken for optimization using Multi Criteria Decision Making (MCDM) techniques driven by Entropy.

INTRODUCTION

For the product conceptualization, careful attentions must be paid towards the requirement of the customer in order to compete in the globalized environment so as to develop the product successful. The trend is shifting towards environment friendly product; therefore the manufacturers are focusing on the environmental impact of industrial activities on the product. To develop an environment sound product which fulfills the customer requirement we must focus on the factors which lead to environmental degradation. In this research paper an approach is considered to generate a concept for designing a product with the tradeoff between Green Quality Function Deployment and Multi Criteria Decision Making. The weight for each criteria used for designing a product is calculated by Entropy method.

Entropy

According to the degree of index dispersion, the weight of all indicators is calculated by information entropy. Suppose we have a decision matrix B with *m* alternatives and *n* indicators:

Step 1: In matrix B, feature weight P_{ij} is of the j^{th} alternatives to the j^{th} factor:

$$p_{ij} = X_{ij} \Big/ \sum_{i-1}^{m} X_{ij} \qquad (1 \le i \le m, 1 \le j \le n)$$

Step 2: The output entropy e_j of the j^{th} factor becomes

$$e_j = -k \sum_{i=1}^{m} p_{ij}\, In\, p_{ij} \qquad (k = 1/In\, m; 1 \le j \le n)$$

Step 3: Variation coefficient of the j^{th} factor: g_j can be defined by the following equation:

$$d_j = 1 - e_j \qquad (1 \le j \le n)$$

Step 4: Calculate the weight of entropy w_j:

$$w_j = g_j \Big/ \sum_{j=1}^{m} g_j \qquad (1 \le j \le n)$$

Quality Function Deployment

To develop a successful product in today's competitive and globalize environment, customer requirements need to be

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carefully considered during product conceptualization. For this purpose, Quality Function Deployment (QFD) has been widely studied and applied to better understand and utilize customer needs in new product development. Quality Function Deployment (QFD) is "an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of the product development and production".

the product. A MCDM problem can be expressed in matrix format as:

$$D = \begin{matrix} * \\ A1 \\ A2 \\ A3 \\ \vdots \\ Am \end{matrix} \begin{bmatrix} C1 & C2 & C3 & \cdots & Cn \\ x11 & x12 & x13 & \cdots & x1n \\ x21 & x22 & x23 & \cdots & x2n \\ x31 & x32 & x33 & \cdots & x3n \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ xm1 & xm2 & xm3 & \cdots & xmn \end{bmatrix}$$

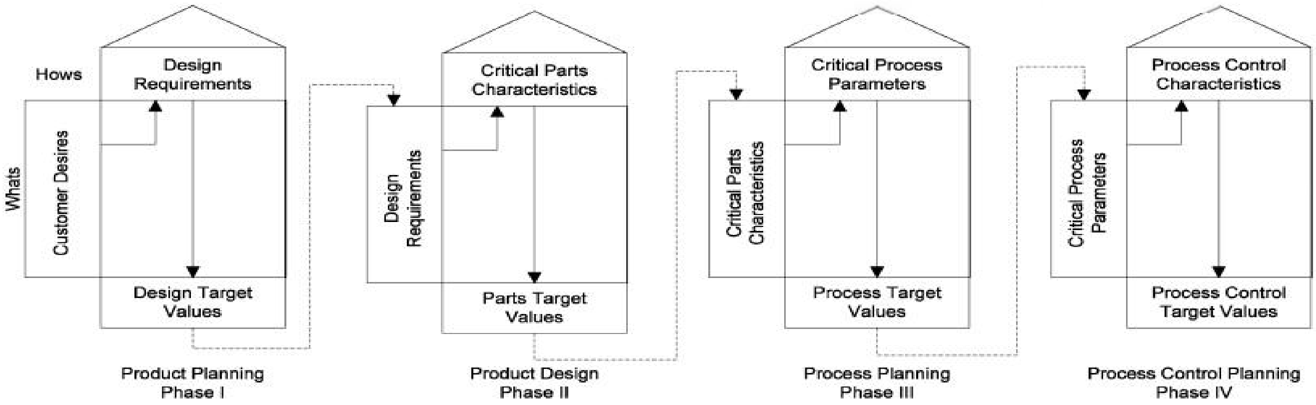

Figure1 Process of QFD

Quality Function Deployment

Among the eco-design practices, some of them are adapted from methods and tools already available in new product development body of knowledge. One of methods and tools that have emerged in the literature is QFD (quality function deployment). There have been a large number of publications on 'environmental QFD' in the past ten years when compared to other methods and tools. One of the main advantages of using QFD in eco-design is the possibility to consider environmental requirements when developing a new product by translating those requirements into design specifications (MASUI, SAKAO, INABA, 2001).

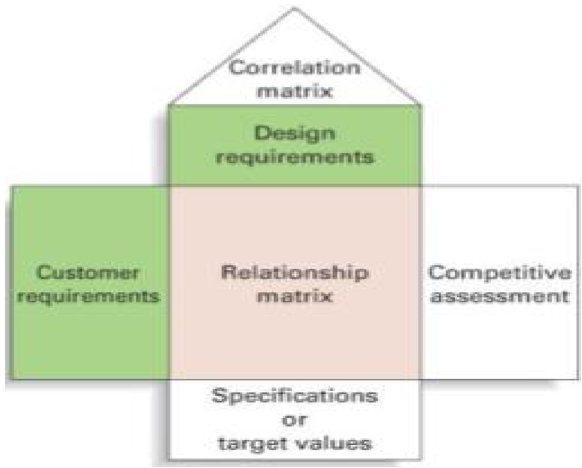

Figure 2 house of quality

Multi Criteria Decision Making

To find out the best quantitative solution from the alternatives, multi criteria decision making process provides ranking solution of the alternatives to select the best alternatives. In this research paper we applied entropy method because it is highly reliable for information measurement and provide high accuracy in determination of weight of the feature attribute of

$$W = [w1 \quad w2 \quad w3 \quad \ldots \quad wn]$$

Where *A1*, *A2*, *A3* ...., *Am* are possible alternatives among which decision makers have to choose, *C1*, *C2*, *C3*, ..., *Cn* are criteria with which alternatives performance are measured, *xij* is the performance value of alternatives *Ai* with respect to criterion *Cj*, *wj* is the weight of criterion *Cj*.

METHODOLOGY

In this research paper various specifications are taken for Air Conditioners of different brand. Entropy methodology is used to find the weight of individual attribute. These weights are used to integrate multi criteria decision making techniques with green quality function deployment. The mathematical model of this integration is as follows:

In Table 5, the highest rank is obtained by brand3 whose specifications are almost nadir to ideal solution. Therefore considering the specification of this brand and trading off with the voice of customer in order to develop the new product using green house of quality.

RESULT AND DISCUSSION

When the obtained ideal solution is blended with QFD (Figure 3), the organizational difficulty measured is 628, whereas the organizational difficulty obtained in G-QFD (Figure 4) is 240, which clearly indicates that in order to develop the product which is user friendly as well as sound for the environment, the overall processing from raw material to converting it into finish good should be green as shown in G-QFD. This approach can be utilized in order to develop an environment sound product for target customers or for a particular segment by the help of what-if analysis.

Table 1 Specifications of various attribute

Brand	Specifications									
Bi	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
B1	14490	0.75	3	9.57	500	39	893	4	10	3195000
B2	14000	0.9	1	9.28	410	28	970	4.3	8.6	38342850
B3	23500	1.2	5	10.78	510	38	1290	6	9	43358000
B4	14800	0.75	3	9.71	543	35	930	4.3	7	36351452
B5	14800	0.8	3	9.81	450	35	940	4.1	7	34157760
B6	17990	0.75	3	9.7	346	39	890	4	9	53992200
B7	16000	0.75	3	9.88	450	50	912	4.1	7	45472000
B8	15740	0.8	3	9.88	450	34	899	4	10	45472000
B9	15000	0.8	2	9.13	450	29	920	4.1	8	33079200
B10	19990	0.75	3	2.93	285	41	910	4.1	8.5	39136260
B11	13900	0.8	3	9.54	450	35	940	3.9	9	41277500

Table 2 Normalization matrix

Brand	Specifications									
Bi	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
B1	-0.2027	-0.2064	-0.222	-0.2243	-0.2344	-0.226	-0.2097	-0.21	-0.2396	-0.1897
B2	-0.1985	-0.2295	-0.1084	-0.2203	-0.2089	-0.1853	-0.2201	-0.2191	-0.2201	-0.2119
B3	-0.2656	-0.2679	-0.2901	-0.2399	-0.237	-0.2227	-0.2576	-0.263	-0.2259	-0.2276
B4	-0.2052	-0.2064	-0.222	-0.2262	-0.2453	-0.2122	-0.2147	-0.2191	-0.1946	-0.2053
B5	-0.2052	-0.2144	-0.222	-0.2275	-0.2208	-0.2122	-0.2162	-0.213	-0.1946	-0.1977
B6	-0.23	-0.2064	-0.222	-0.226	-0.1885	-0.226	-0.2092	-0.21	-0.2259	-0.2566
B7	-0.215	-0.2064	-0.222	-0.2284	-0.2208	-0.259	-0.2123	-0.213	-0.1946	-0.2338
B8	-0.2129	-0.2144	-0.222	-0.2284	-0.2208	-0.2087	-0.2106	-0.21	-0.2396	-0.2338
B9	-0.2069	-0.2144	-0.1733	-0.2183	-0.2208	-0.1894	-0.2134	-0.213	-0.2108	-0.1939
B10	-0.2439	-0.2064	-0.1084	-0.0169	-0.1666	-0.2325	-0.212	-0.213	-0.2185	-0.2145
B11	-0.1976	-0.2144	-0.1084	-0.2239	-0.2208	-0.2122	-0.2162	-0.2069	-0.2259	-0.2213

Table 3 Entropy value, variation coefficient and entropy of the specifications

	Specifications									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
E_j	0.99392	0.995379	0.88429	0.950802	0.99442	0.995045	0.997464	0.996672	0.996672	0.995004
d_j	0.00608	0.004621	0.11571	0.049198	0.00558	0.004955	0.002536	0.003328	0.003328	0.004996
W_j	0.030352	0.023067	0.577587	0.245583	0.027854	0.024732	0.012659	0.016614	0.016614	0.02494

Table 4 Weighted normalization matrix using TOPSIS

Brand	Specifications									
Bi	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
B1	0.007975	0.006266	0.171569	0.075984	0.009419	0.007843	0.00355	0.004659	0.005873	0.0059
B2	0.007705	0.007519	0.05719	0.073681	0.007723	0.005631	0.003856	0.005009	0.005051	0.007081
B3	0.012933	0.010026	0.285948	0.085591	0.009607	0.007642	0.005128	0.006989	0.005286	0.008007
B4	0.008145	0.006266	0.171569	0.077095	0.010229	0.007039	0.003697	0.005009	0.004111	0.006713
B5	0.008145	0.006684	0.171569	0.077889	0.008477	0.007039	0.003737	0.004776	0.004111	0.006308
B6	0.009901	0.006266	0.171569	0.077016	0.006518	0.007843	0.003538	0.004659	0.005286	0.009971
B7	0.008806	0.006266	0.171569	0.078445	0.008477	0.010056	0.003625	0.004776	0.004111	0.008397
B8	0.008663	0.006684	0.171569	0.078445	0.008477	0.006838	0.003574	0.004659	0.005873	0.008397
B9	0.008255	0.006684	0.114379	0.07249	0.008477	0.005832	0.003657	0.004776	0.004699	0.006109
B10	0.011002	0.006266	0.171569	0.023264	0.005369	0.008246	0.003617	0.004776	0.004992	0.007227
B11	0.00765	0.006684	0.171569	0.075746	0.008477	0.007039	0.003737	0.004543	0.005286	0.007623

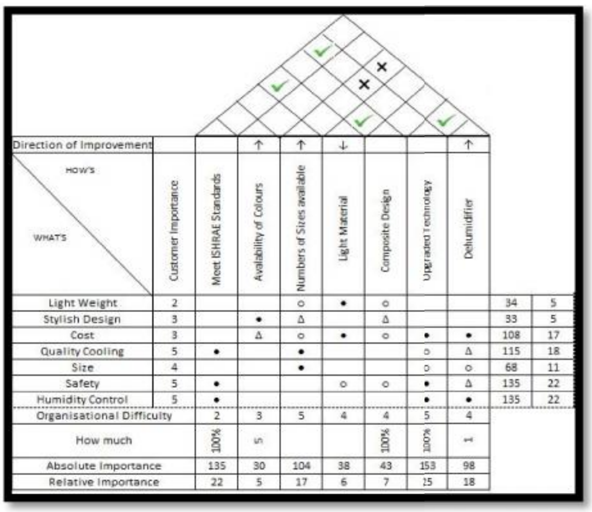

Figure 3 House of Quality

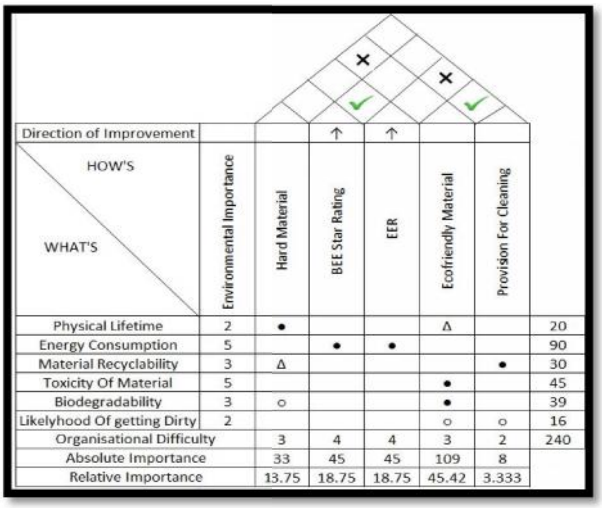

Figure 4 Green House of Quality

Table 5 Rank obtain by TOPSIS

BRANDS	Positive Ideal Solution	Negative Ideal solution	Trade Ideal Solution	Deviation	RANK
B1	0.114881838	0.126224	0.241106	0.523521	7
B2	0.229101549	0.051093	0.280195	0.18235	11
B3	0.006831935	0.237186	0.244018	0.972002	1
B4	0.114769643	0.126712	0.241481	0.524726	5
B5	0.114711245	0.127011	0.241722	0.525442	3
B6	0.11494342	0.126474	0.241417	0.523881	6
B7	0.114895	0.12715	0.242045	0.525315	4
B8	0.114716027	0.127186	0.241902	0.525776	2
B9	0.172112309	0.07594	0.248052	0.306144	9
B10	0.292761965	0.114478	0.40724	0.281106	10
B11	0.114891979	0.126086	0.240978	0.523226	8

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